3GPP TSG-RAN WG1 Meeting #105-e R1- 210NNNN

e-Meeting, May 10th – 27th, 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:

[105-e-NR-ePos-03] Email discussion/approval on accuracy improvements for DL-AoD positioning solutions with checkpoints for agreements on May 25, May 27 – Florent (Ericsson)

The FL proposals are based on submission to AI 8.5.3 [1-22] and treat the following aspects:

* Aspect #1 reporting of first path RSRP
* Aspect #2 extension of number of reported RSRP measurements
* Aspect #3 Adjacent beam identification in AD and reporting by the UE
* Aspect #4 Support of additional gnodeB beam information signalling
* Aspect #5 AoD uncertainty window
1. Aspects for discussion

## Main discussion topics

### 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:

|  |
| --- |
| 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.
 |

The discussion continued in RAN1#104b-e, but did not result in any new agreement.

In [1][2][3][4][5][6][7][8][9][12][13][14][15][17][18][20][22] companies gave their preferred options and provided further details:

|  |  |
| --- | --- |
| Source | Proposal |
| [1] | ***Proposal 1:*** ***In DL-AoD measurement report, support the UE to report the information corresponds to PRS-RSRP and arrival time of the first arriving path.*** |
| [2] | ***Proposal 3: Support the following Options for enhancing DL-AoD.**** ***Option 1: Information corresponds to PRS-RSRP of the first arriving path.***
* ***Option 4: Information corresponds to phase of the CIR corresponding to the first arriving path.***
	+ ***This should target multiple PRS resources transmitted on consecutive symbols within a slot.***
* ***Note: Option 3 (Information corresponds to the arrival time of the first path) can be discussed in the multi-path enhancements.***
* ***Note: Option 2 (Information corresponds to the angle of departure of the first arriving path) can be treated with lower priority and discussed along with DL-AOD angle calculation enhancement.***

***Proposal 4: Introduce a common path power measurement window across multiple PRS resources for a TRP, where the PRS-RSRP per path is evaluated based on the CIR within the window.**** ***The window is centered on the peak of the first path, and the window size can be set to include the main lobe and optionally the sidelobes of the first path.***
 |
| [3] | **Proposal 10*** ***Option 3 should be discussed after option 1 is being agreed upon.***
	+ ***Option 1: Information corresponds to PRS-RSRP of the first arriving path***
	+ ***Option 3: Information corresponds to the arrival time of the first path***
* ***The benefit of reporting timing information needs to be further clarified.***

**Proposal 11*** ***The performance benefits of Option 2, option 4, and option 5 should be evaluated first especially in phase inconsistency cases.***
	+ ***Option 2: Information corresponds to the angle of departure of the first arriving 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***

**Proposal 12*** ***The angle-based AoD positioning or phase-based AoD positioning are postponed to the future release.***
 |
| [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, if the definition of per-path RSRP is introduced.***  |
| [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,** *Time of arrival( i.e. TOA) for at least one reference signal per TRP*
* *Arrival time differences among reference signals from the same TRP (i.e. Intra-TRP TDOA)*

***Proposal 2:*** *UE can report an indicator for each reported reference signal (or each DL PRS-RSRP value) to indicate that the sequence of arrival time of the first path for difference reference signals.*  |
| [6] | Proposal 1: 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: how the “first path” is selected or indicated among PRS resources in a PRS resource set
 |
| [7] | ***Proposal 4: 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.***
 |
| [8] | Proposal 5: In DL-AoD measurement report, support the UE to report:* 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).
 |
| [9] | ***Proposal 1: Enable the UE to measure and report PRS-RSRP of the first arriving path to avoid the problem of angle estimation may be biased.*** |
| [12] | **Proposal 2*** **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 (Proposal 1.2 d/e in the FL’s summary)**
	+ **LMF computes the coordinates**

**Proposal 3*** **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 #2 in Table 1):**
	+ **UE receives DL-PRS resources, performs DL-AOD estimation for the first arrival path per DL PRS resource**
	+ **UE reports DL-AOD to LMF (Proposal 1.2 b in the FL’s summary)**
	+ **LMF computes the coordinates**
 |
| [13] | **Proposal 2**: For DL-AoD technique, support PRS-RSRP measurement within a configured time window wherein the power of paths out of the window, if any, does not contribute in PRS-RSRP.* Alternatively, or additionally, for DL-AoD technique, support PRS-RSRP for the first arrival path only that is measured within a configured time window.
 |
| [14] | **Proposal 1:** **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 2: Time window for PRS-RSRP and selection of the first path are UE implementation aspect.****Proposal 3: Support assistance information from LMF to UE in order to assist UE in selecting the first 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*** |
| [17] | **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. |
| [18] | *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.* |
| [20] | **Proposal 1: 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)**
 |
| [22] | 1. Define a DL PRS path power ratio (DL PRS-PPR) measurement for the relative power of a specific path in the channel impulse response.
2. Include DL PRS-PPR of the first path in NR DL-AoD Location Information alongside the existing DL PRS RSRP measurement.
3. Include DL PRS-PPR of the first path in the NR DL-TDOA Location Information and in NR multi-RTT Location Information alongside the existing DL PRS RSRP measurement.
4. The UE shall report DL PRS-PPR of additional paths in i) NR DL-AoD Location Information, ii) NR DL-TDOA Location Information and in iii) NR multi-RTT Location Information.
5. The UE shall report the strongest detected paths as additional paths (i.e. in addition to the first path).
 |

Support of first-path or per-path RSRP measurement was proposed in [1][2][3][4][6][8][9][13][14][15][17][18][22] In [22] a proposal for a definition of per-path RSRP is introduced. In [15] it is proposed to have an indicator in the report to signal that one or all paths are used to compute the RSRP. In [22] it is proposed to extend the applicability of per-path PRS RSRP to other DL and DL+UL positioning method.

Based on the proposals on per-path RSRP, the following is proposed for discussion:

**Proposal 1.1:**

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: 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 (e.g. use of a time window )
	+ FFS: additional assistance data
	+ FFS: definition of per-path RSRP

In [2][7][12][20] it is proposed to report the phase of the CIR for the first arriving path and / or additional paths. [2] also discuss the conditions to maintain coherence and propose to have the measurement limited to consecutive symbols within a slot. In [3], the contribution comments that phase-based measurements should be evaluated first against phase inconsistency cases.

Based on the proposals on phase reporting, the following is proposed for discussion:

Proposal 1.2:

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

Regarding Time of arrival reporting, [5][8][17][18][20] propose to consider TOA or intra TRP TDOA. In [3], it is proposed to discuss the report the arrival time of the first path if path RSRP reporting is agreed. In[2], the option of reporting TOA per path is suggested to be discussed in the NLOS identification agenda.

Based on the proposals on TOA reporting, the following is proposed for discussion:

Proposal 1.3

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

In[7] it is propose to support AoD reporting by adding antenna configuration, PMI codebook configuration and their PRS association to the assistance data. [12] also propose to support UE reporting of DL AoD. In[2], the option of reporting AoD is suggested to be discussed as part of aspect #5.

Based on the proposals on AoD reporting, the following is proposed for discussion:

Proposal 1.4:

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

#### First round of comments

Companies are encouraged to provide comments in the tables below.

**Proposal 1.1**

|  |  |
| --- | --- |
| **Company** | **Comment** |
| ZTE | What’s the definition of RSRP of first arriving path needs to be clarified first. We may need to consult RAN4 whether UE can be sensitive enough to measure path-RSRP. |
| 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, such as signal amplitude and phase, since RSRP is a time-accumulation quantity instead of an instantaneous quantity. And we also support to discuss how to define PRS-RSRP. RAN4 may need to be involved in the per-path RSRP definition. |
| OPPO | Support in principleWe also think the definition of RSRP of 1st path shall be dicussed by RAN4 |

**Proposal 1.2**

|  |  |
| --- | --- |
| **Company** | **Comment** |
| ZTE | Not support. The phase is so easier to be affected by impairments than power and delay. |
| CATT | Not support, since the signal phase is very sensitive to RF impairments, the benefits are not clear. |
| OPPO | Not support. The phase measuremed at the UE side contains many factors inlucluding hardware impairements and it does not give us meaningful information. |

**Proposal 1.3**

|  |  |
| --- | --- |
| **Company** | **Comment** |
| ZTE | Support. It’s a important feature to identify which DL PRS-RSRP is based on a LOS link. We propose to support TOA and intra-TDOA within a TRP. |
| CATT | Not support. It is not clear on the motivation of measurement and reporting (for UE-assisted) for the arrival time of the first path for the angle-based DL-AoD method. |
| OPPO | SupportThe combination of RSRP and time-of-arrviabla of one PRS shall be considered. |

**Proposal 1.4**

|  |  |
| --- | --- |
| **Company** | **Comment** |
| ZTE | Not support.1. Current DL PRS only support one port, it’s impossible for UE to find a PMI matrix based on a resource.
2. As mentioned by other companies, if the search of PMI matrix is based on multiple resources, in which the phase consistency should be kept among different resources.In addition, this changes the current design since different resources in a DL PRS resource set are normally transmitted with different beams.

We propose to postpone this discussion in future release. |
| CATT | Support to FFS this issue. |
| OPPO | Not supportThe UE is not able to measure the angle of departure. |

**Proposal 1.5**

|  |  |
| --- | --- |
| **Company** | **Comment** |
| CATT | It looks like there is no Proposal 1.5. |

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

###  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:

|  |
| --- |
| 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 issue was discussed in RAN1#104b-e, but did not converge. The following proposals [3][4][6][7][8][9][13][16][17][21][22] have been made

|  |  |
| --- | --- |
| Source | Proposal |
| [3] | ***Proposal 13**** ***To improve the accuracy of DL-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.***
		- ***FFS: value for N.***
 |
| [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.***  |
| [6] | **Proposal 2: For UE-assisted DL AOD, support up to N>=8 measurements for reporting of RSRP measurements per TRP.** |
| [7] | ***Proposal 7: 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***
 |
| [8] | Proposal 4: For UE-assisted DL AoD, support Option1, up to 8 RSRP measurements in a measurement report (as in release 16). |
| [9] | ***Proposal 3: Up to N>=8 measurements in a measurement report for reporting of RSRP measurement per TRP.*** |
| [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. |
| [16] | ***Proposal 3:**** 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 4:**** 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.
 |
| [17] | **Proposal 5**: Support “Option 3: Up to N>8 measurements” as candidate enhancement. FFS value of N.  |
| [21] | ***Proposal 2: Enhance the assistance data to proactively allow the LMF to explicitly configure DL-PRS RSRP measurements to be reported with the same Rx beam.*** |
| [22] | 1. 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 [3][4][6][7][9][17]. [8][13] support to keep the current limit. [16] [21][22] propose to signal to the UE to use a fixed Rx beam.

Based on the proposals from companies, the following is submitted for discussion

**Proposal 2.1**

**For UE-assisted DL AOD, support up to N>=8 measurements for reporting of RSRP measurements per TRP.**

* **FFS: value of N**
* **For the capable UE, The LMF can request that all measurements in a report correspond to the same Rx beam. The choice of Rx beam is left to the UE.**

#### First round of comments

Companies are encouraged to provide comments in the table below.

|  |  |
| --- | --- |
| **Company** | **Comment** |
| ZTE | Prefer not to extend the current limit. We think it’s enough to support 8 measurements per TRP. Although UE can use different Rx beams to receive signals, it’s up to UE to select some of measurements that are measured with high quality. |
| CATT | Support. 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. |
| OPPO | Not supportThere is no justification to extend the number of RSRP measurements.  |

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

###  Aspect #3 adjacent beam reporting

#### Summary and FL proposal

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

|  |
| --- |
| Agreement:Support the following enhancements under UE capability for both UE-B and UE-A DL-AOD positioning method * Enhancing the signaling to UE for the purpose of PRS resource(s) measurement and (for UE-A) report
	+ FFS: The detailed signaling (e.g, the boresight direction for UE-A DL-AoD, further spatial information of PRS resources, processing prioritization of PRS resources).
* FFS: The following options
	+ Option 1: Enhancing the reporting to include the measurements of adjacent beams PRS resources that related with each other indicated by the assistance data.
	+ Option 2: UE can be requested to measure and report on specific PRS resources.
 |

The following proposals [1][2][3][4][7][8][9][11][15][17][18][20][21][22]

have been made in response to the agreement

|  |  |
| --- | --- |
| Source | Proposal |
| [1] | ***Proposal 2: Support Option 1: Enhancing the reporting to include the measurements of adjacent beams PRS resources that related with each other indicated by the assistance data.***  |
| [2] | ***Proposal 2: Define PRS resource-level priority for the purpose of e.g. utilization of adjacent beams.**** ***Note: This is also applicable to DL-TDOA and Multi-RTT positioning methods.***
 |
| [3] | **Proposal 8*** ***Support to provide the boresight direction of PRS resource to UE for UE-A DL-AoD.***

**Proposal 9*** ***DL-AoD measurement with the adjacent beams can be requested when the requirement of latency and power consumption is tight.***
 |
| [4] | ***Proposal 3: Signaling to UE for the purpose of PRS measurement and report may include either an ordered PRS resource ID list, or the boresight directions of the PRS resources.******Proposal 4: Both of the following options should be supported in NR Rel-17:**** ***Option 1: Enhancing the reporting to include the measurements of adjacent PRS resources that are related to each other indicated by the assistance data.***
* ***Option 2: UE can be requested to measure and report on specific PRS resources***
 |
| [6] | **Proposal 3: For UE-assisted DL-AOD positioning method, support the LMF to provide the assistance data where the DL PRS resources in a resource set are listed in an adjacent manner, to implicitly indicate the adjacent beam information to the UE.****Proposal 4: For UE-assisted DL-AOD positioning method, support enhancing the reporting to include the measurements of adjacent beams.** |
| [7] | ***Proposal 6: With regards to PRS resource Prioritization for DL-AoD measurements, support LMF providing in the assistance data support both of the following options:**** ***Opt. 1: Boresight direction of each PRS resource (already supported for UE-B, but not for UE-A)***
* ***Opt. 2: Prioritization information (e.g. prioritization based on the ordering in the PRS resource set as was discussed during NR Rel-16).***
 |
| [8] | Proposal 2: For DL-AoD positioning method, support the following assistance data and reporting:* In the assistance data of PRS configuration, the UE is provided with configuration information that indicates which PRS resources are associated with each other in spatial domain.
* In measurement report, if the UE reports RSRP of one PRS resource, the UE also reports the RSRP of PRS resources that are associated with that PRS resource.
 |
| [9] | ***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.*** |
| [11] | **Proposal 3 : For UE-A positioning, boresight direction for DL-AoD is provided by the LMF to the UE** |
| [15] | ***Proposal 5: For DL-AoD, LMF can request UE to measure and report on specific PRS resources**** ***FFS: by implicit rules and/or explicit signaling***
 |
| [17] | **Proposal 9**: Do not support any enhancements for adjacent beam reporting (i.e., do not support option 1-2 in the FFS of the prior agreement).  |
| [20] | **Proposal 2: Support providing the UE with AD for the purpose of PRS measurements and reports by:*** **providing information on the associated PRS resources within one or more subsets, or**
* **indicating to the UE which PRS resources belong to a subset**

**For DL-AoD, a PRS resource subset may include to a group of adjacent beams.** |
| [21] | ***Proposal 1: Extend current framework of providing boresight information in the UE-based method to the UE-assisted DL-AoD method.*** |
| [18] | *Proposal 4: Adjacent PRS resources can be predefined by resource index.* |
| [22] | Proposal 8 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 9 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. 1. Select the DL PRS Resource corresponding to the highest measured RSRP/ first peak-RSRP. We call this the strongest resource.2. Select the DL PRS Resource with the highest RSRP/first 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/first 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. 1. Select the DL PRS Resource with the highest RSRP/first peak-RSRP measurement. We call this the strongest resource.2. Select the DL PRS Resource with the highest RSRP/first 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/first 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 following can be summarized regarding the signalling of adjacent beams:

* 7 companies [1][3][6][8][20][18][22] support the signalling of a list of adjacent beams
* 3 companies [2][4][7] prefer signalling a priority for the purpose of identifying adjacent beams
* 3 companies [4][9][15] support the request of specific PRS resources to be measured and reported
* 3 companies [7][11][21] support the signalling of the boresight direction for each resource also for UE-A

Since there does not seem to be a clear preference, it is proposed to continue the discussion based on the last agreement, and hopefully select one option to identify the adjacent beams. for option 1 below, it is the feature lead intention that it includes the solution related to indicating to the UE the resources to measure as well as signalling of a list of adjacent beams, and the selection of the solution is FFS. Regarding the FFS on reporting with option 1 and 2 captured in RAN1#104b-e, it is proposed to postpone the discussion to allow the design of the assistance data to be more stable.

Proposal 3.1:

For UE-assisted DL-AOD positioning method, downselect between the following to indicate adjacent beams in the signalling to the UE:

* Option 1: the LMF explicitly identify adjacent beams in the AD
* Option 2: the LMF send the beam information in the AD with an order of priority for the UE measurements.
* Option 3: the LMF includes boresight direction information for each PRS resource in the assistance data.
* 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** |
| InterDigital | We support Option 3. Boresight direction of each PRS resource will assist the UE to determine an optimum RX beam for UE-assisted DL-AoD. |
| ZTE | Not support. We are open to further discuss Option 3 in Proposal 5.1. This is related to how UE can understand expected AOD/ZOD for UE-A based DL-AOD. |
| CATT | Support both Option 2 and Option 3. |
| OPPO | Support both option 1. And do not support Option 2 and 3.Re option 2: it does not make sense to ask the LMF give priority of PRS for the UE to measure because the LMF does not know which beam is „good“ for one particular UE and which is not. Only the UE knows which beam/PRS is good after UE measure them.Re Option 3: the boresight direction of each PRS resource is not feasible for UE becuase that direction is from the perspective of TRP. For UE-assisted method, the UE does not know the location of TRP. |

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

###  Aspect #4 Support of additional gnodeB beam information

#### Summary and FL proposal

The following agreement was reached during RAN1#104b:

|  |
| --- |
| Agreement: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 provide the beam/antenna information.
	+ Note: The antenna information is related to reducing the overhead of beam information
* Send an LS to RAN2/RAN3 regarding the option of angle report from gNB to LMF for UE-A DL-AoD requesting them to consider this option in Rel-17.
 |

The following proposal were made in RAN1#104b-e contributions: [2][3][4][5][6][7][8][11][12][14][17][20][22]:

|  |  |
| --- | --- |
| Source | Proposal |
| [2] | ***Proposal 5: For reporting gNB beam/antenna information, support the following elements**** $N\_{1}$***: The number of antenna elements along the horizontal axis***
* $N\_{2}$***: The number of antenna elements along the vertical axis***
* $d\_{1}$***: The antenna element spacing along the horizontal axis***
* $d\_{2}$***: The antenna element spacing along the vertical axis***
 |
| [3] | **Proposal 1:*** ***For DFT beams, only antenna configuration information needs to be provided, and the antenna configuration information includes at least the following information:***
	+ - * ***[***$N\_{Hor}$***,***$ N\_{ver}$***],*** $N\_{Hor}$ ***is the number of horizontal antennas,*** $N\_{ver}$ ***is the number of the vertical antenna;***
			* ***Antenna spacing: dH, dV***
			* ***(optionally)Antenna pattern, such as omnidirectional or directional***

**Proposal 2*** ***For Non-DFT beams, select one of the following options as the beam/antenna information:***
	+ - * ***Option 1: Providing*** $\left\{RSRP\_{angle}\right\}$ ***mapping table for each PRS resource***
			* ***Option 2: Providing the typical parameter of beams (such as intersection point of multiple beams*** $\left(angle ,RSRP\right)\_{intersection point}$***, beamwidth) for each PRS resource***
			* ***Option 3: The parameters of the approximate function which is used to represent the beam response of the PRS resource.***

**Proposal 3*** ***For Non-DFT beams, support providing the typical parameter of beams (such as intersection point of multiple beams*** $\left(angle ,RSRP\right)\_{intersection point}$***, beamwidth) for UE-A and UE-B DL-AoD. Support providing*** $\left\{RSRP\_{angle}\right\}$ ***mapping table only for UE-A DL-AoD.***
 |
| [4] | ***Proposal 7: NR Rel-17 should support a gNB to report the transmission characteristics of a TRP beam to LMF or UE, including:**** ***The structure and parameters of the transmitting antenna array, such as antenna element distribution, element shape and size, element spacing, etc.***
* ***Analog beamforming vector.***
* ***Digital beamforming vector, such as codebook used for precoding.***

***Proposal 8: In order to improve the accuracy of the beam response established by LMF or UE, it is necessary to consider the amplitude and phase inconsistency parameters in the TX channel of each antenna element of the TRP transmitter. gNB should report the following parameters to LMF or UE:**** ***Timing delays and gains for all RF channels, or differences of timing delays and gains between all RF channels and specific RF channels***
* ***Timing delays from all antenna elements, or time delay differences between all antenna elements and a specific antenna element)***
* ***Gain of all antenna elements, or gain difference between all antenna elements and a specific antenna element.***
 |
| [7] | ***Proposal 1: Study further at least the following options for beam/antenna information delivery:*** * ***Quantized version of the relative Power/Angle response per PRS resource per TRP***
	+ ***Opt. 1: Provide the angle(s) that a relative RSRP level is valid, from a pre-defined/configured RSRP-level set.***
		- ***E.g., Angles for the [-1, -3, -5, -6, -9, -10, -12, -15, -20] dB levels***
	+ ***Opt. 2: Provide the relative RSRP for multiple tuples of (AoD, ZoD)***
* ***Consider Delta Signaling to reduce further the overhead***

***Proposal 2: Introduce more than one levels of quantization for the beam information to trade-off beam representation accuracy and overhead.*** ***Proposal 3: Reuse the associated-dl-PRS-ID as a way of signaling that 2 TRPs have the same beam information and reduce the overhead of sending repetitive beam patterns across TRPs.***  |
| [8] | ***Proposal 1: The TRP can provide the following information to the LMF:**** ***The antenna modeling of the TRP Tx antennas, e.g., including the number antennas, antenna spacing.***
* ***The precoder applied on each DL PRS resource.***
 |
| [11] | **Proposal 1: Beam/antenna information can be provided via LPP ProvideAssistanceData** |
| [12] | **Proposal 1*** + **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 (when information is provided to UE)**
			* **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**
 |
| [14] | **Proposal 4: For UE-A DL-AoD positioning: support gNB to report the TX antenna configuration (e.g., antenna codebook configuration, number of elements, and antenna pattern)and TX beam configuration (e.g. beamwidth and gain). For UE-B DL-AoD positioning: gNB sends this information to the UE.**  |
| [17] | **Proposal 6**: Any additional beam/antenna information reported by the TRP should be optional. **Proposal 7**: Support TRPs to optionally report multiple directions per DL PRS resource with each direction being associated with a power value relative to the boresight power for that resource. **Proposal 8**: Include additional assistance data for UE based positioning, including TRP polarization and geometry. |
| [20] | **Proposal 3: 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**
 |

Based on the proposals, the following ca be summarized:

* 6 companies [2][3][4][8][12][14] propose to have the gnodeB report the antenna configuration including the number of elements (vertical and horizontal), antenna spacing, and precoder information
* 4 companies [3][7][17][20] propose to use a gain/angle table for each PRS resource. In [5] it is proposed to limit the table to the span of the uncertainty window.
	+ In [7], overhead reduction is discussed and it is proposed to link PRSs with equal beam gain tables via their PRS ID.
* In [4], the issue of timing delay is raised. In the FL view, this issue is more suitable to AI 8.5.1
* In [17], it is proposed to specifically include additional assistance data for UE-B, including TRP polarization and geometry.

Since there are two approaches proposed for the content of the beam/antenna information, it is proposed to discuss which of them should be selected, or if both solution should be specified.

**Proposal 4.1**

**For the beam/antenna information to be optionally provided to the LMF by the gnodeB, select one or more of the following:**

* **Option 1: the gNB reports the antenna configuration including**
	+ **the number of antenna elements (vertical and horizontal),**
	+ **antenna spacing dh and dv**
	+ **precoder information**
		- **for DFT-based beams, precoder information is reported with PMI**
		- **FFS for non-DFT beams**
* **Option 2: the gNB reports a mapping of angle and beam gains for each of the PRS resources.**
	+ **FFS: representation of the mapping (e.g. parametric function approximating the beam response, or gain/angle table)**

#### First round of comments

Companies are encouraged to provide comments in the table below.

|  |  |
| --- | --- |
| **Company** | **Comment** |
| ZTE | Agree with this proposal. Option 1 is more appropriate for uniform distributed antenna array. While Option 2 is useful for the case that gNB/TRP has beam pattern information at hand. |
| CATT | Support Option 1. |
| OPPO | Option 1 |

#### Summary of 1st round of comments

###  Aspect #5 AoD uncertainty window

#### Summary and FL proposal

In RAN1#104b-e, the following agreement was reached:

|  |
| --- |
| Agreement:* For the purpose of both UE-B and UE-A DL-AoD, and with regards to the support of AOD measurements with an expected uncertainty window, study further whether to support at most one of the following options:
	+ Option 1: Indication of expected DL-AoD/ZoD value and uncertainty (of the expected DL-AoD/ZoD value) range(s) is signaled by the LMF to the UE
		- Single Expected DL-AoD/ZoD and uncertainty (of the expected DL-AoD/ZoD value) range(s) can be provided to the UE for each [TRP]
	+ Option 2: 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
		- Single Expected DL-AoA/ZoA and uncertainty (of the expected DL-AoA/ZoA value) range(s) can be provided to the UE for each [TRP]
	+ Option 3: Indication of expected AoD/ZoD or AoA/ZoA value and uncertainty is not introduced.
	+ FFS: details of signaling
* FFS: Applicability of this agreement to other Positioning methods
 |

|  |  |
| --- | --- |
| Source | Proposal |
| [2] | ***Proposal 1: Support 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*** * ***Single Expected DL-AoA/ZoA and uncertainty (of the expected DL-AoA/ZoA value) range(s) can be provided to the UE for each [TRP]***
* ***Note: This is also applicable to DL-TDOA and Multi-RTT methods.***
 |
| [3] | **Proposal 4*** ***The validity of the expected DL-AoD may need to be considered since the expected DL-AoD will easily be changed with the UE movement.***

**Proposal 5*** ***Supporting to provide the boresight angle of the PRS resource first for selecting PRS resources by expected DL-AoD/ZoD.***

**Proposal 6*** ***A UE capability for whether UE can identify the GCS angle of Rx Beam needed to be introduced if Rx beam selection within the expected window is agreed.***
* ***UE behavior and selection criterion for Rx Beam selection needed to be considered if Rx beam selection within the expected window is agreed.***

**Proposal 7:*** ***Expected DL-AoD is provided to the UE for each TRP.***
 |
| [4] | ***Proposal 5: Either the expected DL-AoD/ZoD value (option 1) or the expected DL-AoA/ZoA value (option 2) could be provided to UE for each TRP.******Proposal 6: SSB index, DL PRS resource index, or SRS resource index can be used to define the reference direction for the expected DL-AoD/ZoD value*** ***or DL-AoA/ZoA value.*** |
| [5] | ***Proposal 3:*** *For the purpose of both UE-B and UE-A DL-AoD, and with regards to the support of AOD measurements with an expected uncertainty window, which includes,** *Option 1: Indication of expected DL-AoD/ZoD value and uncertainty (of the expected DL-AoD/ZoD value) range(s) is signaled by the LMF to the UE*
* *DL PRS resources transmitted from a single antenna reference point (or geographical coordinate) are associated with a single value of Expected DL-AoD/ZoD and uncertainty (of the expected DL-AoD/ZoD value).*
 |
| [7] | ***Proposal 5: With regards to expected Angle of Departure, support Option 1 with the following signaling details:*** * ***Expected azimuth angle of departure as (φAOD - ΔφAOD/2, φAOD + ΔφAOD/2)***
	+ ***φAOD - expected azimuth angle of departure, ΔφAOD – uncertainty range for expected azimuth angle of departure***
* ***Expected zenith angle of departure as (θAOD - ΔθAOD/2, θAOD + ΔθAOD/2)***
	+ ***θAOD - expected zenith angle of departure ΔθAOD – uncertainty range for expected zenith angle of departure***
 |
| [8] | Proposal 3: On uncertainty window for DL-AoD, support Option 3, i..e, not introduce expected AoD/ZoD or AoA/ZoA and uncertainty |
| [11] | **Proposal 2 : With regards to expected uncertainty window for AoD, support Option 1 “Indication of expected DL-AoD/ZoD value and uncertainty (of the expected DL-AoD/ZoD value) range(s) is signaled by the LMF to the UE** |
| [12] | **Proposal 4*** **For the purpose of UE-A and UE-B DL-AOD positioning solution support indication of the expected DL-AOD/ZOD value and uncertainty (of the expected DL-AOD/ZOD value) range(s) by LMF to the UE for each TRP, if DL-AOD reporting from the UE to LMF is supported**

**Proposal 5*** **For the purpose of UE-A and UE-B DL-AOD positioning solution support indication of the expected DL-AOA/ZOA value and uncertainty (of the expected DL-AOA/ZOA value) range(s) by LMF to the UE for each TRP, if UE antenna orientation in space is known/calibrated**
	+ **Note: an example of such a UE can be a reference UE with known coordinates and antenna orientation in space**
 |
| [13] | **Proposal 3**: For DL-AoD technique, support DL-AoD/ZoD assistance information (expected and uncertainty window), signaled from LMF to the UE for each TRP measurement. |
| [15] | ***Proposal 6: For the purpose of both UE based and UE assisted DL-AoD, the LMF can provide UE the expected DL-AoD/ZoD value and uncertainty (of the expected DL-AoD/ZoD value) ranges if these can be accurately achieved.*** |
| [16] | ***Proposal 1:**** For indication of expected uncertainty window to enhance DL-AoD, the configuration of both expected DL-AoA/ZoA value and uncertainty (option 2) is supported.

***Proposal 2:*** * For UE to judge whether configured expected uncertainty window with is useful or not, pre-calculated location of UE needs to be additionally provided for the UE-based positioning measurement.
 |
| [17] | **Proposal 12**: Support Option 2 - 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.**Proposal 13**: For UE-based mode, support option 1: indication of expected DL-AoD/ZoD value and uncertainty (of the expected DL-AoD/ZoD value) range(s) is signaled by the LMF to the UE. **Proposal 14**: Support of indication of expected AoD/ZoD value and uncertainty (of the expected AoD/ZoD value) range(s) is signaled by the LMF to gNBs/TRPs in on-demand PRS framework.Proposal 15: Study angle difference measurements for AoA of DL PRS resources in Rel-17. |
| [18] | *Proposal 6: Slightly prefer Option 1 for LoS path.* * *Indication of expected DL-AoD/ZoD value and uncertainty (of the expected DL-AoD/ZoD value) range(s) is signaled by the LMF to the UE.*
 |
| [19] | **Proposal 1:*** **We support one of the following options**
	+ **Option 1: Indication of expected DL-AoD/ZoD value and uncertainty (of the expected DL-AoD/ZoD value) range(s) is signaled by the LMF to the UE**
	+ **Option 2: 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**
 |
| [22] | Proposal 12 LMF can optionally signal to the UE an indication that consist of a list of IDs of DL PRS Resources associated to beams that are within a DL-AOD uncertainty region. |

The companies’ proposals are based on the study agreement from RAN1#104b-e. The options are supported as follow:

* + Option 1: Indication of expected DL-AoD/ZoD value and uncertainty
		- Supported by 10 companies [3][4] [5][7][11][12][13][15][17][18]
	+ Option 2: Indication of expected DL-AoA/ZoA value and uncertainty
		- Supported by 4 companies [2] [4][16][17]
	+ Option 3: Indication of expected AoD/ZoD or AoA/ZoA value and uncertainty is not introduced.
		- Supported by 1 company [8]

In [2], it is also proposed to have the AoA window signalled for all DL and DL+UL methods

In [3] it is proposed to introduce a capability for the UE RX beam identification based on the signalled window.[22] propose to instead signal a list of PRS resources within the uncertainty region.

Since both options have a significant amount of support, it is proposed to discuss supporting both options, and discuss whether to support them for other methods than DL AoD

**Proposal 5.1**

**For the purpose of both UE-B and UE-A DL-AoD, and with regards to the support of AOD measurements with an expected uncertainty window, support the following options:**

* **Option 1: Indication of expected DL-AoD/ZoD value and uncertainty (of the expected DL-AoD/ZoD value) range(s) is signaled by the LMF to the UE**
	+ - **Single Expected DL-AoD/ZoD and uncertainty (of the expected DL-AoD/ZoD value) range(s) can be provided to the UE for each [TRP]**
* **Option 2: 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**
	+ - **Single Expected DL-AoA/ZoA and uncertainty (of the expected DL-AoA/ZoA value) range(s) can be provided to the UE for each [TRP]**
* **FFS: details of signaling**
* **FFS: Applicability to other Positioning methods**

#### First round of comments

Companies are encouraged to provide comments in the table below.

|  |  |
| --- | --- |
| **Company** | **Comment** |
| InterDigital | For progress, we are ok with the proposal. |
| ZTE | Our understanding is that only option would be supported. So the main bullet should be “support one of the following options”.Option 1 defines the expected uncertainty angle from TRP perspective, while Option 2 is from UE perspective. In our view, the expected uncertainty angle is used for UE to decide which reference signals that UE has to measure. As we know, for UE-based DL-AOD, the boresight direction of reference signal is defined from TRP perspective. This should be reused for the expected uncertainty angle window, so UE doesn’t have to do coordinate transformation.In addition, we propose to revise the sub-bullet for both options since different antenna reference points within the same TRP may have different geographical coordinates.* + - **Single Expected DL-AoA/ZoA and uncertainty (of the expected DL-AoA/ZoA value) range(s) can be provided to the UE for each antenna reference point.**
 |
| CATT | Either the option 1 or the option 2 is fine for us, but not both of them. The expected DL-AoD/ZoD value (option 1) is defined from gNB perspective, and the expected DL-AoA/ZoA value (option 2) is from the UE perspective. In the LOS scenario, these two options are equivalent. Therefore, either option could be supported. |
| OPPO | As explained in our tdoc, we think either Option 1 or Option 2 are not well justified. However, for progress, we can be ok with Option 1 if Option 1 is majority view. And we do not support Option 2.Re Option 2: we do not think it is valid. The AoA and ZoA is from the perspective of UE. It is not possible/feasible for the LMF to know the expected AoA or ZoA of one UE.  |

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

##  Other aspects

|  |  |
| --- | --- |
| Source | Proposal |
| [8] |  Proposal 6: 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.***  |
| [16] | ***Proposal 5:**** To overcome beam resolution problem, 2-step beam adjustment procedure needs to be considered.
 |
| [17] | **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 it when computing the position estimate.
* Signaling aspects:
	+ LMF signals to TRPs that a BO beam re-tuning is needed. The BO correction may be explicitly signalled to the TRP by the LMF; alternatively, the LMF may send a Boolean indication that a BO recomputation and adjustement is needed.
	+ UE measurement reports to facilitate BO identification and potential correction.

**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.

**Proposal 10**: Consider two stage beam-sweeping for DL-AoD together with on-demand PRS transmission and reception**Proposal 11**: Support association between resources belonging to two DL PRS resource sets (at the same TRP) to facilitate support of two stage beam sweeping.  |
| [18] | *Proposal 5: Estimate the angle error by a reference node whose accurate location is known.* |
| [21] | ***Proposal 3: Supportive of processing priority of PRS measurements for DL-AoD measurements, however this can be discussed under a common framework including other positioning measurements in 8.5.4 latency reduction AI.***  |

# Conclusion

 **TBD**

# References

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15. R1-2105312, Discussion on accuracy improvements for DL-AoD positioning solutions, Samsung
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19. R1-2105701, Discussion on DL-AoD positioning enhancements, NTT DOCOMO, INC.
20. R1-2105858, DL-AoD positioning enhancements, Fraunhofer IIS, Fraunhofer HHI
21. R1-2105860, DL-AoD Positioning Enhancements, Lenovo, Motorola Mobility
22. R1-2105910, Enhancements of DL-AoD positioning solutions, Ericsson