3GPP TSG-RAN WG1 Meeting #103b-e draft R1- 21NNNNN

e-Meeting, April 12th – 20th, 2021

Agenda Item: 8.5.3

Source: Moderator (Ericsson)

Title: FL summary #1 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:

[[104b-e-NR-ePos-03] Email discussion/approval on accuracy improvements for DL-AoD positioning solutions with checkpoints for agreements on Apr-15, Apr-20 – Florent (Ericsson)

The FL proposals are based on submission to AI 8.5.3 [1-24] and treat the following aspects:

Enhancements to UE reporting (LPP)

* Aspect #1 reporting of first path RSRP
* Aspect #2 extension of number of reported RSRP measurements
* Aspect #3 NLOS mitigation and indication (
* Aspect #4 angular information for UE Rx Beams

Enhancements to gnodeB signalling (NRPPa) and assistance data (LPP)

* Aspect #5 Adjacent beam identification in AD and reporting by the UE
* Aspect #6 Support of additional gnodeB beam information signalling
* Aspect #7 Calibration of gNB angle error
* Aspect #8 AoD uncertainty window

1. Aspects for discussion

## Aspects related to UE Reporting

### Aspect #1 reporting of first arrival path

#### Summary and FL proposal

During RAN1#104e, an agreement was reached listing several options for reporting of the first arrival path and additional path:

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| --- |
| Agreement:   * For both UE-based and UE-assisted DL-AOD study the following enhancements that enable the UE to measure and report (for UE-assisted) information related to the first arriving path   + Option 1: Information corresponds to PRS-RSRP of the first arriving path   + Option 2: Information corresponds to the angle of departure of the first arriving path   + Option 3: Information corresponds to the arrival time of the first path   + Option 4: Information corresponds to phase of the CIR corresponding to the first arriving path   + Option 5: Information corresponds to received signal value (amplitude and phase of the channel estimated from the first path which can be achieved as a combination of option 1 and option 4) of the first arriving path * FFS: Reporting of additional path to the first arriving path. * FFS: Measurement definition details * FFS: additional assistance data to support these enhancements * FFS: how the “first path” is selected among PRS resources in a PRS resource set * Note 1: Supporting multiple options as well as none of the options above is not precluded. |

In [1][2][3][4][5][6][7][8][9][10][11][13][14][15][16][17][18][20][21][22][23][24], companies gave their preferred options and provided further details:

|  |  |
| --- | --- |
| Source | Proposal |
| [1] | Proposal 4: In DL-AoD measurement report, the UE reports:   * the RSRP measurement of first arrival path of each PRS resource (i.e, Option 1) * the relative time-of-arrival of those reported PRS resources of each TRP. (i.e., Option 3). |
| [2] | ***Proposal 2***   * ***The “first path” in the definition of first path-RSRP measurement can be selected among PRS resources in a PRS resource set, but for each resource reporting, due to UE mobility, the real first path that corresponding to RSRP is for each resource and near to the “first path”***.   ***Proposal 3***   * ***Information corresponds to PRS-RSRP of the first arriving path together with gNB beam/antenna information enhancement should be supported.***   ***Proposal 4***   * ***Option 3 should be discussed after option 1 is being agreed upon.*** * ***The benefit of reporting timing information needs to be further clarified.***   ***Proposal 5***   * ***The performance benefits of Option 2, option 4, and option 5 should be evaluated first especially in phase inconsistency cases.*** |
| [3] | ***Proposal 1: Enable the UE to measure and report PRS-RSRP of the first arriving path avoid the problem of angle estimation may be biased.*** |
| [4] | ***Proposal 2: UE could be configured to report the PRS-RSRP of the first arriving path in addition to the PRS RSRP already supported in Rel-16 (Option 1).*** |
| [5] | ***Proposal 1:*** *In addition to RSRP measurement for UE-assisted DL-AOD, Rel-17 UE should be able to report information corresponds to the arrival time of the first path, which includes,*   * *the arrival time of the first path from at least one reference signal per TRP* * *reference signal time differences among reference signals from the same TRP* |
| [6] | ***Proposal 1***: Supports reporting of additional path to the first arriving path for improving NLOS detection and positioning accuracy. |
| [7] | ***Proposal 1:***  ***Support UE to measure and report the arriving time information in addition to the RSRP to the LMF for DL-AoD positioning.***  ***Proposal 2:***  ***Only the RSRP measurement of the LOS path can be used for DL-AoD positioning.***  ***Proposal 4: Support the UE to measure and report the phase of the CIR corresponding to the first arriving path.*** |
| [8] | **Proposal 1: Support the following enhancements that enable the UE to measure and report (for UE-assisted) information related to the first arriving path:**   * **Option 1: Information corresponds to PRS-RSRP of the first arriving path** * **Option 3: Information corresponds to the arrival time of the first path** |
| [9] | *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.*  ***Proposal 3: Prefer Option 1 and Option 3 on information related to the first arriving path.*** |
| [10] | **Proposal 3**: Support “Option 3: Information corresponds to the arrival time of the first path” as one candidate enhancement for DL-AoD.  **Proposal 4**: For DL-AoD support reporting of multiple PRS resources per PRS resource set, with each resource being associated with time of arrival information. |
| [11] | **Proposal 1: Option 1 (PRS-RSRP) and Option 3 (arrival time) of the first path should be supported along with PRS-RSRP and arrival time reporting for additoinal path(s)** |
| [13] | **Proposal 2**: For both UE-based and UE-assisted methods of DL-AoD technique, the DL-PRS-RSRP is measured within a time window wherein the received power of paths out of the window, if any, are ignored.  **Proposal 3**: For both UE-based and UE-assisted methods of DL-AoD technique, the relative power of the first detected path to the measured RSRP is also measured and reported. |
| [14] | ***Proposal 1: Support enhancing the UE-A/UE-B DL-AoD method with UE measurements that provide phase-difference and Angle of Departure information related to the first arrival path (Option 2 & 4):***   * ***Assistance Data Enhancement:***    + ***gNBs’ antenna Configuration, PMI Codebook configuration & their association to the transmitted PRS resources, PMI to DL-AoD Mapping Table (for UE-B).*** * ***UE Measurement Enhancement:***   + ***Support a UE measuring multiple single-port PRS resources, sweeping a PMI codebook across the measured ports and determining the PMI index that maximizes the power associated with the earliest arriving path.*** |
| [15] | ***Proposal 1: The DL PLRS-RSRP can be reported for the aggregate of all paths (as defined in Rel-16) or for the first arrival path only. An indicator of whether the report includes all paths or first arrival path only is supported.***  ***Proposal 4: When multiple PRS resources in a PRS resource set are received, the UE can report the measurements associated one single PRS resource ID corresponding to the identified first arrival path*** |
| [16] | **Proposal 1: For both UE-based and UE-assisted DL-AOD, support UE to measure and report (for UE-assisted) information corresponds to complex value (amplitude and phase) of the first arriving path.**  **Proposal 2: As an alternative, For both UE-based and UE-assisted DL-AOD, support UE to measure and report (for UE-assisted) information corresponds to PRS-RSRP of the first arriving path.**  **Proposal 3: Introduce a new measurement parameter and its definition related to the first arriving path.** |
| [18] | ***Proposal 1: Support only the following Option 1 for enhancing DL-AoD.***   * ***Option 1: Information corresponds to PRS-RSRP of the first arriving path.***   ***Proposal 2: The first path across multiple PRS resources should be corresponding to the same TOA in the CIR.*** |
| [20] | ***Proposal 1:***   * RAN1 should discuss about additional elements to be reported to utilize beam index and followings can might be considered.   + Absolute angle values (azimuth and/or zenith) in GCS and/or LCS for each beam index.   + Relative differential values (azimuth and/or zenith) for the angle that used with the same beam index before |
| [21] | **Proposal 3-1**: At least Option 1 “Information corresponds to PRS-RSRP of the first arriving path” is supported  **Proposal 3-2**: FFS on Option 4 “Information corresponds to phase of the CIR corresponding to the first arriving path“ for the phase continuity maintenance during antenna switching  **Proposal 3-3**: For Option 1, when the measurement is conducted in time domain (pre-FFT) after CIR is derived, the “measurement window” containing the first path in each beam (DL-PRS resource) may need to be aligned, which is a fixed measurement window across beams. |
| [22] | **Proposal 2: To improve the DL-AoD accuracy in UE-assisted mode, support enhanced UE measurements and reporting by considering the following:**   * **The UE estimates the delay of the first arriving path of several PRS resources per TRP** * **The UE may select a common ToA per TRP for the first arriving path** * **For the CIR value related to the common ToA the UE shall report the relative phase (or the magnitude and phase or the I/Q component of the first arriving path. This combines Options 1, 3 and 4 (or Options 3 and 5)**   **Proposal 3: For UE-assisted mode, support reporting N samples of the (complex valued) CIR including the first arriving path.**   * **FFS: values of N** |
| [23] | **Proposal 2.1:** The standards should support reporting of DL-AoD along with ToA and power of the first path for configured resources. |
| [24] | **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 3 DL PRS-RSRP is also present in the signal measurement reports in LPP for DL-TDOA and multi RTT. Also here, the DL PRS peak-RSRP should be included alongside the existing DL PRS RSRP measurement.Include the DL PRS peak-RSRP in the NR DL-TDOA and in the NR multi-RTT 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 proposals submitted in contributions, there are a majority of companies supporting the first-path RSRP reporting enhancement (option 1) and the first path TOA reporting enhancement (option 3). Options 2,4, and 5 have also been supported, albeit by fewer companies.

In the first round, of discussion, I would like to check with the group what options are supported and perhaps more importantly, what options are not supported by companies, to see if all options need to be supported or if some downselection is possible.

**Proposal 1.1:**

For both UE-based and UE-assisted DL-AOD the following enhancements that enable the UE to measure and report (for UE-assisted) information related to the first arriving path are supported:

* Option 1: Information corresponds to PRS-RSRP of the first arriving path
* Option 2: Information corresponds to the angle of departure of the first arriving path
* Option 3: Information corresponds to the arrival time of the first path
* Option 4: Information corresponds to phase of the CIR corresponding to the first arriving path
* Option 5: Information corresponds to received signal value (amplitude and phase of the channel estimated from the first path which can be achieved as a combination of option 1 and option 4) of the first arriving path
* FFS: time window for information measurement(s)
* FFS: Reporting of additional path to the first arriving path.
* FFS: Measurement definition details
* FFS: how the “first path” is selected or indicated among PRS resources in a PRS resource set
* FFS: additional assistance data to support these enhancements

#### First round of comments

Companies are encouraged to provide comments in the table below.

|  |  |
| --- | --- |
| **Company** | **Comment** |
| Qualcomm | Support: Option 2, 4  Not support: Option 3   * Arrival time is not needed, since the spec already supports TDOA/RTT jointly with AoD. So the UE will be reporting timing of arrival measurements & DL-AOD measurements.   On Option 1: For us, this is related to Power delay profile reporting, and we prefer to discuss it jointly across all methods when the corresponding agenda opens next meeting. |
| ZTE | Support option 3, we’re open to further discuss option 1.  In our understanding, it’s separate UE capabilities to support different positioning methods. If UE only supports DL-AOD, the timing information would be helpful to identify LOS link and coarse positioning.  Not support: Option 2,4 and 5. DL PRS only support one port, it’s hard to ensure the phase consistency among different resources. In addition, the phase is very sensitive to impairments ,such as carrier frequency offset and doppler effect. Not sure what additional information the phase can provide. |
| vivo | Firstly, we propose to add a bracket for “[FFS: time window for information measurement(s) ]” since the intention is unclear and it does not belong to the agreement in the last meeting  Secondly, we think different companies have different views for the options given they support different enhancement methods. So, if we are not sure of the enhancement method of R17, it seems that the reduction option is not easy. |
| Huawei/HiSilicon | We suppot Option 1.  For Option 2 and Option 4, we think more study is required. Both gNB and UE phase continuity is required to use the phase information for coherent angle estimation.  For Option 3, we would like to understand   * Is the TOA more specifically intra-TRP TOA? * Is the intention to have different first path TOA for different Tx beams? |
| Intel | Support option 2 and option 4. In our view it provides most of the gain for DL-AOD positioning performance accuracy. If these options are supported, it is also beneficial to support option 1. |
| Nokia/NSB | We support Option 3. If the UE is only performing DL-TDOA then one criteria of the PRS resources to report on can be the arrival time of the beams. |
| CATT | Support Option 1.  Don’t support Option 2.  For Option 3, Option 4 and Option 5, we prefer to FFS on these options.  In our opinion, the measurement of the received power (PRS-RSRP) of the first arriving path is in general more stable than other measurements of the first arriving path, such as signal amplitude and phase, since RSRP is a time-accumulation quantity instead of an instantaneous quantity. |
| InterDigital | We support Option 1 and 3. From our view, “arrival time of the first path“ can be arrival time of the received beam. |
| OPPO | Support: Option 1, Option 3. The first path estimated from different PRS resource might have different arrival time.  Do not support: Option 2, Option 4 and Option 5 |
| Sony | Support option 1 and 4. |
| Qualcomm | To the supporters of Option 3: What will the UE report? TOA of a peak? This is not well defined because we need a reference time. Are they suggesting to add a reference TRP in DL-AoD? If yes, then it is the same as TDOA. Why not configure the UE with both TDOA and AoD (already specified)?  If the thinking is a Time Difference between the the paths, together with relative RSRP of the paths, then this is a Power Delay Profile (PDP) reporting that could be supported for all methods and not just DL-AoD, and it is related to the subagenda that is closed in this meeting. |
| Lenovo, Motorola Mobility | Supportive of Option 1 |
| Ericsson | We support option 1 and 3. |
| LG | Support option 3, open to further discuss option 1. |

#### Summary of 1st round of comments and updated proposal

The options are supported as follow:

* Option 1: supported by Huawei/HiSilicon , Intel (condition on O2 and O4), CATT, InterDigital, OPPO, Sony, Lenovo/Motorola Mobility, Ericsson
  + not supported by
  + more study required: ZTE, LG
* Option 2: supported by Qualcomm , Intel
  + not supported by ZTE, CATT, OPPO
  + more study required: Huawei/HiSilicon
* Option 3: supported by ZTE, Nokia/NSB, InterDigital, OPPO, Ericsson, LG
  + not supported by Qualcomm
  + more study required: CATT
* Option 4: supported by Qualcomm , Sony
  + not supported by ZTE, OPPO
  + more study required: Huawei/HiSilicon, CATT
* Option 5: supported by
  + not supported by ZTE, OPPO
  + more study required: CATT

based on the feedback received, it seems that all options have companies supporting and opposing. In order to clarify the discussions, it is proposed to discuss each option separately rather that as a whole in the next round, with the hope to make it easier to reach an agreement.

#### Revised proposals

**Proposal 1.2a:**

For both UE-based and UE-assisted DL-AOD, the UE can be requested to measure and report (for UE-assisted) the PRS RSRP of the first path

* + FFS: time window for the measurement of PRS RSRP.
  + FFS: Measurement definition details
  + FFS: Reporting of additional path to the first arriving path.
  + FFS: how the “first path” is selected or indicated among PRS resources in a PRS resource set
  + FFS: additional assistance data

Companies are encouraged to provide comments in the table below.

|  |  |
| --- | --- |
| **Company** | **Comment** |
| CMCC | Support in principle. We are a bit confused by the 1st FFS, what is the time window intended for? |
| CATT | Support. In our opinion, the measurement of the received power (PRS-RSRP) of the first arriving path is in general more stable than other measurements of the first arriving path. |
| Apple | Support the proposal, and keep the first FFS, as otherwise the RSRP oft he path out of a time window, even though still the first arriving path, could be misleading in position calculation |
| Samsung | SS |
| Huawei/HiSilicon | We support the proposal and we interprete the proposal as the main bullet is supported, correct? |
| ZTE | We can support this proposal. But the first FFS and fourth FFS are not necessary, we don’t need to restrict the selected timings. Each resource can report their own path timing and corresponding path RSRP. |
| Xiaomi | Support the proposal |

Proposal 1.2b:

For both UE-based and UE-assisted DL-AOD, the UE can be requested to measure and report (for UE-assisted) the angle of departure of the first arriving path

* + FFS: Measurement definition details
  + FFS: Reporting of additional path to the first arriving path.
  + FFS: how the “first path” is selected or indicated among PRS resources in a PRS resource set
  + FFS: additional assistance data

Companies are encouraged to provide comments in the table below.

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| --- | --- |
| **Company** | **Comment** |
| CMCC | To our understanding, it seems that restrictions such as phase inconsistency will deteroriate the performance. |
| CATT | Don’t support. In our opinion, the measurement of the received power (PRS-RSRP) of the first arriving path is in general more stable than other measurements of the first arriving path. |
| Apple | Question for clarification, how AoD oft he first path is calculated in UE-assisted. In general, does UE need to perform measurements, including PRS-RSRP, on 1st arrival path to obtain AoD? |
| Samsung | Dont support |
| ZTE | Not support. |
| vivo | Same view with CMCC and CATT |
| Xiaomi | Not support |

Proposal 1.2c:

For both UE-based and UE-assisted DL-AOD, the UE can be requested to measure and report (for UE-assisted) the arrival time of the first path

* + FFS: Measurement definition details
  + FFS: Reporting of additional path to the first arriving path.
  + FFS: how the “first path” is selected or indicated among PRS resources in a PRS resource set
  + FFS: additional assistance data

Companies are encouraged to provide comments in the table below.

|  |  |
| --- | --- |
| **Company** | **Comment** |
| CATT | We prefer to FFS on this proposal, including the feasibility and benefits. |
| Samsung | ffs |
| Huawei/HiSilicon | Is it intra-TRP T(D)OA or inter-TRP TDOA? |
| ZTE | Support.  To Huawei, we think this is intra-TRP T(D)OA. In addition, it’s separate UE capabilities to support different positioning methods in Rel-16. If UE only supports DL-AOD, the intra-TRP T(D)OA information would be helpful to improve the positioning performance even there is only one TRP configured. |
| vivo | Same view with CATT and Samsung  In addition, we prefer not to measure and report the arrival time in AoD positioning. For us，it is more like a hybrid positioning. |
| Xiaomi | Support the proposal |

Proposal 1.2d:

For both UE-based and UE-assisted DL-AOD, the UE can be requested to measure and report (for UE-assisted) the phase of the CIR corresponding to the first arriving path

* + FFS: Measurement definition details
  + FFS: Reporting of additional path to the first arriving path.
  + FFS: how the “first path” is selected or indicated among PRS resources in a PRS resource set
  + FFS: additional assistance data

Companies are encouraged to provide comments in the table below.

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| --- | --- |
| **Company** | **Comment** |
| CMCC | Similar comments as Proposal 1.2b |
| CATT | We prefer to FFS on this proposal, including the feasibility and benefits. |
| Samsung | FFS is fine for us. |
| ZTE | Need further study. As we commented in last round, phase is very sensitive to impairments. |
| vivo | Not Support |
| Xiaomi | Need further study |

Proposal 1.2e:

For both UE-based and UE-assisted DL-AOD, the UE can be requested to measure and report (for UE-assisted) the received signal value (amplitude and phase of the channel estimated from the first path) of the first arriving path.

* + FFS: Measurement definition details
  + FFS: Reporting of additional path to the first arriving path.
  + FFS: how the “first path” is selected or indicated among PRS resources in a PRS resource set
  + FFS: additional assistance data

Companies are encouraged to provide comments in the table below.

|  |  |
| --- | --- |
| **Company** | **Comment** |
| CATT | We prefer to FFS on this proposal, including the feasibility and benefits. |
| Samsung | We support.  By this information, in which the value will be used by differential beam method, the values will be divided, so that as long as the values are obtained from the same tx and rx side, the experienced FO can be illuminated. |
| ZTE | Similar view as Proposal 1.2d. |
| vivo | Not Support |
| Xiaomi | Need further study |

### Aspect #2 extension of number of reported RSRP measurements

#### Summary and FL proposal

During RAN1#104e, it was agreed to select from 3 options regarding the number of RSRP measurements:

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| --- |
| Agreement:  For UE-assisted DL AOD, select one of the following options for reporting of RSRP measurements per TRP   * Option 1: Up to 8 measurements in a measurement report (as in release 16) * Option 2: Up to 8 measurements in a measurement report, for the same Rx beam index * Option 3: Up to N>=8 measurements   + Note: Multiple measurements corresponding to different Rx Beam index may be  reported for a given PRS resource.   + FFS: value for N. |

The following proposals [1][2][3][4][8][10][13][14][16][17][18][20][21][24] have been made in response to the agreement

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| --- | --- |
| Source | Proposal |
| [1] | Proposal 2: For UE-assisted DL AoD, support Option1, up to 8 RSRP measurements in a measurement report (as in release 16). |
| [2] | ***Proposal 7***   * ***To improve the accuracy of AoD and to avoid the impact of Rx beam, choose one of option 2 and option 3.***    + ***Option 2: Up to 8 measurements in a measurement report, for the same Rx beam index***   + ***Option 3: Up to N>=8 measurements***     - ***Note: Multiple measurements corresponding to different Rx Beam index may be reported for a given PRS resource.*** |
| [3] | ***Proposal 3: Up to 8 measurements in a measurement report for the same Rx beam index for reporting of RSRP measurements per TRP.*** |
| [4] | ***Proposal 1: For UE-assisted DL-AoD, the maximum number of RSRP measurements per TRP should be increased from 8 to [16]. Whether to support reporting more than 8 RSRP measurements per TRP can be subject to UE capability.*** |
| [8] | **Proposal 2: For UE-assisted DL AOD, support up to N>=8 measurements for reporting of RSRP measurements per TRP.** |
| [10] | **Proposal 5**: Support “Option 3: Up to N>8 measurements” as candidate enhancement. FFS value of N. |
| [13] | **Proposal 1**: For reporting of RSRP measurements per TRP, subject to UE capability, support Option 1, i.e. up to 8 measurements in a measurement report, as in release 16. |
| [14] | ***Proposal 5: For UE-A DL-AOD, support reporting more than 8 RSRP measurements per TRP.***   * ***Note: Multiple RSRPs corresponding to same or different Rx Beam index should be able to be reported for a given PRS resource for different timestamps.*** * ***FFS: Value for N*** |
| [16] | **Proposal 4: Keep the legacy Rel-16 DL-AOD on the number of RSRP measurements per TRP (i.e., up-to 8 RSRP measurements).** |
| [17] | ***Proposal 1: Support Option 3 of the agreements related to enhancing the DL-AoD reporting of DL-PRS RSRP measurements and this is to be further jointly discussed with the agreements made in AI 8.5.1 on single measurement reporting.*** |
| [18] | ***Proposal 5: Support up to 8 measurements [for a path] in a measurement report for the same Rx beam index.*** |
| [21] | **Proposal 2-1**: Consider Option 3 “Up to N>=8 measurements“ |
| [24] | **RSRP/peak-RSRP measurements for adjacent DL PRS Resources that the UE reports should be done using the same Rx-beam.**  **Proposal 8 The network can signal in the assistance data that it is interested in receiving RSRP/peak-RSRP measurement reports on more than one Rx beam.** |
|  |  |

From the contributions, there is a majority of companies supporting the extension of the number of measurements beyond eight.

In the companies not supporting option 2 or 3 and preferring option 1, the following concern has been noted:

* Tying a set of measurement to one Rx beam would bias the measurement to a particular Tx beam. The UE should derive the Rx beam based on QCL information [1]
* Increasing the number of PRS-RSRP measurement per TRP for different PRS resources should help to identify NLOS impact but this has not been quantified[13]
* The UE could send new positioning measurement IEs rather than increasing the size of the measurement report[16]

Regarding option 2, it is the FL understanding that option3 and option 2 are not mutually exclusive, and option 2 could be supported in option 3 if the LMF is allowed to request a measurement where all PRS in a TRP are measured in the same Rx beam and if N is set to equal or more than 8x the number of Rx beams.

Based on these observation, an additional options is proposed based on option 3, but also trying to take into account concerns from companies supporting option 1 or 2. Compared to option 3, the following is added:

* Option 3 is used as a starting point, and is assumed to be a UE capability. If not supported by the UE, rel16 (i.e. option 1) will be used.
* FFS: maximum number of measurement per Rx beam and maximum number of measurements across all rx beams, both of which are UE capabilities.
* FFS: whether to support requesting measurement on an Rx beam

**Proposal 2.1 :**

**For UE-assisted DL AOD, select one of the following options for reporting of RSRP measurements per TRP**

* **Option 1: Up to 8 measurements in a measurement report (as in release 16)**
* **Option 2: Up to 8 measurements in a measurement report, for the same Rx beam index**
* **Option 3: Up to N>=8 measurements**
  + **Note: Multiple measurements corresponding to different Rx Beam index may be reported for a given PRS resource.**
  + **FFS: value for N.**
* **Option 4: based on a UE capability, Up to N>=8 measurements in a measurement report over all Rx beam , with up to M measurements per Rx beam**
  + **M and N are UE capabilities**
  + **FFS: whether to support requesting measurement on an Rx beam**
  + **FFS: value for N, M.**
  + **Note: Multiple measurements corresponding to different Rx Beam index may be reported for a given PRS resource.**

#### First round of comments

Companies are encouraged to provide comments in the table below.

|  |  |
| --- | --- |
| **Company** | **Comment** |
| Qualcomm | Low priority from our side.  We support Option 3.  Comment: Option 3 and 4 seem very similar to me. Noone said in Option 3 that there will not be UE capabilities. All the features that we are introducing in Rel-17 will be separate UE capabilities, so we prefer to leave the UE capabilities for later discussion. |
| ZTE | Support Option 1. Rel-16 supports 8 RSRPs per TRP, it’s enough. No enhancement is needed. UE may measure different resources and different Rx beams, so it’s up to UE to select some of the measurements for reporting. |
| vivo | Support in principle  Based on our evaluation in our Tdoc, if we adopt different Rx beam index to estimate the AoD, the accuracy of estimated AoD will be impacted by the Rx beam response, and the performance will be worse than the measurement by the same Rx beam. So, we also propose to remove option 1 in the proposal. |
| Intel | Support option 1. |
| Nokia/NSB | We support Option 3 but agree with QC that this is low priority. |
| CATT | We prefer Option 3 or Option 4.  Don’t support Option 1 and Option 2.  In Rel-16, for each TRP, the maximum number of Rx beams is 8 and the maximum number of RSRP measurements on different PRS resources is also limited to 8. With this limitation, for a UE with 8 Rx beams, only one RSRP can be reported for each PRS resource for a TRP, if RSRPs correspond to all the Rx beams are reported. In addition, according to the spec, only those RSRPs from different PRS resources measured by the same Rx beam are associated with a Rx beam index in the measurement report. So, no Rx beam index would be reported in this case. As a result, LMF could not choose those RSRPs associated with the same beam for DL-AoD calculation.  In order to solve the problem, we prefer to adopt Option 3 or Option 4, and don’t support Option 1 and Option 2. |
| OPPO | We think this is low priority. Suggest to diuss it later. At the current moment, Option 1 is preferred. |
| Sony | Support option 1. We don’t see the benefit of reporting more than 8 beams. |
| Lenovo, Motorola Mobility | Support option 3 but the impact of the DL-AoD accuracy enhancement might be lower when compared to other discussed enhancements. |
| LG | We slightly prefer to suppot option 3 and 4. |

#### Summary of 1st round of comments and updated proposal

Several companies have expressed that this aspect could be downprioritized. The support is split between option 1 and 3 or 4. We propose to continue the discussion, but we will not bring up this topic for discussion in the first GTW call.

#### Second round of comments

Companies are encouraged to provide comments in the table below.

|  |  |
| --- | --- |
| **Company** | **Comment** |
| CMCC | Prefer Option 3 |
| SS | We consider the proposal as low priority. Our preference is Option 2 since it is not clear how much gain we can obtain by increasing the number of RSRP measurements more than 8 per Rx beam. |
| ZTE | We think second round will not change the situation too much, so we should bring up this topic in GTW. |
| vivo | For some comments about low priority, we don’t think it should be seen as a low priority since the Tx side and Rx side will affect positioning accuracy. We should consider both.  And for the ZTE comment about no enhancement is needed and 8 RSRPs is enough per TRP, we would like to reply to it based on our evaluation in the following figure. In the following simulation, 3,8,15 strongest RSRPs with the same and different Rx beam index are used for AoD positioning  It is observed that the performance is similar for 8 beams (blue line )and 15 beams(green line) if that RSRP on the same Rx Beam index, So, 8 RSRPs per TRP is enough if all the reporting RSRP with the same Rx Beam index.    Otherwise, for different Rx Beam measurements and reporting, we need to report more RSRPs since the 15 beams(green dotted line) reporting are better than 8 beams. |

### Aspect #3 NLOS mitigation and indication (not treated this meeting)

#### Summary and FL proposal

|  |  |
| --- | --- |
| Source | Proposal |
| [6] | *.****Proposal 2***: 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 3***: To improve positioning accuracy by regularization techniques the UE should report LOS indicators as soft values for each link for UE-assisted positioning. |
| [7] | ***Proposal 3:***  ***Support the UE to report LOS/NLOS indicator together with the RSRP measurement of first arriving path.*** |
| [17] | ***Proposal 2: Support UE reporting of RSRP side information, e.g. LOS/NLOS indicators within configured time window ‘T’, to mitigate effects of multipath/NLOS on DL-RSRP measurements.***  ***Proposal 3: Continue to discuss techniques to mitigate multipath/NLOS effects for DL-AOD positioning based on the following options:***   * ***Option 1: Continue the discussion of the proposal from the RAN1#104-e FL’s summary update (R1-2102093) meeting, which includes:***   + ***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)*** * ***Option 2: Continue the discussion of multipath/NLOS mitigation under a common framework for all positioning methods including DL-AoD methods.*** |

According to the agenda set for RAN1#104b, NLOS mitigation topics will not be treated:

|  |
| --- |
| 8.5.5 Potential enhancements of information reporting from UE and gNB for multipath/NLOS mitigation *Void (not be handled during this e-meeting). No contributions please.* |

Therefore, the discussion for these proposal is postponed to RAN1#105e, and closed for 104b-e.

### Aspect #4 angular information for UE Rx Beams

#### Summary and FL proposal

|  |  |
| --- | --- |
| Source | Proposal |
| [5] | ***Proposal 2****: Rel-17 should support UE to report angular differences between Rx beams when receiving reference signals for UE-assisted DL-AOD.* |
| [10] | Proposal 10: Study angle difference measurements for AoA of DL PRS resources in Rel-17. |

Two companies have expressed support for the reporting of angle difference between UE RX beams.

Proposal 4.1:

For AOD, the UE may optionally indicate the angular difference between Rx beams when using different Rx beams.

FFS: detail on how to signal the angle difference.

#### First round of comments

Companies are encouraged to provide comments in the table below.

|  |  |
| --- | --- |
| **Company** | **Comment** |
| Qualcomm | Not support |
| ZTE | Support. As we discussed in our tDoc, the information could be helpful for LOS identification and NLOS link as supplementary information for positioning. |
| vivo | In general, we think it is one of assistance information to identify NLoS path. Therefore, the discussion for this proposal should be postponed to RAN1#105e. |
| Intel | If benefits are jsutified for the LOS/NLOS identification, then it can be further discussed a part of the multipath/NLOS mitigation agenda item. |
| Nokia/NSB | Support. |
| CATT | We prefer to postpone this issue to next meeting, since it is related to LOS/NLOS identification. |
| OPPO | Not support. We do not see the benefit of reporting such information. Furthermore, UE Rx beam is up to UE hardware implementation. It is not feasible for the UE to report such information. |
| Sony | We, in principle, support the proposal. We also suggest:  The reported information should not be restricted as the time angular difference. There could be more options, such as:  1, UE DL-AoA measurements (in LCS) associated with different TRPs.  2, The UE Rx beams IDs.  This information can also be used in the LMF to calculate the angular difference. Compare with reporting the angular difference (each measurement is associated with two TRPs), the new options are TRP-specified which is easy to be identified. |
| Ericsson | support |
| LG | Support. In the current specification, the beam index is conditionally reported. As beam orientation varies depending on the mobility and/or rotation of the UE, it may be questionable whether the reporting multiple measurement results for the same beam index is beneficial or not in terms of angle measurement. For this reason, we think this is helpful for LMF to estimate angle. |

#### Summary of 1st round of comments and updated proposal

Based on the feedback, it is proposed to downprioritize the issue for this meeting and bring it up within the scope of NLOS/LOS identification during the next meeting.

Companies are encouraged to provide their view on the proposal to postpone in the table below.

|  |  |
| --- | --- |
| **Company** | **Comment** |
| ZTE | In light of current situation, we’re OK with FL’s suggestion. |
| CATT | Support FL’s updated proposal to postpone this topic in next meeting. |

## Aspects related to Assistance data (from LMF to UE or gnodeB to LMF)

### Aspect #5 adjacent beam reporting

#### Summary and FL proposal

During RAN1#104e, the following agreement was made:

|  |
| --- |
| Agreement:  For UE-assisted DL-AOD positioning method, study the following options to enable the UE to measure/report a PRS resource with an additional, adjacent PRS resources measurement/report:   * Option 1: UE can be requested to measure and report on specific PRS resources * Option 2: Enhancing the assistance data to identify adjacent beams * Option 3: Enhancing the reporting to include the measurements of adjacent beams      * FFS: Detailed signaling and procedure * FFS: How to define adjacent beams * Note: Depending on the discussion results, none/one/multiple of above options may be adopted in Rel-17 |

The following proposals [1][2][3][4][5][8][9][10][20][18][21][23] [24]

have been made in response to the agreement

|  |  |
| --- | --- |
| Source | Proposal |
| [1] | Proposal 3: In DL-AoD measurement reporting, support reporting RSRP of PRS resources carrying adjacent Tx beams:   * In the assistance data of PRS configuration, the UE is provided with configuration information that indicates which PRS resources carry adjacent Tx beams. * In measurement report, the UE reports RSRP of one PRS resource and also reports the RSRP of PRS resources that are adjacent to that PRS resource in terms of Tx beam direction. |
| [2] | ***Proposal 6***   * ***Enhancing the assistance data (such as adding PRS beam information) to UE to identify adjacent beams.*** |
| [3] | ***Proposal 2: For UE-assisted DL-AOD positioning method, to enable the UE to measure/report a PRS resource with an additional, adjacent PRS resources measurement/report, UE can be requested to measure and report on specific PRS resources.*** |
| [4] | ***Proposal 3: Whether to enable a UE to measure/report a PRS resource with additional, adjacent PRS resources can be further discussed.*** |
| [5] | ***Proposal 6****: It’s not necessary to enhance UE to measure/report a PRS resource with an additional, adjacent PRS resources measurement/report.* |
| [8] | **Proposal 4: For UE-assisted DL-AOD positioning method, support the following options to enable the UE to measure/report a PRS resource with an additional, adjacent PRS resources measurement/report:**   * **Option 2: Enhancing the assistance data to identify adjacent beams in an implicit manner** * **Option 3: Enhancing the reporting to include the measurements of adjacent beams** |
| [9] | *Proposal 4: Adjacent PRS resources can be predefined by resource index.* |
| [10] | **Proposal 6**: Do not support any enhancements for adjacent beam reporting (i.e., do not support option 1-3 in the prior agreement). |
| [20] | ***Proposal 2:***   * RAN1 does not need to discuss on adjacent beam reporting if extension of number of reported RSRP measurements is supported. |
| [14] | ***Proposal 4: With regards to PRS resource Prioritization for DL-AoD measurements, support LMF providing in the assistance data support one or both of the following options:***   * ***Opt. 1: Boresight direction of each PRS resource (already supported for UE-B, but not for UE-A) & expected DL-AoD value***   ***Opt. 2: Prioritization information (e.g. prioritization based on the ordering in the PRS resource set as was discussed during NR Rel-16).*** |
| [18] | ***Proposal 4: Do not introduce the concept of the adjacent beams.*** |
| [21] | **Proposal 4-1**: UE may report RSRPs with decreasing order of measured value |
| [23] | **Proposal 4.1**: The standards should support enhance the assistance information to identify the adjacent beams at UE for measurement and reporting to LMF. |
| [24] | **Proposal 9 When the beam directions vary in only one dimension, use the DL-PRS Resource IDs as beam structure order numbers by assigning them in a way such that they increase or decrease by one for each beam along the one spatial dimension.**  **Proposal 10 The ordering of the beams in two dimensions is supplied to the UE as assistance information in one of the following formats:**   * **1/For each DL PRS Resource, one list of neighbors in dimension 1 and another list of neighbors in dimension 2.** * **2/One adjacency matrix for neighbors in dimension 1 and another adjacency matrix for neighbors in dimension 2.** * **3/For each DL PRS Resource, one list of general neighbors.** * **4/ One adjacency matrix for general neighbors.**   If the beam structure information is specified for each dimension separately (either in 1D or 2D), we propose the following selection procedure in two steps (for a 1D beam structure) or three steps (for a 2D beam structure):  1. Select the DL PRS Resource corresponding to the highest measured RSRP/peak-RSRP. We call this the strongest resource. 2. Select the DL PRS Resource with the highest RSRP/peak-RSRP measurement among the DL PRS Resources which are neighbors to the strongest resource in dimension 1. We call this the strongest dimension 1 neighbor resource. 3. If applicable, select the DL PRS Resource with the highest RSRP/peak-RSRP measurement among the DL PRS Resources which are neighbors to the strongest resource in dimension 2. We call this the strongest dimension 2 neighbor resource.  In 2D, if the beam structure is given as general neighbors, we propose the following selection procedure:  1. Select the DL PRS Resource with the highest RSRP/peak-RSRP measurement. We call this the strongest resource. 2. Select the DL PRS Resource with the highest RSRP/peak-RSRP measurement among the DL PRS Resources which are general neighbors of the strongest resource. We call this the first neighbor resource.  3. Select the DL PRS Resource with the highest RSRP/peak-RSRP measurement among the DL PRS Resources which are general neighbors of both the strongest resource and the first neighbor resource. We call this the second neighbor resource. |
|  |  |

From the proposals in the contributions, the opinions are similar to what was shown during RAN1#104. The following can be summarized:

* 6 [5][10][11] (note: in an observation) [18][20][21] companies think the concept of adjacent beams need not be introduced (i.e. option 1,2,or 3 from RAN1#104e are not supported)
* 2 [19][3] companies support the request of specific beams to be measured and reported (option 1 in RAN1#104e).
* 7 [1][2][4][8][9][14][24] companies think that some kind of assistance data enhancements (i.e., prioritization of AD, adjacent beams identification, etc.) is needed (option 2 in RAN1#104e)
* 2[1][8] companies support reporting enhancements (option 3 in RAN1#104e)

Since there does not seem to be a clear preference, it is proposed to continue the discussion based on the last agreement This time, it is proposed to select one or more of the options instead of just study. That is to say, we should try to decide whether enhancements are needed.

Proposal 5.1:

For UE-assisted DL-AOD positioning method, select one or more of the following options to enable the UE to measure/report a PRS resource with an additional, adjacent PRS resources measurement/report:

* Option 1: UE can be requested to measure and report on specific PRS resources
* Option 2: Enhancing the assistance data to identify adjacent beams
* Option 3: Enhancing the reporting to include the measurements of adjacent beams
* FFS: Detailed signaling and procedure
* FFS: How to define adjacent beams

#### First round of comments

Companies are encouraged to provide comments in the table below.

|  |  |
| --- | --- |
| **Company** | **Comment** |
| Qualcomm | Generally low priority for us. However, we do think that there is a simple enhancement we could do with minimal spec effort: Include the boresight directions of the PRS resource in the UE-A AD (as *already* done in UE-based, so really minimal spec impact), and support expectedAoD infomation to the UE (Aspect #8) which can be useful for both UE-B and UE-A, and therefore can be discussed in Aspect #8. Then, the UE would have enough information to do measurements in „adjacent“ PRS resources, if it considers important to prioritize these resources. |
| ZTE | Similar view as QC. We don’t see obvious benefit to explicitly configure and report adjacent beams. This may not be good for the case that LOS link is blocked. |
| vivo | Support  And we would like to noted that first-path RSRP may be helpful for AoD positioning. But, in a reality environment, whether the path-specific RSRP can be accurately measured is uncertain. So, it is beneficial if the AoD performance can be improved based on DL PRS-RSRP.  Then, as for DL PRS-RSRP, the performance with adjacent beam( the right figure) is better than the strongest beam selection algorithm( the left figure), and 1m@80% and 2.49m@90% can be achieved. |
| Huawei/HiSilicon | We do not see the need to introduce adjacement beams, which means that it can be Option 1 (spec transparent), or not to discuss it at all. |
| vivo 2 | Reply to Huawei  For the reason of introducing adjacent beam, at least, OPPO and vivo provided the evaluation result and it shows the performance benefit with adjacent beam.  And for the option 1, we wonder how to support it by spec transparent. |
| Nokia/NSB | In general we don’t support adjacent beam enhancements but we could be okay with the proposal (or something similar) from QC which simply gives the UE more information about the beams. |
| CATT | We prefer Option 2(enhancing the assistance data to identify adjacent beams). As each gNB has its own adjacent beam information, this information could be sent to LMF and then configured in the DL assistance data. Whether to enable a UE to measure/report a PRS resource with additional, adjacent PRS resources can be further discussed. |
| OPPO | Support the proposal and we prefer Option 2 and Option 3. Our evaluation results show that reporting RSRP of adjacent Tx beam can improve the positioning performance of DL AoD method. |
| Huawei/HiSilicon | Reply to vivo: LMF may simply only configure the selected PRS resources for UE to measure based on earlier measurement reporting, which is spec transparent. Providing the info on the adjacent beams will not reduce any effort for the UE to conduct the measurement because UE will anyway measure all the DL PRS resources (within its measurement capability); instead reducing UE measurement effort can only be achieved via reducing the PRS resources in the assistance data. |
| Sony | Do not support the above options.  Option 1 doesn’t make sense to us. For example, If LMF has the knowledge of which Tx sweeping beams could cover the range of UE, then it is more reasonable to only transmit PRS over those specific beams, rather than requesting the UE to measures and reports specific beams. |
| Lenovo, Motorola Mobility | Agree with Intel, that if the motivations are for multipath/NLOS mitigation it should be treated similarly to Aspect 2.1.3 |
| Ericsson | Support option 2 and 3. In our view the enhancement is motivated to enable efficient interpolation. We are ok with discussing the details of how the adjacent beams can be identified later. |
| LG | Do not support reporting of adjacent beam. Currently, the discussion on extension of the number of measurements (Aspect #2) has been discussed. we think it can fully cover the motivation of introducing the adjacent beam reporting. |

#### Summary of 1st round of comments and updated proposal

There is support for enhancing the assistance data in some way from multiple companies (vivo, OPPO, CATT, Ericsso, and to some extent Qualcomm and Nokia/NSB), but with different approach. Qualcomm proposed to forward boresight directions of DL PRS beams to the UE for UE-A. vivo and Oppo support the signaling of adjacent beams.

Companies not supporting the enhancements (Huawei/HiSilicon, Sony, ZTE, Nokia – except for the type of solution brought up by QC) have concerns regarding the benefits.

As there are still many companies who have yet to comment, we propose to wait another round for this discussion and let companies provide their support for their preferred options.

#### Second round of comments

Companies are encouraged to provide comments in the table below.

|  |  |
| --- | --- |
| **Company** | **Comment** |
| CMCC | We support to discuss enhancements on adjacent beams, and we prefer Option 2 and 3. |
| vivo | Based on the views of Nokia, QC, and CATT, We can support enhancing assistance data and FFS for other options.  And for some comments about“adjacent“, from our point, it is only a description wording, the core part is enhancing the AoD positioning accuracy and reduce the power consumption.  For Huawei's proposal adopt option 1 by spec transparent method, this will introduce more information exchange, and due to the latency of exchange assistance date and measurement, the update assistance data may not proper. In addition, we note Huawei also agrees to enhance the assitance date in aspect 8. We think it is the same issue.  Reply to ZTE, We want to note that there are more than 98% UE that can receive 4 LOS in R17 scenario. And if LOS is blocked, the LOS from all resources is blocked. The right resource also can be selected. If for the NLOS case, we don’t think R17 will address the problem.  Reply to LG, yes, if we report many RSRPs, adjacent Tx beams measurement results will in the reporting. But in this aspect, we hope to reduce the measurement and reporting with the enhancement(for example option 2 enhancing the assistance data) and then reduce power consumption. That is, in some cases, we only need to measure and report limited beams and got similar performance.  So we propose  Proposal 5.1:  For UE-assisted DL-AOD positioning method, ~~select one or more of the following options to~~ Support the following enhancement to enable the UE to measure/report a PRS resource with an additional, adjacent PRS resources measurement/report:   * FFS: Option 1: UE can be requested to measure and report on specific PRS resources * Option 2: Enhancing the assistance data to identify adjacent beams * FFS: Option 3: Enhancing the reporting to include the measurements of adjacent beams * FFS: Detailed signaling and procedure * FFS: How to define adjacent beams |
| Xiaomi | We support option 2. |
| Huawei/HiSilicon | Just clarify to vivo, our preference in Aspect #8 is about giving the DL-AoA information for the UE, and it should have nothing to do with adjacent beams.  In our view, people tend to think the beams should be DFT beams, but in reality this may not be the case. For example, Samsung raised the issue using differential beam coefficients, in which it is not easy to identify what beams are adjacent.  It is also our understanding that ***gNB beamformer can be a gNB implementation, e.g. DFT, windowed DFT, omni-directional, differential, which is our reason of insisting gNB should calculate the angle of DL AoD***. There could even be multiple peaks in the spatial domain. The parameters of the beam coefficients may not be easily standardized, and parameterized beam coefficient may not be aligned with gNB internal optimization. For adjacent beams in particular, we do not think the concept should be adopted in the specification, and it should falls in the implementation category. |
| vivo | To Huawei, yes , we agree with the beamformer can be a gNB implementation. But , if LMF can get beam boresight and additional information in aspect 6, there is a way to identify the direction information for UE. And we want to noted that “adjacent” is only a description wording, it can not only indicate the adjacency between beams as DFT beams, but also indicate that the beam patterns of multiple PRS resources are located within a certain spatial range.  If there are many resources are close to the direction of UE (just like the example from Huawei), it means that the UE may select more resources that need to be measured and reported in addition to the strongest RSRP resources. Futhermore, we also believe it is beneficial for reducing measurement overhead and improve accuracy in many cases. |

### Aspect #6 Support of additional gnodeB beam information signalling

#### Summary and FL proposal

During RAN1#104e, there was a lengthy discussion regarding whether the network should provide further beam information to the LMF or the gnodeB should be able to perform AOD computations and report the aod measurement.

|  |
| --- |
| **Proposal 10f-bis Regarding support of angle calculation enhancement for DL-AoD, consider the following options:**  ·        **Option 1: Support gNB providing the beam/antenna information  to the LMF.**  **o   FFS the details of contents of the beam/antenna information.**  o   **FFS the details of how to report the beam/antenna information.**  o   **Note: The gNB beam/antenna information can be provided to the UE for UE-based DL-AoD**  o   **Note 2: The antenna information is related to reducing the overhead of beam information**  ·        **Option 2: Support angle report from gNB to LMF.**  o   **Note: Option 2 could be down prioritized to Option 1 if angle calculation enhancement for DL-AoD is supported**  o   **Note 2: Input from other WGs may be needed to evaluate this enhancement.**  ·        **FFS: Applicability of both options to either or both of UE-assisted DL-AoD and UE-based DL-AoD** |

The following proposal were made in RAN1#104b-e contributions: [2][4][5][8][12][14][18][22]:

|  |  |
| --- | --- |
| Source | Proposal |
| [2] | ***Proposal 1***   * ***AoD enhancement of additional beam information should be supported in R17 AoD positioning. The following proposal in RAN1# 104e meeting for additional beam information can be agreed as a start point.***  |  | | --- | | Regarding support of angle calculation enhancement for DL-AoD, consider the following options:   * **Option 1: Support gNB providing the beam/antenna information ~~gNB~~ to the LMF.**   + FFS the details of contents of the beam/antenna information.   + FFS the details of how to report the beam/antenna information.   + Note: The gNB beam/antenna information can be provided to the UE for UE-based DL-AoD   + Note 2: The antenna information is related to reducing the overhead of beam information * Option 2: Support angle report from gNB to LMF.   + Note: Option 2 could be down prioritized to Option 1 if angle calculation enhancement for DL-AoD is supported   + Note ~~2~~: Input from other WGs may be needed to evaluate this enhancement.   + FFS: Applicability of ~~both~~ the option~~s~~ to either or both of UE-assisted DL-AoD and UE-based DL-AoD | |
| [4] | ***Proposal 5: NR Rel-17 should support a gNB to report the transmission characteristics of a TRP beam to LMF, including:***   * ***The structure and parameters of the transmitting antenna array, such as antenna element distribution, element shape and size, element spacing, etc.*** * ***Parameters of transmitting RF channels, such as time delay of different RF channels.*** * ***Analog beamforming vector.*** * ***Digital beamforming vector, such as codebook used for precoding.*** |
| [5] | ***Proposal 3****: Support gNB providing the beam/antenna information to the LMF and further discuss the details of contents of the beam/antenna information.*  ***Proposal 5****: To reduce overhead for providing radiation pattern in use by UE-based DL-AOD, the radiation pattern for each DL PRS resource is restricted to the angle range provided by expected AOD and AOD uncertainty.* |
| [8] | **Proposal 3: Support of gNB providing the beam/antenna information to the LMF for the angle calculation enhancement for DL-AoD**   * **FFS the details of contents of the beam/antenna information.** * **FFS the details of how to report the beam/antenna information.** |
| [12] | * + **Support enhancement for the DL-AOD estimation in Rel-17 by utilizing the gNB/TRP beam/antenna information, including the following:**     - **gNB/TRP beam information:**       * **Phase value per antenna element / port**       * **Amplitude value per antenna element (optionally)**     - **gNB/TRP antenna array information:**       * **Antenna array orientation in space with respect to the global coordinate system**       * **Antenna pattern of the single antenna element (optionally)**       * **For the uniform rectangular planar array, provide the total number of elements over horizontal and vertical dimension as well as the antenna spacing per dimension**       * **In general case, provide the coordinates of the antenna array elements in the local coordinate system** * **Support the network-based DL-AOD solution, where the gNB/TRP beam/antenna assistance information is shared with the LMF, including the following steps, measurements, and reporting (option #1 in Table 1):**   + **UE receives DL-PRS resources, performs phase/amplitude measurements for the first arrival path per DL PRS resource**   + **UE reports phase/amplitude measurements to LMF**   + **LMF computes the coordinates** * **Support the network-based DL-AOD solution, where the gNB/TRP beam/antenna assistance information is not shared with the LMF/UE, including the following steps, measurements, and reporting (option #2 in Table 1):**   + **UE receives DL-PRS resources, performs phase/amplitude measurements for the first arrival path per DL PRS resource**   + **UE reports phase/amplitude measurements to gNB**     - **It can be reported directly from UE to gNB**     - **Or it can be reported using LMF, i.e. first UE sends the report to LMF and then LMF sends the report to gNB**   + **gNB estimates DL-AOD and reports it to LMF**   + **LMF computes the coordinates** * **Support the UE-based DL-AOD solution, where the gNB/TRP beam/antenna assistance information is shared with the UE, including the following steps, measurements, and reporting (option #4 in Table 2):**   + **UE receives DL-PRS resources, performs phase/amplitude and/or DL-AOD estimation**   + **UE computes the coordinates** * **Support the network-based DL-AOD solution, where the gNB/TRP beam/antenna assistance information is shared with the UE, including the following steps, measurements, and reporting (option #3 in Table 1):**   + **UE receives DL-PRS resources, performs DL-AOD estimation**   + **UE reports DL-AOD to LMF**   + **LMF computes the coordinates** |
| [14] | ***Proposal 2: For the UE-B/UE-A DL-AoD method, support gNB providing of beam/antenna information to the LMF (UE-A) and to the UE (UE-B). Consider one or more of the following Options on the format of the beam/antenna information:***   * ***Opt. 1: Quantized or Parametrizated version of the Power/Angle response per PRS resource*** * ***Opt. 2: Antenna element pattern with UPA antenna configuration & PMI index per PRS resource*** |
| [18] | ***Proposal 6: Support the following DL-AoD angle calculation enhancements***   * ***The RAN nodes calculate the AoD with the RSRP information based on gNB configuration and send the AoD information back to LMF.*** |
| [22] | **Proposal 1:**   * **Support the TRP providing beam information to the LMF; the information includes:**   + **a gain level for the reported main lobe and a the side lobe levels**   + **a relative gain level a gain level for the reported main lobe and a the side lobe levels** |

The proposals in the contributions follow the options in the latest proposal for that issue in RAN1#104b:

* 6 companies explicitely support providing additional beam information from the gnodeB to the LMF [4][5][8] [12] [14][22]
* 2 Companies supporting computations of AOD at gnodeB: [12] [18]
* 1 Company open to continue the discussion: [2]

As the proposals are in line with the last proposal on the issue in RAN1#104e, we propose to start with this proposal, to see if there is a way forward first regarding whether to support transferring beam information to the LMF from the gnodeB (option1) or instead support computation of AoD in the gnodeB and reporting to the LMF (option2). Once this is resolved we could processed with further details for either of the options.

**Proposal 6.1 Regarding support of angle calculation enhancement for DL-AoD, consider the following options:**

·        **Option 1: Support gNB providing the beam/antenna information  to the LMF.**

**o   FFS the details of contents of the beam/antenna information.**

o   **FFS the details of how to report the beam/antenna information.**

o   **Note: The gNB beam/antenna information can be provided to the UE for UE-based DL-AoD**

o   **Note 2: The antenna information is related to reducing the overhead of beam information**

·        **Option 2: Support angle report from gNB to LMF.**

o   **Note: Option 2 could be down prioritized to Option 1 if angle calculation enhancement for DL-AoD is supported**

o   **Note 2: Input from other WGs may be needed to evaluate this enhancement.**

·        **FFS: Applicability of both options to either or both of UE-assisted DL-AoD and UE-based DL-AoD**

#### First round of comments

Companies are encouraged to provide comments in the table below.

|  |  |
| --- | --- |
| **Company** | **Comment** |
| Qualcomm | Highest Priority for discussion across all issues in the DL-AoD agenda. Given the discussion from previous meeting, We prefer to start the discussion from this topic during the Ran1 104b meeting.  Support of Option 1, which can handle both UE-B and UE-A methods. Option 2 can only work for UE-A and needs input from RAN2/3 which already discussed lengthy this topic and avoided. It has high impact in arcitecture, and if Option 1 (which is aligned to current architecture) is supported, we would significantly enhance DL-AoD for both UE-A and UE-B.  From our side, DL-AoD is considered „broken“ as a high-accuracy method without this feature, unless it is technically clarified by some company how we can get degree or sub-degree AoD accuracy without this informaiton. In current Rel-16 specification, the UE (or LMF) ONLY knows the boresight direction of each PRS resource. |
| ZTE | We suggest to further discuss Option 1 for both UE-B and UE-A. We think Option 2 is not a good scheme in terms of positioning latency. |
| vivo | Support in principle |
| Huawei/HiSilicon | We do not support down-prioritizing Option 2 for this meeting.  To ZTE, we do not think latency should be the concern here, as we are discussing the accuracy enhancement. Even from latency aspects, LMF calculating the angle is more of a centralized way, while TRP calculating the agnle is more of a distributed way, and distributing the angle calculation to TRPs (offloading) may reduce latency given that LMF may be overloaded since AoD calculation times will be NumUE x NumTRPs.  To QC, the beam pattern of the TRP can be managed/collected by the operator and configured in LMF, without specifying in NRPPa. This is widely used in RSRP/RSSI finger-printing.  We do not think that it is fair that to achieve high accuracy DL-AoD, gNB has no alternative other than revealing its beamforming implementation. |
| Intel | We support both Option 1 and Option 2. We also consider this topic having highest priority.  We disagree to down prioritize the Option 2 to Option 1 due to similar reason as HW mentioned.  We believe that operators may be concerned or be sensitive to share/disclose beam/antenna information to the third party. Therefore, in addition to option 1 we suggest supporting option 2 and remove the note about down prioritization of option 2 if DL-AOD enhancements are supported. |
| Nokia/NSB | Support option 1 in principle.  Do not support option 2 as we don’t consider it in RAN1 scope. |
| CATT | We prefer Option 1, and maybe Option 2 can also be keep in the candidate list in this meeting and further discuss them in next meeting.  We think providing the gNB beam/antenna information to LMF or UE can help both angle calculation enhancement and beam orientation impairement mitigation for DL-AoD. |
| OPPO | Support in principle and Option 1 is preferred. |
| Huawei/HiSilicon | We disagree with Nokia’s comments. Why is it that option 1 is in RAN1 scope while option 2 is not? |
| Sony | We support Option 1. Furthermore, we should consider an assistance information from LMF to gNB (e.g. AoD range). |
| Qualcomm | To HW and with regards to this: „To QC, the beam pattern of the TRP can be managed/collected by the operator and configured in LMF, without specifying in NRPPa. This is widely used in RSRP/RSSI finger-printing.“  OK thanks for the reply, and confirming that the way to make DL-AoD work as a high accuracy method in NR Rel-16 is by outside-of-3GPP bilateral agreements. However, in principle, we should avoid such unfortunate „big bugs“ in the 3GPP specs, since, at the end of the day, we are trying to have an inclusive & global specification. Also, such a bilateral agreements with LMFs is not easily scalable, creates „side specs“, barriers to new vendors, and also barriers to deploying UE-based solutions.  We should try to have complete specifications as much as possible, and for this reason we consider this aspect the most crucial for arguing that 3GPP did a good job specifying a DL-AoD positioning technology |

#### Summary of 1st round of comments

Since the discussion is still ongoing and many companies have not commented yet, it is proposed to wait for more comments. As the discussion already started last meeting, it is proposed to bring it up at the GTW call.

#### second round of comments

Companies are encouraged to provide comments in the table below.

|  |  |
| --- | --- |
| **Company** | **Comment** |
| CMCC | Support in principle. Option 1 is more preferred.  We think that the pro of option 2 over option 1 is that, option 2 can avoid the overhead of reporting the complicated beam/antenna information to the LMF, but since the reporting detials and contents are still FFS, I think some optimization on reducing the reporting overhead can be further discussed. For option 2, the main drawback is the latency, because the UE should first report the PRS-RSRP measurements to the LMF, the LMF then forward the measurement to the gNB. The gNB calculates AoD estimates and report them back to the LMF, which is a long exchaning procedure. |
| Qualcomm | We observe that no concern has been raised for Option 1. We suggest to support at least Option 1 for both UE-A/UE-B and send an LS to RAN2/RAN3 to discuss how/whether it is feasible and beneficial for Option 2 to be supported for UE-A DL-AoD. Remove the note of „down-prioritizing“ of Option 2 to try to find middle ground, and clarify that Option 1 is supported for both UE-A and UE-B.  ***Regarding support of angle calculation enhancement for DL-AoD:***   * ***Support gNB providing the beam/antenna information to the LMF.***   + ***The gNB beam/antenna information can be provided to the UE for UE-based DL-AoD***   + ***FFS the details of contents of the beam/antenna information***   + ***FFS the details of how to report the beam/antenna information.***   + ***Note: The antenna information is related to reducing the overhead of beam information*** * ***Continue the study on the Option of Supporting angle report from gNB to LMF for UE-A DL-AoD.***   + ***Send an LS to RAN2/RAN3 to ask them whether this option is feasible and beneficial to be supported for UE-A DL-AoD in NR Rel-17*** |
| SS | Support this proposal in general. Option 1 is our preference. |
| Huawei/HiSilicon | To CMCC, we do not think LMF calculating the AoD can ensure latency gain. In fact, for every UE to be positioned, LMF needs to calculate the angle for each TRP. The load on the LMF will be high, and further affect the latency. Offloading the angle calculation to gNB can avoid this issue.  To QC, we have concern for only supporting Option 1, which was expressed early.  We offer the following compromise proposal.  ***Regarding support of angle calculation enhancement for DL-AoD:***   * ***Support gNB providing the beam/antenna information to the LMF.***   + ***The gNB beam/antenna information can be provided to the UE for UE-based DL-AoD***   + ***FFS the details of contents of the beam/antenna information***   + ***FFS the details of how to report the beam/antenna information.***   + ***Note: The antenna information is related to reducing the overhead of beam information*** * ***For supporting angle report from gNB to LMF for UE-A DL-AoD.***   + ***Send an LS to RAN2/RAN3***     - ***Inform them that RAN1 sees the feasibility and benefit of this option for UE-A DL-AoD in NR Rel-17***     - ***Ask them whether this option is feasible and beneficial to be supported*** |

### Aspect #7 Calibration of gNB angle error

#### Summary and FL proposal

|  |  |
| --- | --- |
| Source | Proposal |
| [4] | ***Proposal 4: For DL-AOD calibration, Rel-17 should support the signalling and procedure for the network to select UEs, whose locations are known, as to reference UEs. The reference UE should report DL positioning measurements together with the associated position coordinates to LMF.*** |
| [9] | *Proposal 5: Estimate the angle error by a reference node whose accurate location is known.* |
| [10] | **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. |
| [10] | **Proposal 2:** RAN1 to specify support for enabling a selected device with known location to support configuration by the network to help with beam offset estimation, among other parameters. In particular, RAN1 should investigate methods and signaling required to enable the selected reference device to:   * Be configured as a reference device, e.g. device should reports its capabilities such as fixed location knowledge or high accuracy GNSS receiver availability, device estimated velocity, etc. * Report back a selected set of measurements of beamed PRS used by the network to compute and compensate for beam offset errors. This could include additional reporting capabilities (i.e., higher number of beam reports) * Ability of reference device to determine beam offset errors are present. |

All companies with contribution on the issue support the principle of having specific support for reference devices used to calibrate angle errors/ beam offsets at the gnodeB. During the RAN1#104e meeting, similar proposal were made and across all agenda items. Similarly, there are proposal on the topic of reference devices and calibration across all Ais in the current meeting. The preference of the feature lead is to have a unified discussion across all Ais.

Proposal 7.1:

Discuss calibration/reference devices support in agenda item 8.5.1.

#### First round of comments

Companies are encouraged to provide comments in the table below.

|  |  |
| --- | --- |
| **Company** | **Comment** |
| Qualcomm | Support Reference Location Devices (RLD) in NR Rel-17 for the purpose of DL-AoD (or UL-AoA) method. Further discussions can continue in RAN2/3 |
| ZTE | Support FL’s arrangement. |
| Intel | Support FL’s proposal |
| Nokia/NSB | We are okay to discuss reference devices in a single AI as long as the same handling is performed across all AIs. We support using reference devices for DL-AoD. |
| CATT | We think the calibration methods and spec impacts will be different between using reference device to mitigate of timing error and using reference device to improve the AoD accuracy. Therefore, we prefer to also discuss this issue in AoD aspect or in a single AI covering all reference device issues. |
| OPPO | Support it. This can be made as a conclusion, instead of an agreement. |

#### Summary of 1st round of comments and updated proposal

Based on the feedback received, the FLs will coordinate to transfer the discussion to 8.5.1.

### Aspect #8 AoD uncertainty window

#### Summary and FL proposal

|  |  |
| --- | --- |
| Source | Proposal |
| [5] | *.*  ***Proposal 4****: To assist UE’s DL measurement, support LMF providing expected AOD and AOD uncertainty to UE. The expected AOD and AOD uncertainty can follow similar definition as expected AOA/ZOA and AOA/ZOA uncertainty.* |
| [10] | **Proposal 9**: Introduce an expectedAoD parameter to assist Tx beamforming for gNBs and/or TRPs in DL-AoD positioning. This parameter could be signaled between the LMF and TRPs (e.g., using NRPPa). |
| [14] | ***Proposal 3: NR supports at least the following additional assistance signaling from LMF to UE to facilitate DL measurements for DL-AoD:***   * ***Indication of expected AoD/ZoD value and uncertainty (of the expected AoD/ZoD value) range(s)*** |
| [16] | **Proposal 5: Support AoD range assistance information from LMF to TRP/gNB.** |
| [18] | ***Proposal 3: Support introducing expected DL AoA information in the assistance data to assist UE to selected Rx beam at least for DL-AoD.*** |
| [20] | ***Proposal #3:***   * For beam alignment between gNB/TRP and UE, following additional enhancement (procedure and/or signaling from LMF or gNB/TRP to UE) should be considered:   + Additional signaling: the location of UE and the amount of uncertainty     - Here the location of UE might be the pre-calculated location of UE at LMF.   + Based on the above information, UE adjusts Rx spatial filter based on the information to align LOS direction. |
| [23] | **Proposal 3.1:** LMF should provide the gNB with angle measurement windows, both in azimuth and elevation directions, to gNB as an assistance information for DL-AoD. |

Several proposals mention the use of an uncertainty window for AoD in the same way it was discussed in AoA. The proposal differ with respect to what node is the receiver of the uncertainty window:

* Companies [5][14][18][20] supporting having the LMF send the expected AoD and uncertainty window to the UE
* Companies [10][16][23] supporting having the LMF send the expected AoD and uncertainty window to the gnodeB

Proposal 8.1: to support DL-AoD measurements with the expected AoD and an AoD uncertainty window, select one or more of the following options:

* Option 1: Indication of expected AoD/ZoD value and uncertainty (of the expected AoD/ZoD value) range(s) is signaled by the LMF to the UE
  + FFS: details of signaling
* Option 2: Indication of expected AoD/ZoD value and uncertainty (of the expected AoD/ZoD value) range(s) is signaled by the LMF to the gnodeB
  + FFS: details of signaling
* Option 3: Indication of expected AoD/ZoD value and uncertainty is not introduced.

#### First round of comments

Companies are encouraged to provide comments in the table below.

|  |  |
| --- | --- |
| **Company** | **Comment** |
| Qualcomm | Support at least Option 1.  We would like Clarification for Option 2. Does option 2 mean that the serving gNB forwards the expectedDl-AoD to the UE, or is it is for the gNB to pick a good PRS? If it is the latter, then i assume it is related to LMF-initiated on-demand DL-PRS right? If yes, then we are also supportive of having Option 2 also, but as a 2nd priority compared to Option 1 for this subagenda, since we tend to see this more related to on-demand PRS. |
| ZTE | Support Option1. |
| vivo | We would like more clarifications for the format of the expected AoD and an AoD uncertainty window and how to use it.  For example, it is easy to understand that AoA method makes use of expected AoA to search an angle and DL-TDOA method makes use of expected RSTD to search a ToA given the measurement volume of those method is angle-based or timing-based positioning.  But, for AoD method, since it doesn’t need UE to measure an angle, how to make use of angle information, and whether UE can correctly understand the expected AoD angle that indicated by LMF. |
| Huawei/HiSilicon | Unclear why we need Option 2 for DL-AoD.  In addition, we propose to add another Option here based on our t-doc and we support the following Option instead of Option 1/2.   * Option x: Indication of expected (DL-)AoA/ZoA value and uncertainty (of the expected DL-AoA/ZoA value) range(s) is signaled by the LMF to the UE   + FFS: details of signaling |
| Nokia/NSB | We support Option 1 and Option 2.  We agree with QC that on-demand PRS seems the most likely candidate for signaling expected AoD to TRP.  To vivo, many UE may be orientation aware and in UE-based they then gain the advantage of having a pre-determined expected region so the same argument for expectedAoA apply in our view. It can help to limit the UE measurement burden. |
| CATT | Support Option 1. |
| OPPO | Support Option 3:   * For Option 1: In our view, there is no justification to send such information to a UE. In DL AoD method, the UE measures the RSRP of multiple PRS resources and reports the best RSRP. The UE is not aware of any angle information. * For option 2: we do not know why such information shall be sent to gNB. gNB does not estimate the AoD of one UE. |
| Ericsson | Support option 1 and option x from Huawei. For option 2, we’re ok to discuss it in the scope of on-demand PRS. |
| LG | Support Option1. |

#### Summary of 1st round of comments and updated proposal

The proposal is updated with option-x from the comment from Huawei/Hisilicon. There were several comments asking for clarification on option 2, and proponents are encourage to clarify their intention.

Proposal 8.1: to support DL-AoD measurements with the expected AoD and an AoD uncertainty window, select one or more of the following options:

* Option 1: Indication of expected AoD/ZoD value and uncertainty (of the expected AoD/ZoD value) range(s) is signaled by the LMF to the UE
  + FFS: details of signaling
* Option 2: Indication of expected AoD/ZoD value and uncertainty (of the expected AoD/ZoD value) range(s) is signaled by the LMF to the gnodeB
  + FFS: details of signaling
* Option 3: Indication of expected (DL-)AoA/ZoA value and uncertainty (of the expected DL-AoA/ZoA value) range(s) is signaled by the LMF to the UE
  + FFS: details of signaling
* Option 4: Indication of expected AoD/ZoD value and uncertainty is not introduced.

#### second round of comments

Companies are encouraged to provide comments in the table below.

|  |  |
| --- | --- |
| **Company** | **Comment** |
| Huawei/HiSilicon | We think the main bullet can be revised.  Proposal 8.1: to support DL-AoD measurements with the angle search window, select one or more of the following options: |
| ZTE | We can accept this proposal. We assume we’ll down-select one or more options in next meeting. |
| vivo | To Huawei and all, We would like more clarification for the angle search window, whether it means to request UE measure the PRS resource(s) in the angle search window? |
| Huawei/HiSilicon | To vivo, in our view, this is the direct method of reducing UE Rx beam training if UE knows its orientation. UE may use the beamformer matching the expected DL-AoA to receive the PRS from a TRP, and of course UE may try a couple of alternative beamformers within the seach window for further optimization, which is subject to RAN4 RRM discussion.  In Rel-16, PRS-SSB QCL was used to provide the Rx beam information, but UE may not be able to measure the SSB due to coverage issues.  Note that this is also from the same principle for expected AoA for the UL-AoA method: LMF knows the TRP coodinates, LMF knows the UE (coarse) location, and LMF provides the LOS path direction to TRP or to the UE. |
| vivo | Thanks for the further explanation from Huawei, we wonder whether it is a common understanding that the expected AoD is only used for UE to choose RX beam? If is, it is more like expected Rx Beam direction, other than expected AoD. And we want to confirm the function of uncertainty, it is for choosing more RX beams?  In our view, we think it is also helpful to choose PRS resources and reduce measurement overhead. But it needs the additional assistance date for UE-A (such as boresight angle information).  So we would like to discuss two cases together. |
| CATT | We think Option 1, Option 3 and Option 4 can be further studied and down-selection in next meeting. But we failed to see the motivation and benefit of Option 2. |

### Other aspects

|  |  |
| --- | --- |
| Source | Proposal |
| [1] | Observation 1: Large number of DL PRS resource is needed for high accuracy of DL-AoD positioning.  Proposal 1: To enhance the performance of DL AoD, support UE-specific beam refinement on DL PRS resource for DL-AoD measurement. |
| [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.*** |
| [10] | **Proposal 7**: Consider two stage beam-sweeping for DL-AoD together with on-demand PRS transmission and reception.  **Proposal 8**: Support association between resources belonging to two DL PRS resource sets (at the same TRP) to facilitate support of two stage beam sweeping. |
| [20] | ***Proposal 4:***   * To overcome beam resolution problem, 2-step beam adjustment procedure needs to be considered. |

# Conclusion

**TBD**

# References

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4. R1-2102637, Discussion on accuracy improvements for DL-AoD positioning solutions, CATT
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14. R1-2103172, Potential Enhancements on DL-AoD positioning, Qualcomm Incorporated
15. R1-2103245, Accuracy improvements for DL-AoD positioning solutions, Samsung
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20. R1-2103623, Discussion on accuracy improvement for DL-AoD positioning, LG Electronics
21. R1-2103649, Accuracy enhancement for DL-AOD technique, MediaTek Inc.
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