3GPP TSG-RAN WG1 Meeting #106b-e R1-21NNNN

e-Meeting, October 11th – 19th, 2021

Agenda Item: 8.5.3

Source: Moderator (Ericsson)

Title: FL summary #2 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:

[106bis-e-NR-ePos-03] Email discussion/approval on accuracy improvements for DL-AoD positioning solutions with checkpoints for agreements on October 14 and 19 – 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
  + First path RSRP measurement definition
  + Receiver diversity aspects
  + Reporting of additional information (time of arrival)
  + Reporting of first path PRS RSRP relative to PRS RSRP
* Aspect #2 extension of number of reported RSRP measurements
  + Value for max number of reported measurement
  + Extension of the agreement to path RSRP
  + RX beam considerations
* Aspect #3 Adjacent beam identification in AD and reporting by the UE
  + LMF Request of a subset of PRS measurement related to a PRS measurement
  + Indication of the subsets
  + Prioritization of measurements
* Aspect #4 Support of additional gnodeB beam information signalling
  + Signalling of the beam information, representation of beam angle and power
* Aspect #5 AoD uncertainty window
* Aspect#6 2-step beam refinement

1. Aspects for discussion

## Main discussion topics

### Aspect #1 reporting of first arrival path

#### Summary

During RAN1#106e, an agreement was reached for reporting of the first arrival path and additional path:

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| Agreement:  For definition of the path PRS RSRP, consider the following options until RAN1#106b-e:   * Option 1: the measured path PRS RSRP correspond to the power of the channel impulse response, at a certain path delay, over which the DL PRS is received. * Option 2: the path PRS RSRP correspond to the accumulated power of the channel impulse response over which the DL PRS is received, over a time duration corresponding to the given path delay   + FFS: whether/how is the window conveyed to the UE (i.e., fixed in specification or configured in measurement request or determined by the UE) * FFS on relationship with the UE DL PRS measurement bandwidth. * FFS: normalization of the path RSRP measurement with DL PRS RSRP (i.e. RSRP for all path as defined in Rel-16) could be included in the measurement definition. * FFS: Further details of the definition, e.g. definition of the certain path delay * Up to RAN4 to define any test/requirement for the measurement. |

In [1][2][3][4][5][8][9]10][11][15][16][17][18][19][20][21][22], companies have provided further proposals on the following issues related to first path measurements:

* Definition of first path RSRP [1][2][3][4] [5][8][9][10][11][15][16][17][18][19][20]
  + Path RSRP is defined at a given delay (option 1 from RAN1#106e) [1][2][3][4][5][8][11][20][21] [22]
  + Path RSRP is defined over a time duration / configured window (option 2 from RAN1#106e)[8] (FFS window size), [9][10],[15][17][18][19]
    - The time window duration can be provided by the LMF to the UE[17]
    - window size is up to UE implementation[10]
  + Measurement is normalized with PRS RSRP [5][11]
  + Reported Relative to PRS RSRP [2][18][19]
  + One resource is used as a reference and other resources in the report are reported relative to it [4]
  + Definition is 38.215 or 37355 [2]
* Reporting of first path RSRP when the UE uses receiver diversity [1] [19]:
* Reporting of first path RSRP and PRS RSRP
  + First path RSRP is included alongside RSRP
  + First path RSRP is included as replacement for RSRP, with an indicator signaling which measurement is reported[10].
* Support of further measurements beside power[4][8] [21][22],
  + Reporting of Timing information is supported [4] [21] [22], (one proposal not to support it in [3]
  + Use RSTD to report timing for reporting timing of PRS resources in a PRS resource set. [8]
* Inclusion of path RSRP in other methods (multi RTT, DL TDOA)[22]

|  |  |
| --- | --- |
| Source | Proposal |
| [1] | ***Proposal 1: Adopt the following definition of path DL PRS-RSRP measurement***   * ***Path DL PRS-RSRP of delay-D is the power (in [W]) of the linear average of the delay-D compensated channel frequency response of the resource elements that carry DL PRS reference signals configured for path DL PRS-RSRP measurement within the configured with measurement frequency bandwidth.***   ***Proposal 2: For path DL PRS-RSRP measurement reporting, when receiver diversity is in use, at least consider additionally reporting the Rx branch ID to identify whether different path DL PRS-RSRP measurements are associated with the same Rx branch.*** |
| [2] | ***Proposal 1:*** *The path PRS RSRP, is defined as the power of the channel impulse response at a certain path delay in time domain divided by the number of the resource elements that carry DL PRS reference signals configured for RSRP measurements within the considered measurement frequency bandwidth*   * *The path PRS RSRP of a DL PRS resource is reported relative to the corresponding DL PRS-RSRP.* * *There is no need to introduce new measurement type dedicated for path PRS RSRP in TS 38.215, which can be included in the field description in TS 37.355 instead.* |
| [3] | * ***Support option 1 with a small modification***   + ***The path PRS RSRP corresponds to the power of the channel impulse response, at a certain path delay, over which the DL PRS is received.***   + ***Reporting value of path RSRP can be a normalization of the path RSRP with DL PRS RSRP.*** * ***Reporting timing information and path RSRP together shouldn’t be supported by both DL-TDOA and DL-AoD.*** * ***Only support first path RSRP reporting in DL-AoD positioning, and reporting multipath RSRP(s) are not introduced in DL-AoD.*** * ***Reporting timing information is not introduced in DL-AoD.*** |
| [4] | Proposal 1: For the RSRP reporting of the first path of PRS resource:   * The path PRS RSRP is defined as the linear average over the power contributions of the REs that carry the DL PRS reference signals that are received at a certain path delay. * The UE reports the PRS RSRP of one PRS resource and the differential RSRP of the first path with respect to the PRS RSRP of that PRS resource.   Proposal 2: In DL-AoD measurement report, the UE report the time-of-arrival of each reported PRS resource or each path. |
| [5] | ***Proposal 1: The path PRS RSRP should be defined as the measured path PRS RSRP correspond to the instantaneous power (in [W]) of the channel impulse response, at a certain path delay, over which the resource elements that carry DL PRS reference signals are received.***  ***Proposal 2: Normalization of the path RSRP measurement with DL PRS RSRP could be included in the measurement definition.*** |
| [8] | **Proposal 1**: For DL-AoD support reporting of multiple PRS resources per PRS resource set, with each resource being associated with time of arrival information or RSTD.  **Proposal 2:** The measured first-path PRS RSRP corresponds to the power of the channel impulse response, at the first path delay, over which the DL PRS is received.   * Note: the first path delay is independent of sampling grid. * Note: the first path delay is the channel tap where the UE measures ToA for reporting of the RSRP of the first path * FFS: window/time-duration around the first path (e.g., size of 1 Ts) to calculate power |
| [9] | *Proposal 5: Prefer Option 2 for definition of the path PRS-RSRP.* |
| 10] | ***Proposal 1: An indicator of whether the report for PRS RSRP includes all the paths or the first arrival path only is supported.***  ***Proposal 5: A revised option 2 is supported:***   * ***the path PRS RSRP corresponds to the accumulated power of the channel impulse response through which the DL PRS is received, over a time duration (which is up to UE implementation without specification) corresponding to the given path delay*** |
| [11] | Proposal 4   * + **For definition of the path PRS RSRP support option 1, where the measured path PRS RSRP corresponds to the power of the channel impulse response at a certain delay path over which the DL PRS is received**     - **The certain path delay is defined as a relative time with respect to the first detected path in units of sample time duration, which is inversely proportional to the measurement bandwidth**     - **The certain path delay of the first detected path is equal to zero**     - **The path RSRP measurement is normalized to the total DL PRS RSRP (RSRP of all paths as defined in Rel.16)** |
| [15] | **Proposal 1**: The path PRS RSRP correspond to the accumulated power of the channel impulse response over which the DL PRS is received, over a time duration corresponding to the given path delay |
| [16] | ***Proposal 1:***   * RAN1 should adopt a window to calculate path PRS RSRP for the case that the propagation delay between two adjacent taps within a very short time duration is not crucial factor for accuracy performance. |
| [17] | **Proposal 3: Support Option 2 for the definition of the path RSRP, “the path PRS RSRP correspond to the accumulated power of the channel impulse response over which the DL PRS is received, over a time duration corresponding to the given path delay”**  **Proposal 4: The configurable parameter for the window, over which the path power is accumulated, is conveyed to the UE by LMF through the measurement request** |
| [18] | ***Proposal 5: For the measurement & signaling of the path RSRP, support Option 1.***  ***Proposal 6: Signaling details of the path RSRP report: The UE shall report the relative ratio of the power of the path over the total RSRP of the PRS resource using the following format:***   * ***Maximum value is 0 dB*** * ***Minimum value: [-30] dB*** * ***Step size: [0.5] dB*** |
| [19] | **Proposal 2-1**: For frequency range 1 and 2, if receiver diversity is in use by the UE, the reported path RSRP value of the first path shall be measured by the receiver branch with earliest path timing among all the receiver branches, and shall not be lower than the corresponding path RSRP of first path of any of the individual receiver branches that have equivalent first path delay  **Proposal 3-1**: The option 2 is supported: the path PRS RSRP correspond to the accumulated power of the channel impulse response over which the DL PRS is received, over a time duration corresponding to the given path delay. And the time duration is determined by UE  **Proposal 3-2**: When UE measures a PRS resource and reports the corresponding path RSRP, the optional reporting of differential RSRP between path RSRP and all-path RSRP is supported |
| [20] | ***Proposal 3: Support Option 1 of path RSRP definition, where the path PRS RSRP corresponds to the power of the channel impulse response, at a certain path delay, over which the DL PRS is received.*** |
| [21] | **Proposal-1:** We support Option 1 for definition of the path-PRS-RSRP.  **Proposal-2:** The delay of a certain path, whose path-RSRP has to be reported, should be estimated at the receiver itself.  **Proposal-3:** The UE should report the path-delay corresponding to the path-PRS-RSRP also in DL-AoD report. |
| [22] | ***Proposal 1 Introduce the DL PRS-RSRP-PP measurement according to Definition (DL PRS-RSRP-PP).***  ***Proposal 2 Include DL PRS-RSRP-PP of the first path in NR DL-AoD Location Information alongside the existing DL PRS-RSRP measurement.***  ***Proposal 3 Include DL PRS-RSRP-PP 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.***  ***Proposal 4 The DL PRS-RSRP-PP is reported together with an associated timing measurement of the corresponding path.***  ***Proposal 5 Include additional paths in the DL-AOD measurement report. For each additional path the DL PRS-RSRP-PP and the associated timing measurement should be reported.***  ***Proposal 6 The nr-AdditionalPathList-r16 IE is included as a Rel. 17 addition at the top level of the NR-DL-AoD-MeasElement-r16 IE as well as in the NR-DL-AoD-AdditionalMeasurements-r16 IE.***  ***Proposal 7 DL PRS-RSRP-PP is included as a Rel. 17 addition for each additional path in the nr-AdditionalPathList-r16 IE.*** |

Based on the contributions, the following is proposed on aspect #1:

#### Proposal 1.1 (definition of path RSRP)

#### First round of discussion

There is still a split between companies supporting option 1 and 2 for the definition of PRS RSRP. As a compromise, it is propose to use the definition from option 1, and leave to the UE implementation whether a window is required to produce the measurement.

There are proposal regarding the applicability of path PRS RSRP reporting to all DL methods. The inclusion of power reporting per path in multi-RTT and DL-TDOA was also discussed in agenda 8.5.5 and therefore is not included in this summary.

**Proposal 1.1:**

**The path DL PRS RSRP is defined as the power in [W] of the linear average of the channel frequency response for the resource elements that carry DL PRS reference signals configured for path DL PRS RSRP measurements, for a delay D, over the configured measurement frequency bandwidth.**

* **UE may choose to use a time window around the delay D to compute path DL PRS RSRP** 
  + **FFS: The LMF may provide a time window around the delay D to compute path DL PRS RSRP**
* **FFS: whether the path RSRP measurement is normalized with PRS RSRP.**

Companies are encouraged to provide comments in the table below.

**Proposal 1.1**

|  |  |
| --- | --- |
| **Company** | **Comment** |
| CATT | Support. |
| vivo | We doubt whether further interpretation about delay D needs to beintroduced if delay D is used in the definition, or new measurement（e.g ToA）needs to be introduced for delay D.  For the first sub-bullet, we prefer up to RAN4 decision or adding a FFS. |
| Huawei, HiSilicon | We think that if we do the average on the complex CFR, the delay should be compensated. |
| Qualcomm | The above proposal is not Option 1. We still prefer the original Option 1 as was agreed in previous meeting. |

#### second round of discussion

the first GTW discussion showed that there are still concerns with the path RSRP definition. Most companies with concern think that a definition would be clearer in the time domain. The following was left on the chair’s notes for the session to capture the discussion status:

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| Proposal:  The measured path PRS RSRP corresponds to ~~the power of~~ the channel impulse response of the channel corresponding to the received PRS, at a certain path delay, [divided by the number of elements] over which the DL PRS is received.   * FFS: Whether the path RSRP measurement is normalized with PRS RSRP. * Note: UE may choose to use a time window to compute path DL PRS RSRP by UE implementation * Send LS to RAN4 to check the details of the definition   + ~~FFS: The LMF may provide a time window around the delay D to compute path DL PRS RSRP~~ |

From the FL perspective, both definition are interchangeable. The definition proposed in the past meeting assumes the time-domain perspective, meaning that the definition assume the UE will first run an IFFT over the received symbol and correlate the time domain signal with a time-domain PRS and then evaluate the power of the channel impulse response resulting from the correlation at different time delay to report path power.

In proposal 1.1, instead the definition is taken in the frequency domain, which is consistent with the PRS RSRP given in 38.215. the path RSRP is then extracted by isolating each path component in the channel frequency response for each RE carrying PRS. This is done by applying the phase rotation (Fourier transform of the delay) corresponding to the delay.

Based on the latest available proposal in the chair notes, I have tried to reword the proposal as follow:

**Proposal 1.1b**

**The measured path PRS RSRP for path delay D is defined as the power of the channel impulse response experienced by the DL PRS reference signals configured for the measurement, at a delay D.**

* **FFS: Whether the path RSRP measurement is normalized with PRS RSRP.**
* **Note: UE may choose to use a time window to compute path DL PRS RSRP by UE implementation**
* **Send LS to RAN4 to check the details of the definition**

Companies are encouraged to provide comments in the table below.

**Proposal 1.1b**

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| --- | --- |
| **Company** | **Comment** |
| CATT | Support. |
| vivo | We doubt whether further interpretation about delay D needs to beintroduced if delay D is used in the definition, or new measurement（e.g ToA）needs to be introduced for delay D.  For the first sub-bullet, we prefer up to RAN4 decision or adding a FFS. |
| Huawei, HiSilicon | We think that if we do the average on the complex CFR, the delay should be compensated. |
| Qualcomm | The above proposal is not Option 1. We still prefer the original Option 1 as was agreed in previous meeting. |
| Nokia/NSB | We are okay to keep ‘‘the path PRS RSRP for path delay D‘‘ in the current proposal. It is okay to send an LS to RAN4, but we prefer to define the path RSRP as a normalized value of PRS RSRP. |

#### Proposal 1.2 (receiver diversity aspects)

#### First round of discussion

Regarding the path PRS RSRP measurement with receiver diversity, the expected UE behaviour should be discussed. Based on the available proposal, we propose to start with the following:

**Proposal 1.2**

**For path DL PRS-RSRP measurement reporting, when receiver diversity is in use,**

* **The UE reports the path PRS RSRP measurement corresponding to the RX branch where PRS is received the earliest across all RX branches**
* **The UE reports the Rx branch ID to identify whether different path DL PRS-RSRP measurements are associated with the same Rx branch.**

Companies are encouraged to provide comments in the table below.

**Proposal 1.2**

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| --- | --- |
| **Company** | **Comment** |
| vivo | The proposal needs more discussion, for example: whether UE chooses the Rx branch first or chooses the first path across all Rx branches first. For us, per UE path RSRP is simpler, and how to determine it is up to UE implementation. |
| Huawei, HiSilicon | We think Rx branch ID is useful for multi-path power reporting, and we support the second bullet. |
| Nokia/NSB | For the RSTD reporting for additional paths, our understanding is that LMF may not expect that the UE reports RSTD additional paths estimated by using a different Rx branch than the Rx branch used for the first RSTD reporting. We think it may be a similar issue. In our understanding, the UE needs to report n-th path RSRP made by the same Rx branch to avoid confusion from LMF. |

#### Proposal 1.3 (reporting timing information)

#### First round of discussion

companies proposed to include timing information. The information can take the form of a TOA report, or an RSTD if multiple measurements are reported in a single report.

**Proposal 1.3**

**When path PRS RSRP is reported for DL AOD, an associated timing measurement of the corresponding path can also be reported.**

* **In a measurement report, the reported timing can done with RSTD between a reference PRS also present in the measurement report and the measured PRS.**
* **the reference path PRS RSRP in the measurement report can be associated with a time of arrival measurement for the path.**

Companies are encouraged to provide comments in the table below.

**Proposal 1.3**

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| **Company** | **Comment** |
| CATT | Support the proposal in principle, since we believe the associated timing information would be helpful for the LMF to use the path PRS RSRP information. |
| vivo | Not supported |
| Huawei, HiSilicon | The proposal is not clear to us.  For first path PRS RSRP for DL-AoD, we think that the RSRP should be from the same path across multiple PRS resources. There is no need to report the timing of the first path. |
| Qualcomm | We do not support reporting the TOA in DL-AoD. Even the „timing“ may not be the same across teh PRS resources: Imagine if the gNB has a few nsec of timing miscalibration, and the path in one resouce is arriving a bit later. The UE will „try to match/identify“ the earliest path in both PRS resources, and report accordingly. It is really up to UE implementation to try to do a good job in this regards. |
| Nokia/NSB | We have a similar view with CATT. |

#### Proposal 1.4 (reporting of first path RSRP and PRS RSRP)

#### First round of discussion

Several companies proposed to report first path PRS RSRP relative to PRS RSRP. Additionally, multiple measurement in a report have been proposed to be reported relative to a reference measurement in the report.

Regarding the use of indicator to signal the use of RSRP or path RSRP, the issue seem to be more of a signalling optimization for RAN2. RAN2 could discuss whether to re-use the IE for RSRP in some cases and whether an indicator should be used.

**Proposal 1.4:**

**The UE can be requested to report path PRS RSRP together with PRS RSRP in an AOD measurement report.**

* **If PRS RSRP is included in the report of path PRS RSRP, path PRS RSRP can be reported relative to the included PRS RSRP.**
* **If more than 1 PRS resource is included in a measurement report, one resource can be identified as reference resource and the measurements for all other resources in the report are reported with a power value relative to the reference PRS resource.**

Companies are encouraged to provide comments in the table below.

**Proposal 1.4**

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| **Company** | **Comment** |
| vivo | We are wondering if any modifications is needed for the second sub-bullet since the current specification includes up to 8 DL PRS RSRP reporting, the AdditionalMeasurements is a power value relative to “nr-DL-PRS-RSRP-Result-r16“ .  NR-DL-AoD-MeasElement-r16 ::= SEQUENCE {  ...  nr-DL-PRS-RSRP-Result-r16 INTEGER (0..126),  nr-DL-PRS-RxBeamIndex-r16 INTEGER (1..8) OPTIONAL,  nr-DL-AoD-AdditionalMeasurements-r16  NR-DL-AoD-AdditionalMeasurements-r16 OPTIONAL,  ...  }  NR-DL-AoD-AdditionalMeasurements-r16 ::= SEQUENCE (SIZE (1..7)) OF  NR-DL-AoD-AdditionalMeasurementElement-r16  NR-DL-AoD-AdditionalMeasurementElement-r16 ::= SEQUENCE {  ...  nr-DL-PRS-RSRP-ResultDiff-r16 INTEGER (0..30),  nr-DL-PRS-RxBeamIndex-r16 INTEGER (1..8) OPTIONAL,  ...  } |
| Huawei, HiSilicon | We are in general fine with it.  For the sake of better understanding, should it be RAN4 to discuss the first bullet when there is only relative RSRP requirement? |
| Qualcomm | We think the reporting of path-RSRP should always be relative to the RSRP of the channel. We dont see the need to have both options: one of path-RSRP that is „absolute“ and another that is relative to the „RSRP“. |
|  |  |

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

#### Summary and Proposal 2.1

During RAN1#106e, it was agreed to increase the number of RSRP measurements per TRP, with the number of measurement left to be decided. Additionally, the issue of the maximum number of reports per RX beam was left FFS:

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| Agreement:   * For UE-A DL-AOD, support reporting more than 8 DL PRS 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: Limit the maximum number of DL PRS RSRP associated with the same Rx beam index |

Regarding the maximum number of DL PRS RSRP measurements, the following values were proposed:

* 16 [2][3][8][18]

Regarding the maximum number of measurement per RX beams, there are candidate values proposed and some companies also proposed not to limit the number

* values per Rx Beam: 8[2][7][8], up to the UE/no limitations [4][10][18]

there are also additional feature proposed to be supported:

* the LMF can request the UE to report measurement with the same Rx beam.[3]
* the UE may report a Rx beam index even when a report uses a single beam index[3]
* the agreement is also applicable to first path RSRP[8][22]

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| --- | --- |
| Source | Proposal |
| [2] | ***Proposal 4:*** *For UE-A DL-AOD, support reporting up to 16 DL PRS RSRP measurements per TRP. Consider one of the following options to limit maximum number of DL PRS RSRP measurements associated with the same Rx beam index per TRP,*   * *Option 1: The maximum number is 8* * *Option 2: The maximum number is determined according to the value of maxDL-PRS-RSRP-MeasurementsPerTRP requested by LMF (e.g. a half of the value indicated by maxDL-PRS-RSRP-MeasurementsPerTRP)*   ***Proposal 5****: To extend the application scope of DL PRS Rx beam index, when the UE reports DL PRS-RSRP measurements from DL PRS resource sets associated with the same positioning frequency layer and the same TRP, the UE may indicate which DL PRS-RSRP measurements associated with the same higher layer parameter DL PRS Rx beam index have been performed using the same spatial domain filter for reception.* |
| [3] | * ***To improve the accuracy of DL-AoD and to avoid the impact of Rx beam, support the following options:***   + ***The LMF requests a UE to report different DL PRS RSRP measurements from a TRP with the same Rx beam index.***   + ***The UE may indicate a RxBeamIndex for a DL PRS RSRP measurement when the DL PRS RSRP measurement uses a Rx spatial domain filter different from what nr-DL-PRS-RxBeamIndex(s) represents and reports in Rel-16 positioning.*** * ***The maximum number of DL PRS RSRP to be reported per TRP is 16.*** |
| [4] | Proposal 3: Reporting more than 8 DL PRS RSRP measurement per TRP is UE capability and the UE reports the maximum number of DL PRS RSRP measurements per TRP. The number of DL PRS RSRP associated with same Rx beam index in one beam report is up to UE implementation. |
| [7] | ***Proposal 1: Multiple RSRPs corresponding to same or different Rx Beam index should be able to be reported for a given PRS resource for different timestamps:***   * For the same Rx beam index, up to 8 RSRP measurements in a measurement report per TRP is preferred * For different Rx beams, up to N>=8 RSRS measurements in a measurement report per TRP is more preferred. |
| [8] | **Proposal 3:** For UE-A DL AoD,   * The maximum number of DL PRS RSRP measurements per TRP that can be reported is [N=16] * The maximum number of DL PRS RSRP associated with the same Rx beam index is [8]. * The maximum number of the measurements for the RSRP for the first path per TRP that can be reported is the same as the maximum number of DL PRS RSRP measurements per TRP that can be reported. |
| [10] | ***Proposal 6: Do not support limiting the maximum number of DL PRS RSRP associated with the same Rx beam index.*** |
| [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. |
| [18] | ***Proposal 9: For UE-A DL-AOD, do not introduce a limit on maximum number of DL PRS RSRPs associated with the same Rx beam index***  ***Proposal 10: For UE-A DL-AOD, support reporting up to [16] DL PRS RSRP measurements per TRP.*** |
| [22] | ***Proposal 13 Any agreement on UE reporting DL PRS-RSRP for UE-A DL-AOD should apply also to the DL PRS-RSRP-PP measurement for the first path.*** |

#### First round of discussion

Based on the proposal, it is propose to agree to support reporting up to 16 measurements per TRP. The applicable measurements are PRS RSRP and PRS RSRP per path. Regarding the maximum number of measurement for the same rx beam, we propose to leave it to the UE implementation. However, considering that there are as many proponents and opponents to this solution, we need to find a compromise on the issue.

**Proposal 2.1**

**The agreement from RAN1#106e on the number of DL PRS RSRP measurements per TRP is extended as follow:**

* **For UE-A DL-AOD, support reporting ~~more than 8~~ up to 16 DL PRS RSRP or first path PRS 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.**
* **the maximum number of DL PRS RSRP associated with the same Rx beam index is up to the UE implementation.**

Companies are encouraged to provide comments in the table below.

**Proposal 2.1**

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| **Company** | **Comment** |
| CATT | Support. |
| Huawei, HiSilicon | OK |
| Qualcomm | We think that it can be up to 64 RSRPs since there are up to 64 beams in a set (in FR2). Either way it will be up to UE implementation how many to support and/or include. |
| Nokia/NSB | In the first main bullet, we have a small suggestion for clarification. Can we change "or " to "and/or" ? We have in mind that the UE may report the RSRP of the first path along with the legacy RSRP. |

### Aspect #3 adjacent beam reporting

#### Summary

The discussion did not converge during RAN1#106e, but the proposals managed to make some progress and the latest proposal on the table was as follow:

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| **Proposal 3.1e.**  For UE-assisted DL-AOD positioning method, to enhance the signaling to the UE for the purpose of PRS resource(s) measurement and reporting, the LMF indicates in the assistance data (AD) for each PRS resource, a subset of PRS resources which indicates the beam information for the purpose of prioritization of DL-AOD measurement and reporting:   * Subject to UE capability, a UE may include the RSRPs for the subset of the PRS in the DL-AoD additional measurements if RSRP of the associated PRS is reported in nr-DL-PRS-RSRP-Result. * The subset associated with a PRS resource can be in a different PRS resource set than the PRS resource * FFS: Details on the subset of PRS resources * FFS: the impact of processing the subset of PRS resources * FFS: Subject to UE capability, a UE may include the RSRPs for the subset of the PRS in the DL-AoD additional measurements if RSRP of the associated PRS is reported in nr-DL-PRS-RSRP-Result. * Note: This does not imply any restriction on UE measurement |

The proposals in [1][3][4][5][6][7][8][9][10][13][14][16][17][18][20][22] can be summarized as follow:

* For reporting of adjeacent beams, comfirm the proposal 3.1e from RAN1#106e[1] [3][4]
* For requesting adjeacent beams/PRS subset measurements,
  + The LMF indicates the subsets to be measured for each PRS in assistance data [4][5][6][7][9][10][13][14][16][22]
    - The subset/adjacent PRS resources can be predefined by resource index[9][13]
  + The LMF indicates boresight direction information for each PRS resource in the assistance data[5][6 (2nd prio)] [13][17][18][20]
  + The LMF provides a prioritized list of resources to be measured [18]
    - [22] proposes to leave the priority to the UE, but the UE should at least report the PRS with highest path RSRP and its adjeacent neighbours.
* [8] see the issue as low priority or do not support the enhancement
* [22] proposes to extend the proposal by including both path PRS RSRP and PRS RSRP

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| Source | Proposal |
| [1] | ***Proposal 3: For UE-assisted DL-AOD positioning method, to enhance the signaling to the UE for the purpose of PRS resource(s) measurement and reporting, the LMF indicates in the assistance data (AD) for each PRS resource, a subset of PRS resources which indicates the beam information for the purpose of prioritization of DL-AOD measurement and reporting:***   * ***Subject to UE capability, a UE may include the RSRPs for the subset of the PRS in the DL-AoD additional measurements if RSRP of the associated PRS is reported in nr-DL-PRS-RSRP-Result.*** * ***The subset associated with a PRS resource can be in a different PRS resource set than the PRS resource.*** * ***FFS: Details on the subset of PRS resources.*** * ***FFS: the impact of processing the subset of PRS resources.*** * ***FFS: Subject to UE capability, a UE may include the RSRPs for the subset of the PRS in the DL-AoD additional measurements if RSRP of the associated PRS is reported in nr-DL-PRS-RSRP-Result.*** * ***Note: This does not imply any restriction on UE measurement.*** |
| [3] | Proposal 9   * ***For UE-A DL-AOD positioning method, to enhance the signaling to the UE for the purpose of PRS resource(s) reporting, the LMF indicates in the assistance data (AD) for each PRS resource, a subset of PRS resources which indicates the beam information for the purpose of prioritization of DL-AOD reporting:***   + ***Subject to UE capability, support the LMF to request a UE to optionally report the RSRPs for the subset of the PRS in the DL-AoD additional measurements if RSRP of the associated PRS is reported in nr-DL-PRS-RSRP-Result.*** |
| [4] | Proposal 4: For UE-assisted DL-AoD positioning, support Option 1, i.e., LMF indicates adjacent beams in assistance data:   * 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. |
| [5] | ***Proposal 3: For UE-Based and UE-Assisted DL-AOD positioning method in Rel-17, both option 1 and option 3 of the agreement of the RAN1#105-e meeting should be supported:***   * ***Option 1: The LMF explicitly identify adjacent beams in the assistance data (AD)*** * ***Option 3: The LMF includes boresight direction information for each PRS resource in the assistance data*** |
| [6] | **Proposal 1: For UE-assisted DL-AOD positioning method, to enhance the signaling to the UE for the purpose of PRS resource(s) measurement and reporting, support the following as the 1st priority:**   * **The LMF indicates in the assistance data (AD) for each PRS resource, a subset of PRS resources which indicates the beam information for the purpose of prioritization of DL-AOD measurement and reporting**   **Proposal 2: For UE-assisted DL-AOD positioning method, to enhance the signaling to the UE for the purpose of PRS resource(s) measurement and reporting, support the following as the 2nd priority:**   * **The LMF can include boresight direction information for each PRS resource in the assistance data.** |
| [7] | ***Proposal 2: The LMF indicates in the assistance data (AD) for each PRS resource, a subset of PRS resources which indicates the beam information for the purpose of prioritization of DL-AOD measurement and reporting.*** |
| [8] | **Proposal 5**: Do not support the explicit identification of adjacent beams. |
| [9] | *Proposal 1: Adjacent PRS resources can be predefined by resource index.*  *Proposal 2: For UE-assisted DL-AOD positioning method, to enhance the signaling to the UE for the purpose of PRS resource(s) measurement and reporting, in order to reduce the number of measured PRS resource, the LMF indicates in the assistance data (AD) for each PRS resource, a subset of PRS resources which indicates the beam information for the purpose of DL-AOD measurement.* |
| [10] | ***Proposal 2: For UE-assisted DL-AOD positioning method, support that the LMF sends the beam information in the assistance data with indicated subset of PRS resources.*** |
| [13] | **Proposal 1: support LMF to indicate UE of the resource IDs, which corresponds to the boresight direction and the expected AoD range, in the assistance data report.**  **Proposal 2: Defining adjacent beam is UE implementation. No indication from LMF is needed.** |
| [14] | **Proposal 1: Support that for UE-assisted DL-AOD positioning method, to enhance the signaling to the UE for the purpose of PRS resource(s) measurement and reporting, the LMF indicates in the assistance data (AD) for each PRS resource, a subset of PRS resources which indicates the beam information for the purpose of DL-AOD measurement.** |
| [16] | ***Proposal 2:***   * For UE-assisted DL-AOD positioning method, select option 4 (‘the LMF send the beam information in the AD with indicated subset of PRS resources’) |
| [17] | **Proposal 5: For UE-assisted DL-AOD positioning method, the LMF can include boresight direction information for each PRS resource in the assistance data.** |
| [18] | ***Proposal 8: With regards to PRS resource Prioritization for DL-AoD measurements, support LMF providing in the assistance data support both of the following options:***   * ***Opt. 3: 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).*** |
| [20] | ***Proposal 2: Extend the current DL-AoD framework of providing boresight information in the case of UE-assisted DL-AoD positioning.*** |
| [22] | ***Proposal 11 For UE-assisted DL-AOD positioning method, to enhance the signaling to the UE for the purpose of PRS resource(s) measurement and reporting: the LMF explicitly identify adjacent beams in the assistance data (AD). (Option 1 in the agreement at RAN1#105e)***  ***Proposal 12 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) For each DL PRS Resource, one list of general neighbors.***  ***Proposal 12 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) For each DL PRS Resource, one list of general neighbors.***  ***Proposal 13 Any agreement on UE reporting DL PRS-RSRP for UE-A DL-AOD should apply also to the DL PRS-RSRP-PP measurement for the first path.***  ***Proposal 14 The UE should report the DL PRS-RSRP-PP measurement for the DL PRS Resource with the highest first path DL PRS-RSRP-PP measurement and all its neighbors.***  ***Proposal 15 First path DL PRS-RSRP-PP measurements of adjacent DL PRS Resources that the UE reports should be performed using the same Rx-beam.*** |

#### Proposal 3.1 (high priority proposal)

#### First round of discussion

Based on the received comments, it is proposed to start the discussion from proposal 3.1e with some updates:

* The use of boresight information is proposed to be supported in addition to the adjeacent beam/subset information . Even if the majority of support is to signal PRS subsets to be measured, at least one company has expressed the possibility of using boresight information as a second priority,
* Prioritization of measurements on resources and subsets and processing issues should also be discussed.

**Proposal 3.1**

**For UE-assisted DL-AOD positioning method, to enhance the signaling to the UE for the purpose of PRS resource(s) measurement and reporting, the LMF indicates in the assistance data (AD) for each PRS resource, a subset of PRS resources which indicates the beam information for the purpose of prioritization of DL-AOD measurement and reporting:**

* **Subject to UE capability, a UE may include the requested PRS measurement for the subset of the PRS in the DL-AoD additional measurements if the requested PRS measurement of the associated PRS is reported** 
  + **The requested PRS measurement can be DL PRS RSRP and/or path PRS RSRP.**
* **For each subset of PRS resources:**
  + **For each PRS resource, The LMF indicates a subset of DL PRS resources IDs**
  + **The subset associated with a PRS resource can be in a different PRS resource set than the PRS resource**
  + **The LMF may additionally indicate the boresight direction information for each PRS resource**
* **Note: This does not imply any restriction on UE measurement**
* **FFS: prioritization of the PRS resources and resource subsets to be measured**
* **FFS: the impact of processing the subset of PRS resources**

**Proposal 3.1:**

Companies are encouraged to provide comments in the table below.

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| CATT | Support the proposal in principle.  For the second bullet, we think the first sub-bullet can be removed since it had been mentioned in the main sentence. And the second and the third sub-bullet of the second bullet can upgrade one level and become the second bullet and the third bullet with some modifications marked in Yellow color backgroud. The last bullet is not clear for us and looks like implementation issue so we prefer to remove it.  we prefer the updated version as follows.  **Updated Proposal 3.1**  **For UE-assisted DL-AOD positioning method, to enhance the signaling to the UE for the purpose of PRS resource(s) measurement and reporting, the LMF indicates in the assistance data (AD) for each PRS resource, a subset of PRS resources which indicates the beam information for the purpose of prioritization of DL-AOD measurement and reporting:**   * **Subject to UE capability, a UE may include the requested PRS measurement for the subset of the PRS in the DL-AoD additional measurements if the requested PRS measurement of the associated PRS is reported**    + **The requested PRS measurement can be DL PRS RSRP and/or path PRS RSRP.** * **~~For each subset of PRS resources:~~**   + **~~For each PRS resource, The LMF indicates a subset of DL PRS resources IDs~~**   + **~~The subset associated with a PRS resource can be in a different PRS resource set than the PRS resource~~**   + **~~The LMF may additionally indicate the boresight direction information for each PRS resource~~** * **The LMF may additionally indicate the boresight direction information for each PRS resource** * **Note: The subset associated with a PRS resource can be in a same or different PRS resource set than the PRS resource** * **Note: This does not imply any restriction on UE measurement** * **FFS: prioritization of the PRS resources and resource subsets to be measured** * **~~FFS: the impact of processing the subset of PRS resources~~** |
| vivo | support |
| Huawei, HiSilicon | We do not think adding boresight direction is helpful. |
| Qualcomm | We are still not supportive of this feature. Including just the boresight directions   * will be enough for teh UE to derive the „beam association“ that is being proposed. * A UE will, up to implementation, perform the same steps as those described by the companies * Much less specification impact, since the boresight directions have been alreayd specified for UE-B * Much less overhead; instead of sending, for each PRS resoruce, a list of PRS resources, the LMF sends just boresight directions. |

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

#### Summary

The following agreement was reached during RAN1#106e:

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| Agreement:  For the beam/antenna information to be optionally provided to the LMF by the gnodeB, decide to support one of the following options:   * Option 2.1: The gNB reports quantized version of the relative Power/Angle response per PRS resource per TRP   + The relative power is defined with respect to the peak power of that resource   + FFS: How many relative power levels can be included (e.g., single -3 dB power-levels, multiple power-levels, etc). * Option 2.2: The gNB reports quantized version of the relative Power between PRS resources per angle per TRP.   + The relative power is defined with respect to the peak power in each angle   + For each angle, at least two PRS resources are reported. * FFS: support of multiple levels of quantization * FFS: how the report is constructed * FFS: overhead reduction mechanisms, including reusing of associated-dl-PRS-ID as a way of signaling that 2 TRPs have the same beam information * The gNB beam/antenna information can optionally be provided to the UE by the LMF * Note: Up to RAN2 & RAN3 the signaling/procedures on how the LMF receives this information from the gNBs * Send an LS to RAN2 & RAN3 with this agreement |

The options were discussed in [1][2][3][4][5][8][9][11][13][14][17][18]20[21][22]. The options are supported as follow:

* Option 2.1 is proposed in [3][4][8][11][14][17][18]
* Option 2.2 is supported by in [1][2][9]
  + The relative power mapping follows the mapping of differential RSRP [1]
* Range of the Beam antenna information
  + provided within the expected AoD/ZoD range [2]
  + [-90, 90] for omnidirectional antenna and [-60, 60] for directional antenna[3]
  + Signalled with number of samples and spatial resolution, Uniform sampling within range[11]
  + Flexible quatization range is proposed in [18]
  + 3dB Beam width is sufficient [22]
* Granularity of power:
  + 1dB step from -30dB to 0dB[3]
  + Power reported with Nb bits, with Nb parameter can be set as one of {2, 3, 4, 5, 6, 7, 8} bits[11]
  + Flexible quantization range is proposed in [18]
* Overhead reduction methods:
  + Support reusing of associated-dl-PRS-Id for 2 TRPs have the same beam information. [3][18]
    - FFS: case of same beam shape with different boresight angle[3].
* Support of option 1 from ran1#105e[3][13][21]
* Support UE based positioning with signalling to the UE of the beam information. However, the LMF is provided with the beam information via O&M (no NRPPa impact ) [22]

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| Source | Proposal |
| [1] | ***Proposal 4: For DL-AoD angle calculation enhancements, the gNB reports the quantized version of the relative power between PRS resources per angle per TRP.***  ***The quantized relative power follow the mapping of differential RSRP*** |
| [2] | ***Proposal 3:*** *For the beam/antenna information to be optionally provided to the LMF by the gnodeB,*   * *The gNB reports quantized version of the relative Power between PRS resources per angle per TRP.* * *The relative power is defined with respect to the peak power in each angle* * *For each angle, at least two PRS resources are reported.* * *To save the overhead for UE-based DL-AOD, the beam/antenna information is provided to UE only for the angles that are within an expected uncertainty window determined by the expected DL-AoD/ZoD value and uncertainty (of the expected DL-AoD/ZoD value) range(s).* |
| [3] | Proposal 4   * ***Choose one option for the beam/antenna information***   + ***Option 2.1: The gNB reports quantized version of the relative Power/Angle response per PRS resource per TRP***      - * + ***Reporting the peak power of that resources together***   + ***Option 2.2: The gNB reports quantized version of the relative Power between PRS resources per angle per TRP.***   Proposal 5   * ***Support*** ***the following angle range and angle granularity for relative Power/Angle response***   + ***[-90, 90] for omnidirectional antenna and [-60, 60] for directional antenna***     - * + ***0 degree is represented as the boresight angle of the resource.***   + ***Granularity angle can be 0.5, 1, 2, 4 degrees.***   Proposal 6   * ***Support*** ***the quantization accuracy of relative power refer to the reporting range of differential PRS-RSRP is defined from -30 dB to 0 dB with 1 dB resolution as in TS 38.133.***   Proposal 7   * ***Support reusing of associated-dl-PRS-Id for 2 TRPs have the same beam information.*** * ***To consider associated-PRS-resource-ID for 2 resources have the same beam information and different boresight angle.***   Proposal 8   * ***Support reporting 4 parameters (horizontal number of antennas, vertical number of antennas, dH, dV) for one resource as an overhead reduced mechanism and without quantized method for DFT beam.*** |
| [4] | Proposal 6: Support to select Option 2.1 for providing beam/antenna information to the LMF by the gNB.  ***Proposal 7: The gNB reports the peak beamforming gain of each PRS resource to the LMF:***   * ***The gNB can indicate which PRS resource has the largest peak beamforming gain.*** * ***The gNB reports the relative peak beamforming gain of other PRS resource with respect to the PRS resource with the largest peak beamforming gain.***   Proposal 8: The TRP reports the relative beamforming gain per angle for each PRS resource in IE NR PRS beam information.  Proposal 9: The TRP reports the information of peak beamforming gain for each PRS resource.  Proposal 10: Multi-level quantization is supported for relative beamforming gain reporting:   * For example, 1dB step size is used for relative power gain from 0 to -10dB and 3dB step size is used for relative power gain < -10dB. |
| [5] | ***Proposal 6: For the beam/antenna information provided to the LMF, the gNB could report quantized version of the relative Power/Angle response per PRS resource per TRP.*** |
| [8] | **Proposal 4:** Support option 2.1: The gNB reports quantized version of the relative Power/Angle response per PRS resource per TRP. |
| [9] | *Proposal 4: slightly prefer Option 2.2 for UE-B DL AoD positioning for the beam/antenna information provided by gNB.* |
| [11] | Proposal 1   * + **Support option 2.1 where gNB reports quantized version of the relative power corresponding to the set of the sampled azimuth and zenith angles per PRS Resource per TRP**     - **The relative power is defined with respect to the peak power of that resource**   Proposal 2   * + **Support uniform sampling for the azimuth angle *φ* in the spatial sector [-(*N*/2)×Δ*φ*, +(*N*/2)×Δ*φ*], defined by the parameters Δ*φ* and *N*, where**     - **Δ*φ* is the spatial resolution, defined in deg**     - ***N* +1 is the total number of samples per spatial sector**   + **For a given azimuth angle, support uniform sampling for the zenith angle *θ* in the spatial sector [-(*M*/2)×Δ*θ*, +(*M*/2)×Δ*θ*], defined by the parameters Δ*θ* and *M*, where**     - **Δ*θ* is the spatial resolution, defined in deg**     - ***M* is the total number of samples per spatial sector**   Proposal 3   * + **Support quantization of the power levels in the decibel scale in accordance with the following equation:**     - ***PL*(*n*) = 20×lg(*n*) - 20×lg(2*Nb*), where *PL*(*n*) corresponds to the power of the *n*th level with the total number of levels equal to 2*Nb***     - ***Nb* is the number of bits used to signal a power level value**     - ***PL* = 0 dB corresponds to the peak power of the PRS Resource**     - ***PL* = - 20×lg(2*Nb*) dB corresponds to the sensitivity level or the minimum value used to signal a power level value**   + ***Nb* parameter can be set as one of the following {2, 3, 4, 5, 6, 7, 8} bits**     - **The choice of the *Nb* parameter provides a trade-off between the required accuracy and signaling overhead** |
| [13] | **Proposal 3: In case of using multiple sweeping beams with MIMO, support gNB to report the Tx beam codebook to the LMF to assist the positioning estimation.**  **Proposal 4: Optionally, support Tx beam configuration, such as beamwidth and gain, sent from gNB to LMF, for minimizing the reporting size.** |
| [14] | **Proposal 2: Support that the gNB reports quantized version of the relative Power/Angle response per PRS resource per TRP (Option 2.1).**   * **The Power/Angle information shall include the notches in the antenna pattern** |
| [17] | **Proposal 1: Support Option 2.1, “The gNB reports quantized version of the relative Power/Angle response per PRS resource per TRP”**  **Proposal 2: Under Option 2.1, “The gNB reports quantized version of the relative Power/Angle response per PRS resource per TRP”, support to include information related to -3dB power level** |
| [18] | ***Proposal 1: For beam-shape signaling, include additional signaling to allow a full comparison of beam strengths across angles and PRS resources.***   * ***For Option 2.1: also report the peak strength across angles for each resource, relative to the peak of this quantity across all resources***   + A normalized version of the vector where N is the number of PRS resources of the TRP * ***For Option 2.2: also report the peak strength across resources for each angle, relative to the peak of this quantity across all angles.***   + A normalized version of the vector where K is the number of angles in the set A.   ***Observation 1: Option 2.2 requires beam-shapes of all resources to use the same set of angles A, whereas Option 2.1 does not have this constraint.***  ***Proposal 2: Support Option 2.1 of proposal 1 rather than Option 2.2.***  ***Proposal 3: Introduce more than one levels of quantization for the beam information to trade-off beam representation accuracy and overhead. For Option 2.1 support at least the following cases:***   * ***Case 1: Configuration of a uniform grid in azimuth and zenith using 6 parameters for all the PRS resources of a TRP:***   + ***Azimuth: (),***   + ***Zenith: ()***   ***where and can at least take the values {0.5, 1, 2, 5} degrees.***   * ***Case 2: Explicit configuration of ( for each reported power value for each PRS resource***   ***Proposal 4: 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.*** |
| [21] | **Proposal-4:** For additional gNodeB beam information to UE, option-1 should also be supported along with option-2.  **Proposal-5:** Aleast () the number of antennas, along horizontal and vertical, () inter-element spacing along horizontal and vertical, () the boresight AoD and boresight ZoD respectively should be provided to the UE as the beam assitance information. |
| [22] | ***Proposal 8 The LMF should be provided information of beams associated with PRS Resources over O&M. This can be done without specification impact.***  ***Proposal 9 Option 2.1 is reformulated as: The beam/antenna information consists of beam peak direction and a quantized version of the relative Power/Angle response per PRS resource per TRP. The relative power is defined with respect to the peak power of that resource.***  ***Proposal 10 For Option 2.1, include the angles at only the -3dB relative power level.*** |
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#### Proposal 4.1 (signalling of beam information)

#### First round of discussion

Based on the majority support, it is propose to start the discussion using option 2.1 as a basis. There was a proposal to use a reference power across all resource in a TRP, which is included as FFS. There was a comment that signalling may only be required for UE-based positioning, as UE assisted could rely on O&M to provide the beam information to the LMF. In RAN1#106e, it was agreed that it was up to RAN2 & RAN3 to discuss the signaling/procedures on how the LMF receives this information from the gNBs.

**Proposal 4.1:**

**For the beam/antenna information to be optionally provided to the LMF**

**At least for UE based positioning, the LMF can signal the following information for each TRP**

* **Beam information consisting of quantized version of the relative Power/Angle response per PRS resource per TRP**
* **Note: Up to RAN2 & RAN3 the signaling/procedures on how the LMF receives this information from the gNBs**

**For a TRP, The beam power information is quantized as follow**

* **For each PRS resource in a TRP, a reference value with the strongest power across all angles is defined.** 
  + **FFS: use of a reference value per TRP, where all other resources power is reported relative to this reference value.**
* **The power of a resource at a given angle is expressed in dB relative to the reference value and quantized with Nb bits, where Nb is configurable**
  + **FFS values of Nb**
  + **Note: the power of a resource relative to the reference resource is always equal or lower than 0dB.**
* **For the step size used to represent the quantized power, chose between:**
  + **Option 1 A fixed step size**
    - **FFS step size value to be decided, including multi level quantization**
  + **Option 2 A configurable step size**
    - **FFS possible values, including multi level quantization**
* **Note: the number of power values per PRS resource signalled in AD can be smaller than the number of possible power values corresponding to the quantization step, range and number of bits for reported power.**

**For a TRP, the beam angle information is quantized as follow:**

* **For the range of reported angles the angle are represented with K bits, where K is configurable. select between the following options**
  + **Option 1 B: the angles can take possible values over a defined range of angles [*θ1, θ2*] and the quantization step is (*θ2- θ1)/2K***
    - **FFS: values for [*θ1, θ2*]**
    - **FFS: whether the range of angle is fixed or configurable**
    - **FFS: whether the UE can use the AoD uncertainty window as default for [*θ1, θ2*] if the range is not configured and the uncertainty window is available.**
  + **Option 2 B: the quantization step Δ*θ* and the number of bits *K* are defined and the the range of possible angle is [-(*2K-1*/2)×Δ*θ*, +(*2K-1*/2)×Δ*θ*],**
    - **FFS: values of the quantization step Δ*θ***
    - **FFS: whether the quantization step can be configurable (multiple quantization steps)**
  + **FFS: overhead reduction for case of reporting of 3-dB beamwidth**
  + **Note: the number of angle values per PRS resource signalled in AD can be smaller than the number of possible angle values corresponding to the quantization step, range and number of bits for reported angles.**

Companies are encouraged to provide comments in the table below.

**Proposal 4.1**

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| **Company** | **Comment** |
| CATT | We prefer to devide the proposal 4.1 into three sub-proposals for further discussion as follows, then we can discuss them one by one.  We support Proposal 4.1-1.  **Proposal 4.1-1:**  **For the beam/antenna information to be optionally provided to the LMF**  **At least for UE based positioning, the LMF can signal the following information for each TRP**   * **Beam information consisting of quantized version of the relative Power/Angle response per PRS resource per TRP** * **.......**   **Proposal 4.1-2:**  **For a TRP, The beam power information is quantized as follow**   * **For each PRS resource in a TRP, a reference value with the strongest power across all angles is defined.** * **......**   **Proposal 4.1-3:**  **For a TRP, the beam angle information is quantized as follow:**   * **For the range of reported angles the angle are represented with K bits, where K is configurable. select between the following options** * **......** |
| vivo | Agree with CATT proposal and adding some views for each bullet.  For the first main bullet, “ **the LMF can signal the following information for each TRP**”, is “**the LMF can signal the following information to UE**”, or “t**he LMF can be signaled the following information by gNB**”  For the power, we prefer quantization accuracy of relative power refer to the reporting range of differential PRS-RSRP is defined from -30 dB to 0 dB with 1 dB resolution as in TS 38.133  For the angle, we prefer to choose the granularity(for example 1 degree, 0.5 degree) first other than confirm the granularity based on the bits |
| Huawei, HiSilicon | Do not support.  Reporting relative powers among PRS resource across angles (Option 2.2) matches what UE report and can also facilitate RSRP finger-printing collection, that does not require normalization across PRS resources and across spatial domain. |
| Qualcomm | We support CATT’s proposal to split them in separate sub-proposals for easier discussion. We support the main concept of supporting Option 1. |

#### Second round of discussion

Based on the feedback the proposal is broken in 3 proposals to help the discussion:

**Proposal 4.1-1:**

**For the beam/antenna information to be optionally provided to the LMF**

**At least for UE based positioning, the LMF can signal the following information for each TRP**

* **Beam information consisting of quantized version of the relative Power/Angle response per PRS resource per TRP**
* **Note: Up to RAN2 & RAN3 the signaling/procedures on how the LMF receives this information from the gNBs**

**Proposal 4.1-2:**

**For a TRP, The beam power information is quantized as follow**

* **For each PRS resource in a TRP, a reference value with the strongest power across all angles is defined.** 
  + **FFS: use of a reference value per TRP, where all other resources power is reported relative to this reference value.**
* **The power of a resource at a given angle is expressed in dB relative to the reference value and quantized with Nb bits, where Nb is configurable**
  + **FFS values of Nb**
  + **Note: the power of a resource relative to the reference resource is always equal or lower than 0dB.**
* **For the step size used to represent the quantized power, chose between:**
  + **Option 1 A fixed step size**
    - **FFS step size value to be decided, including multi level quantization**
  + **Option 2 A configurable step size**
    - **FFS possible values, including multi level quantization**
* **Note: the number of power values per PRS resource signalled in AD can be smaller than the number of possible power values corresponding to the quantization step, range and number of bits for reported power.**

**Proposal 4.1-3:**

**For a TRP, the beam angle information is quantized as follow:**

* **For the range of reported angles the angle are represented with K bits, where K is configurable. select between the following options**
  + **Option 1 B: the angles can take possible values over a defined range of angles [*θ1, θ2*] and the quantization step is (*θ2- θ1)/2K***
    - **FFS: values for [*θ1, θ2*]**
    - **FFS: whether the range of angle is fixed or configurable**
    - **FFS: whether the UE can use the AoD uncertainty window as default for [*θ1, θ2*] if the range is not configured and the uncertainty window is available.**
  + **Option 2 B: the quantization step Δ*θ* and the number of bits *K* are defined and the the range of possible angle is [-(*2K-1*/2)×Δ*θ*, +(*2K-1*/2)×Δ*θ*],**
    - **FFS: values of the quantization step Δ*θ***
    - **FFS: whether the quantization step can be configurable (multiple quantization steps)**
  + **FFS: overhead reduction for case of reporting of 3-dB beamwidth**
  + **Note: the number of angle values per PRS resource signalled in AD can be smaller than the number of possible angle values corresponding to the quantization step, range and number of bits for reported angles.**

Companies are encouraged to provide comments in the table below.

**Proposal 4.1-1,**

|  |  |
| --- | --- |
| **Company** | **Comment** |
| Nokia/NSB | We would like to ask for clarification. In our understanding, we had agreed to list two options about providing antenna/beam information and we need a down-selection. However, we are confused that the current proposal is focusing on only UE-based positioning. In our understanding, the main purpose of this functionality is to assist LMF to calculate AoD more accurately. In consideration of the procedure, we would suggest first discussing which option will be supported in the previous agreement, and then discuss if we really need to discuss narrow down UE-based positioning. |

**Proposal 4.1-2,**

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| --- | --- |
| **Company** | **Comment** |
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**Proposal 4.1-3,**

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| **Company** | **Comment** |
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### Aspect #5 AoD uncertainty window

#### Summary and FL proposal

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

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| 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 |

The proposal did not converge to an agreement in RAN1#106e. The following was captured out of the discussion during the GTW:

|  |
| --- |
| **Proposal5.1b:**  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, the following is supported   * 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   + - FFS: how to signal value and range:       * Option A: 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 B: a list of PRS indices corresponding to the uncertainty, with one PRS index identifying the expected value, if any. * FFS: details of signaling * FFS: Applicability to other Positioning methods |

Proposals in [1][2][4][5][8][9][10][12][15][18][22] provide updated view on the issue.

* Option 1 from the previous agreement is supported by [2][8][9][10][15][18]
  + use of PRS ID(s) as an alternative to the expected value and uncertainty of AoD/ZoD is mentioned in [22]
* Option 2 from the previous agreement is supported by [1][8]
  + Extend Support for DL TDOA and multi RTT [1]
* [4] does not support introducing the feature

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| --- | --- |
| Source | Proposal |
| [1] | ***Proposal 5: 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.*** |
| [2] | ***Proposal 2:*** *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,*   * *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 TRP (or a single ARP if configured) are associated with a single value of expected DL-AoD/ZoD and uncertainty (of the expected DL-AoD/ZoD value).* * *Note: The expected uncertainty window is defined by the LOS direction between a TRP (or a ARP if configured) and a UE.* |
| [4] | Proposal 5: On uncertainty window for DL-AoD, support Option 3, i.e., do not introduce expected AoD/ZoD or AoA/ZoA and uncertainty |
| [5] | ***Proposal 4: The reference direction of the expected DL-AoD/ZoD or DL-AoA/ZoA, which can be the resource ID(s) of DL/UL reference signals or SSB index, should be indicated to UE.*** |
| [8] | **Proposal 9**: 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 10**: 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 11**: 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. |
| [9] | *Proposal 3: 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.* |
| [10] | ***Proposal 3: For the purpose of both UE based and UE assisted DL-AoD, the LMF can provide the UE with the expected DL-AoD/ZoD value and uncertainty (of the expected DL-AoD/ZoD value) ranges if these can be accurately determined.*** |
| [12] | **Proposal 1:**   * **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** |
| [15] | **Proposal 2**: For DL-AoD technique, support DL-AoD/ZoD assistance information (expected and uncertainty window), signaled from LMF to the UE for each TRP measurement. |
| [18] | ***Proposal 7: 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*** |
| [22] | ***Proposal 16 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.*** |

As there is a majority of contribution supporting the 1st option to support AoD/ZoD uncertainty window, it is propose to use the latest proposal from the past meeting and check if the discussion can converge

**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, the following is supported**

* **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**
  + - **FFS: how to signal value and range:**
      * **Option A: 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 B: a list of PRS indices corresponding to the uncertainty, with one PRS index identifying the expected value, if any.**
* **FFS: details of signaling**
* **FFS: Applicability to other Positioning methods**

Companies are encouraged to provide comments in the table below.

**Proposal 5.1**

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| --- | --- |
| **Company** | **Comment** |
| CATT | Support. |
| Huawei, HiSilicon | We still prefer DL-AoA in the context. |
| Qualcomm | Support |
| Nokia/NSB | We prefer option 2 (DL-AoA). If it is unacceptable, we are okay to support both options. |

### Aspect #6 2-step beam refinement

#### Summary and FL proposal

The issue of beam refinement/two-stage beam sweeping was discussed In [2][4][5][8][10][16] with the following proposals:

* [4] proposes to support PRS beam information in UE assisted methods
* [5] proposes to support dynamic association between PRS resources in different resource sets of the same TRP.
* [8][10][16] discuss association/refinement between PRS in two separate resource sets in the same TRP
* [2] proposes to deprioritize the issue

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| Source | Proposal |
| [2] | ***Observation 2:*** *Two-stage PRS beam sweeping can leave up to implementation or be covered by other topics (angle calculation enhancement or on-demand PRS).*  ***Proposal 7:*** *Don’t support or at least deprioritize corresponding enhancements on two-stage PRS beam sweeping.* |
| [4] | Proposal 11: For beam refinement on DL PRS:   * Support to provide DL PRS beam information (NR-DL-PRS-BeamInfo) to the UE for UE-assisted methods. * Do not introduce additional association between PRS resources for beam operation. |
| [5] | ***Proposal 5: For two-stage PRS beam sweeping, the dynamic association between DL PRS resources belonging to two DL PRS resource sets of the same TRP should be supported.*** |
| [8] | **Proposal 6:** LMF provides in the assistance data association information between two PRS resources where the two PRS resources are in different PRS resource set.  **Proposal 7:** For the overhead reduction of PRS reporting for UE-assisted DL-AoD positioning, a UE may be able to report the DL PRS RSRPs only for the associated PRS resources within a single set if the LMF provided association information to the UE.  **Proposal 8:** Support and study on-demand PRS framework for two-stage PRS beam sweeping. |
| [10] | ***Proposal 4: For two-stage PRS beam sweeping, support that one PRS resource set corresponding to wide beams with each PRS resource is associated with the PRS resources in another PRS resource set corresponding to narrow beams.*** |
| [16] | ***Proposal 5:***   * Regarding 2-stage PRS beam sweeping, RAN1 should consider the following procedure for 2-stage beam reporting:   + In case of the first PRS resource set, it can be composed of multiple PRS resources and they are associated with wide beams.   + And then, the multiple PRS resources that are in the second PRS resource set can be associated with narrow beams. LMF can configure associated PRS resources based on the measurement report in the first step.   ***Proposal 6:***   * RAN1 needs to consider applying different resolution and range for measured quantity value in each stage respectively. |
|  |  |

#### First round of discussion

Before making a proposal, it is propose to gauge the interest of companies on the issues of supporting additional association between resources in different sets, and whether dynamic association should be supported.

**Question 6-1: should additional association between PRS resources in different resource sets be supported**

* **(if yes to question 6-1): what kind of association should be supported:**
  + - **Dynamic association between PRS resources in different sets should be supported**
    - **A semi static relation between PRS resources in different set should be supported**

Companies are encouraged to provide comments in the table below.

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| --- | --- |
| **Company** | **Comment** |
| CATT | Support the additional association.  For the kind of the association, we prefer dynamic association.  From our point of view, dynamic association is more flexible with less PRS overhead. Moreover, with the same number of PRS resources of second-stage resource set, dynamic association achieves better beam refinement (more narrow beams could be used). Therefore, dynamic association should be at least supported in Rel-17. |
| vivo | No, we prefer based on the QCL relation and without additional signaling for the association. |
| Nokia/NSB | We are supportive of the additional association between PRS resources in different resource sets. The PRS resource transmitted by a specific beam may be a common resource for the multiple UEs. The TRP might change the transmission beam dynamically, so semi-static relation may be enough to support the two-stage beam DL-AoD. However, we are open to discuss this kind of 2nd level details further. |

## Other aspects

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| Source | Proposal |
| [2] | ***Proposal 6****: The source reference signal for QCL of a target DL PRS resource can be,*   * *A SSB: the SSB and the target DL PRS resource are from the same band. Meanwhile, the associated Physical Cell ID of the SSB should be the same as corresponding information associated the target DL PRS resource.* * *A source DL PRS resource: the source DL PRS resource and the target DL PRS resource are from the same positioning frequency layer (or the same band) and the same TRP.* |
| [8] | **Proposal 12:** 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 13:** RAN1 to specify support for enabling a PRU 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 ability of reference device to determine beam offset errors are present. |
| [9] | *Proposal 6: Estimate the angle error by a reference node whose accurate location is known.* |
| [21] | **Proposal-6:** For UE-assisted positioning, the UE-FAP-AoA should be reported from UE to LMF for DL-AoD positioning method. |
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#### Comments

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| --- | --- |
| **Company** | **Comment** |
|  |  |

1. Conclusion

**TBD**

1. References
2. R1-2108732,Remaining issues of DL AoD enhancements,Huawei, HiSilicon
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7. R1-2109284,Discussion on DL-AoD enhancements,CMCC
8. R1-2109346,Discussion on enhancements for DL-AoD positioning,CAICT
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20. R1-2110256,Accuracy enhancement for DL-AOD technique,MediaTek Inc.
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22. R1-2110343,Discussion on enhancements for DL-AoD positioning,CEWiT
23. R1-2110351,Enhancements of DL-AoD positioning solutions,Ericsson