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

e-Meeting, October 11th – 19th, 2021

Agenda Item: 8.5.3

Source: Moderator (Ericsson)

Title: FL summary #3 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:

|  |
| --- |
| 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**

|  |  |
| --- | --- |
| **Company** | **Comment** |
| 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. |
| OPPO | The issue of wording in latest 1.1b is still the “power of channel impulse response“. The channel impulse reposnse is the channel power antenuatation and phase rotation. So it is not the power of received signal. How can we use it as the RSRP? The path RSRP is the Received power of the PRS signal that pass through the delay D path of the channel. Furthermore, we do not think the note on UE may choose to use a time window.. is needed. That is UE implementation and why do we need to mention here?  **Proposal 1.1b**  **The measured path PRS RSRP for path delay D is defined as the power of PRS signal received ~~the channel impulse response experienced by the DL PRS reference signals configured for the measurement,~~ at a delay D of the channel impulse response.**   * **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** |
| MTK | Appreciate FL’s hard effort for the wording. It is not easy.  We are not picky. The measurement is after the channel. I am wondering whether the current wording of proposal 1.1b may confuse people that RSRP is to measure the channel  Input signel (dbm) 🡪 channel 🡪 output signal (dbm)  So we provide some revisions as suggestion,  **The measured path PRS RSRP for path delay D is defined as the power at the output of the channel experienced by the DL PRS reference signals configured for the measurement, at a delay D.** |
| Vivo | For us, we are okay to define the path-RSRP either in the time domain or frequency domain. But we concern about the introduction of path delay D in DL-AoD positioning. That is, we are fine with reporting path RSRP, path delay in hybrid positioning, but not in AoD positioning. So, we propose adding a note if path delay D is introduced in the definition.  Note: This does not imply that **path delay D** have to be reported in DL-AoD positioning |
| Huawei, HiSilicon | In response to MTK’s comments, we generally agree with MTK’s understanding, but would clarify that when we say input signal/output signal in the context of EPRE/RSRP, we should note that this is about per RE power/energy for the path.  The total Rx signals in the frequency domain is the sum of all component complex exponentials each corresponding to a delay, i.e., on each RE index , the receive signal (after scrambling with the transmit sequence) should be  So PRS-RSRP should be the mean of with respect to according to the TS 38.215 definition, which can be approximated as below according to Parcevals‘ theorem  And the path PRS-RSRP ideally should be for the path with delay (expressed in sec).  A simple way to estimate from is  Of course, one can do IFFT to convert it back to time domain, e.g.  Where is the time domain shaping filter (with sin/sin format if index k is contiguous) corresponding to delay at sampling point with  Then should be derived via  Which is supposed to be the „channel impulse reponse at delay D |
| Fraunhofer | Suggest replacing “**channel impulse response**” with “**baseband impulse response**”.  From our view, the definition can simply be:  “**The measured path PRS RSRP for a path delay D, is defined as the received DL-PRS power associated with the path delay D of the baseband impulse response.”** |
| ZTE | The current DL PRS RSRP calculate the contributions from all paths, which is a total powers of the channel frequency response of all resource element divided by the number of resource element. However, we’re not able to obtain each path component in the channel frequency response for each RE carrying PRS. Instead, we will do the IFFT to get the channel impulse response. In time domain, the power of a path component has already included the contributions from all resource elements. Therefore, the power of channel impulse response at a delay D should do the linear average over the number of resource elements so that the value of path RSRP is comparable to DL PRS RSRP. |
| CEWiT | We are okay with FL’s proposal, but we do believe that it is better to agree on an equivalent frequency domain definition to maintain the consistency between the definition of PRS-RSRP and path-PRS-RSRP. |
| CATT | We think it is important to send an LS to RAN4 to check RAN1’s definition of path PRS RSRP, and we prefer the following version of path PRS RSPR:  **The measured path PRS RSRP for path delay D is defined as the received DL-PRS power corresponding to ~~of~~ the channel impulse response at a delay D, 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** |
| Lenovo, Motorola Mobility | Generally support FL’s proposal and is important to be consistent with either the time-domain or frequency-domain characterization of the measurement. |
| Intel | Generally we are OK with the FL’s proposal.  However, we do not understand the meaning of delay D. Our understanding, if this is a first detected path, then D = 0, and delay of the additional path is defined relative to the first detected path. We suggest to clarify that.   * **Delay of the first detected path is equal to zero, i.e., D = 0** * **The delay of the additional path is defined as a relative time with respect to the first detected path** |
| LGE | We prefer to keep the note regarding time window. We think introducing the window to calculate path PRS RSRP considering multiple taps within the short time duration is necessary. |
| Sony | We prefer the suggested modified proposal by CATT. |
| Samsung | |  | | --- | | One clarification is that the usage of channel impulse response means that the input of the channel is the unit pulse, thus we suggest not using the term “channel impulse response”. We prefer the following modification: |   **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, with respect to the channel response at the path 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** |
| Apple | We prefer the modidfication suggested by OPPO |

#### Third round of discussion

The comments for this round centered on clarifying what is meant by “channel impulse response”. Oppo’s rewording can be used as the basis for further discussion. I have tried to include the wording from CATT regarding the configured RS. Again, I would like to underscore that any definition in time or frequency domain should be equivalent and we should not waste more time if the issue is only frequency or time domain representation.

Summary of comments:

* rewording of the time domain definition: OPPO, Sony, CATT, Samsung)
* Prefer frequency domain definition: CEWIT
* Note on the time window should be removed (Oppo), or kept (LGE)
* Note to clarify that the delay D does not have to be reported (vivo)
* Replace channel impulse response with “baseband impulse response (Fraunhofer)
* Further scaling with the number of resource elements to be comparable with PRS RSRP (ZTE)
  + FL note: the scaling should always be applied by the IFFT operation in order to preserve the power between time and frequency domain
* Clarify that first path is for delay D=0

**Proposal 1.1c**

**The measured path PRS RSRP for path delay D is defined as the power of the received PRS signal configured for the measurement at a delay D of the baseband impulse response.**

* **Delay of the first detected path is equal to zero, i.e., D = 0**
* **The delay of the additional path is defined as a relative time with respect to the first detected path**
* **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**
* **Note: This does not imply that path delay D have to be reported in DL-AoD positioning**
* **Send LS to RAN4 to check the details of the definition**

Companies are encouraged to provide comments in the table below.

**Proposal 1.1c**

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| --- | --- |
| **Company** | **Comment** |
| Qualcomm | We don’t see the need to change the “channel impule response” to “baseband impulse response”.  The first 2 subbulets, seems to be saying the same thing, and just having the 2nd would be enough. |
| vivo | In my opinion, delayD is more like a way of representation for“a certain path delay”，we doubt the first sub-bullets are needed.  In addition, we doubt the first detected path can always equal to zero if path RSRP will be used in DL TDOA since the additional path value is relative to the detected path timing of the reference resource |
| Nokia/NSB | We prefer the previous version. We are trying to define the path RSPRP for delay D path. We do not see the necessity of adding the first sub-bullet and the second bullet. |
| CATT | If we use CIR in the definition, the meaniing of CIR is clear since it had been widely used. But for the basedband impulse response, it is not a general termiology, if we use this term, maybe we need to further explain what is baseband impulse response and its differernce with CIR. |

#### Fourth round of discussion

The proposal is updated based on the latest available proposal at the GTW:

**Proposal 1.1.d**

**The measured path PRS RSRP for path delay D is defined as the power of the received PRS signal configured for the measurement at delay D of the channel response.**

* **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**
* **Note: This does not imply that delay D have to be reported in DL-AoD positioning**
* **Send LS to RAN4 to check the details of the definition**

Companies are encouraged to provide comments in the table below.

**Proposal 1.1d**

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| --- | --- |
| **Company** | **Comment** |
| Huawei, HiSilicon | Even though we consider the definition itself is not complete, we consider it represents what RAN1 asks for path PRS RSRP definition in mind.  We suggest to modify the last bullet to   * **Send LS to RAN4 to check the details of the definition and feedback if they identify any update is necessary** |
| ZTE | It’s a controversial issue. The suggestion from Huawei can a way forward. |
| CATT | We think RAN4 should be involved into the final version of definition of path PRS RSRP. So Huawei’s version is fine for us. |
| OPPO | Suggest to move with HW’s version to involve RAN4 in the dicussion. |
| Qualcomm | OK with HW’s addition. |
| Nokia/NSB | We think RAN4 involvement is necessary to complete this work so we are fine with the modification from Huawei, but it is not sure if it is really necessary to have the 3rd sub-bullet. This discussion is to define a new measurement so we prefer a separate discussion for the reporting. |
| NTT DOCOMO | Considering the current situation, we prefer HW’s modification. |
| LGE | Agree with HW’s suggestion. |
| Lenovo, Motorola Mobility | HW’s update looks fine since RAN4 will have to confirm the definition. |
| Intel | We think that current definition is incomplete. The meaning of delay D is unclear to us and needs to be defined. |
| Apple | Support FL’s proposal with HW’s addition |
| Futurewei | Our view would be that D is important and it is not clear to us that D can be left entirely to UE implementation i.e. not needed to be reported together with the path RSRP. Without further details on D, then the definition is incomplete in our view. If the group wishes to let RAN4 completes this definition so that we can stop spending additional time, then we think some revisions of the above to express our intention.  ***Proposal for LS to RAN4:***  **It is RAN1 understanding that** t**he measured path PRS RSRP for path delay D ~~is~~ can be defined as the power of the received PRS signal configured for the measurement at delay D of the channel response.**  **Some questions that RAN1 would like to get RAN4 views and feedback, and if they identify any updates needed to the above definition:**   * **Whether the path RSRP measurement is normalized with PRS RSRP.** * **~~Note:~~ Whether it is up to UE implementation on the ~~may choose to~~ use a of time window to compute path DL PRS RSRP ~~by UE implementation~~** * **Whether the ~~Note: This does not imply that~~ delay D have to be reported or if further definition of D is needed ~~in DL-AoD positioning~~**   **~~Send LS to RAN4 to check the details of the definition~~** |
| Samsung | We are okay with FL‘s propsal with HW’s modification. But it is still not clear why we need to introduce the delay D here. What we want to define are the first path RSRP, 2nd path RSRP… In current 215, the term of first arrival path is already there, and it is up to UE to decide the location of first arrival path. Thus, for path RSRP, our understanding is that the delay D is just some certain delay without further specification. If it is not aligned with other people’s understanding, then we propse to modify the proposal on top of HW’s version:  **Proposal 1.1.d**  **The measured path PRS RSRP for the *i*th path ~~delay D~~ is defined as the power of the received PRS signal configured for the measurement at the *i*th path delay ~~D~~ of the channel response.**   * **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** * **~~Note: This does not imply that delay D have to be reported in DL-AoD positioning~~** * **Send LS to RAN4 to check the details of the definition and feedback if they identify any update is necessary**   Overall, our intention is not to disucss the further definition of delay D, and it should be up to UE implementation. |
| vivo | For us, it is because this definition is discussing that measurement which has nothing to do with reporting, so we are not okay to remove the second note since some companies seem to think that reporting timing is needed based on the agreement.  And in the note, it is only said that the main bullet does not mean “ **delay D have to be reported**”， and does not preclude the further discussion about reporting. So, I don’t know why it cannot be placed here . |
| Intel | We think that this is RAN1 responsibility to provide definition of path RSRP. It is OK to ask for feedback from RAN4 and but not ask them to come up with details of the definition.  We see the following aternatives:   * Alt 1.: Separate definition of RSRP for the first path and additional path   + For the first path: delay D is up to implementation and it is not reported   + For additional path: delay D is introduced with respect to the estimated first path timing * Alt 2.: Common definition for path RSRP, but in this case delay D should be explicitly defined   We propose the following changes:  **The measured path DL PRS RSRP for path delay D is defined as the power of the received DL PRS signal ~~configured~~ for the measurement at delay D of the channel response.**   * **For the first detected path delay D is left up to implementation** * **For additional path the delay D is defined relative to the first detected path** * **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** * **Note: This does not imply that delay D have to be reported in DL-AoD positioning** * **Send LS to RAN4 to check the details of the definition** |

#### Fifth round of discussion

It seems that the main point of contention is whether the path delay itself should be defined. Looking at the specification for positioning measurements (RSTD, UL RTOA, UE and gNB RxTx time difference), the specification does not include a definition for how timing is acquired. but we have a generic statement regarding time of measurement. For example RxTx time diference defines the time of reception as “TUE-RX is the UE received timing of downlink subframe #i from a Transmission Point (TP) [18], defined by the first detected path in time”.

Futurewei propose to pass the issue to RAN4 but Intel commented that the responsibility of the measurement is on RAN1. I tend to agree with intel that we cannot ask RAN4 to fix the definition. We can ask about a detail that could help RAN4 with what they need in their work, normalization for example. But it is not up to RAN4 to define the measurement, it is up to us.

To Nokia and samsung: I hope it can be acceptable to keep the note, if that means we can secure an agreement. The note does not impact the 215 measurement definition.

With this in mind, and based on the comments by intel, Huawei, and Samsung, the following update is proposed:

**Proposal 1.1.e**

**The measured path DL PRS RSRP for ith path delay is defined as the power of the received DL PRS signal configured for the measurement at the ith path delay of the channel response, and**

* **path DL PRS RSRP for 1st path delay is the power corresponding to the earliest detected path**
* **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**
* **Note: This does not imply that the path delay have to be reported in DL-AoD positioning**
* **Send LS to RAN4 to check the details of the definition and feedback if they identify any update is necessary**

Companies are encouraged to provide comments in the table below.

**Proposal 1.1e**

|  |  |
| --- | --- |
| **Company** | **Comment** |
| ZTE | Support with one suggestion,  Change the “earliest detected path” into “first detected path in time” to align the description in 38.215. |

#### 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**

|  |  |
| --- | --- |
| **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. |
| OPPO | We do not support the proposal.  When Rx diversity is in use, there is no merit for supporting per-Rx branch RSRP measurement. The combined signal can be use in this case. |
| Xiaomi | We support to define some restriction that when receiver diversity is in use by the UE to obtain the path DL PRS-RSRP measurement, the reported path DL PRS-RSRP value shall not be lower than the corresponding path DL PRS-RSRP of any of the individual receiver branches. But we don’t prefer to report the receiver branch ID. If the receiver branch ID is different, what is the expected behavior of LMF? |
| Huawei, HiSilicon | To OPPO, we do not think combined signal from multiple Rx branches is the solution, since the RSRP measurement reference point is UE antenna connector for FR1, and the point after analogue Rx beamforming for FR2. Rx diversity means there are multiple Rx chains and the RSRP ignaling corresponds to each Rx chain (not antenna for FR2). For DL-AoD, we already have same Rx beam index at least for FR2, but for FR1, if we want to extend to path RSRP, the same Rx branch should be used for path RSRP measurement for different PRS resources.  We would like to note that the proposals on additional path RSRP is awaiting the discussion here, and we are fine with all path RSRPs for a single resource is received by the same Rx branch even without Rx branch indication, but this any requires further discussion. |
| ZTE | The proposal seems RAN4 has to define requirement for single Rx branch, which should be avoided.  We can simply reuse the same description defined in TS 38.215,  “the reported DL PRS-RSRP value shall not be lower than the corresponding DL PRS-RSRP of any of the individual receiver branches.” |
| CEWiT | Don’t see a ignaling gain by reporting path-RSRP per Rx-branch. This can be left to UE implementation. |
| LGE | We have a similar view with OPPO and we also do not agree with the proposal |
| Qualcomm | Dont see the need of this proposal |
| Samsung | Don’t support |
| Apple | Nothing tob e specified here |
| FL | It seems that no consensus can be reached for this proposal. We can continue the discussion during the meeting but it does not seem that a GTW time will be useful. |

#### 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**

|  |  |
| --- | --- |
| **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 don’t PRS resources: Imagine if the gNB has a few nsec of timing miscalibration, and the path in one ignalin 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. |
| OPPO | We support the proposal. We share the similar understanding with CATT and Nokia that the timing ignaling ignaling with each reported path would be useful for the LMF to coherently use the per path RSRP reporting. |
| ZTE | Maybe what we need to talk about is whether UE can do hybrid positioning, i.e. DL-AOD and DL TDOA, since RSTD between different signals is already supported for DL-TDOA. The remaining issue is how to associate the path RSRP to RTSD and whether UE can additionally report time of arrival of reference signal. Therefore, we propose the following revision,  **When path PRS RSRP is reported for DL-TDOA, an associated timing measurement of the corresponding path can also be reported.**   * **In a measurement report, for a DL RSTD measurement, one path PRS RSRP corresponds to TOA of “RSTD” reference TRP and one path PRS RSRP corresponds to TOA of neighbor TRP are also reported.** * **In the measurement report, the path PRS RSRP corresponds to TOA of “RSTD” reference TRP can be associated with a time of arrival measurement for the path.** |
| CEWiT | We support this proposal. The time of arrivals don’t different resources are very important in identifying the NloS links. Moreover, small deviation in ToAs in different PRS resources might not be a big issue. |
| LGE | We have similar a concern point as a comment from Huawei. |
| Sony | The intention of additional report for the path delay is still unclear for us. If the purpose is to have association information between paths, we think that having path IDs reporting (have the same order as the delays) will be an easier approach. If the purpose is to support hybrid positioning, we prefer to discuss it in 8.5.5. |
| Samsung | Not support |
| FL | We can continue the discussion but it seems the issue has not reach enough consensus to be discussed at GTW. |

#### 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 ignaling 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**

|  |  |
| --- | --- |
| **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 don’t see the need to have both options: one of path-RSRP that is „absolute“ and another that is relative to the „RSRP“. |
| OPPO | We only need the first bullet of path RSRP and we support it. |
| Xiaomi | We support the first sub-bullet. But for the second sub-bullet, we suggest to update it as below to make it clearer.   * **If more than 1 PRS resource is included in a measurement report, one resource can be identified as reference resource whose PRS RSRP is reported as absolute PRS-RSRP, and the path PRS RSRP for the reference resource, the PRS RSRP and the path PRS RSRP for all other resources in the report are reported with a power value relative to the PRS-RSRP of the reference PRS resource.** |
| ZTE | We don’t see the need to have this proposal. If we agree that the path PRS RSRP is normalized with DL PRS RSRP corresponding to the same DL PRS resource, the path RSRP is always accompanied by PRS RSRP. We prefer to have a clear proposal,  **The UE can be requested to report path PRS RSRP in an AOD measurement report.** |
| CEWiT | Support the proposal. |
| Lenovo, Motorola Mobility | Support |
| Intel | We have the same view as QC, we believe that the path RSRP should be relative to the RSRP of the channel. |
| LGE | Regarding the way of configuration, since the existing way for additional measurement reports (as mentioned by vivo) is not only for the case that the same Rx beam is used, but also it does not reflect the path-specific reporting. (If our understanding is wrong, please feedback please). From this perspective of view, we prefer to agree on the current version of the proposal, and details of configuration need to be discussed in the next meeting. |
| SONY | We also think only first bullet point is needed. |
| Samsung | Support the main bullet. |

#### Second round of discussion

Summary of comments:

* Vivo mentions that the second bullet is already possible within release 16
  + LGE would like to keep it
* Relative Path RSRP
  + Qualcomm, intel supports to always use a relative path RSRP measurement
* Dependency on normalization / ran4 requirements:
  + Huawei has a question whether the use of a relative path RSRP is up to RAN4
  + ZTE points at the dependency on normalization in the path RSRP definition

Based on the comments it seems that the first bullet could be kept since at least 6 companies want to keep it. However there is also a dependency from the path RSRP definition. If the path RSRP is defined with normalization, there is no need to have this agreement. Therefore, it is proposed to postpone the discussion to after the path RSRP definition can be agreed.

**Proposal 1.4b: the discussion on whether to have absolute / relative path RSRP reporting is postponed until the path RSRP definition is settled.**

Companies are encouraged to provide comments in the table below.

**Proposal 1.4b**

|  |  |
| --- | --- |
| **Company** | **Comment** |
| Nokia/NSB | Support |
| Huawei, HiSilicon | OK. |
| ZTE | OK. |
| CATT | OK. |
| OPPO | Ok |
| LGE | Okay. |
| Xiaomi | OK. |

### 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:

|  |
| --- |
| 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]

|  |  |
| --- | --- |
| 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**

|  |  |
| --- | --- |
| **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. |
| ZTE | We prefer to remove “ **or first path PRS RSRP”** in the first main bullet. If path RSRP is normalized with PRS RSRP, the number of first path RSRP is always the same as PRS RSRP. |
| LGE | Support. |

#### Second round of discussion

We can bring the issue to discussion to the next GTW, including the rewording proposed by nokia. Regarding ZTE comments, I suggest keeping path PRS RSRP in the definition to clarify that the number will apply to both measurements.

**Proposal 2.1 b**

**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 and/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 2.1b**

|  |  |
| --- | --- |
| **Company** | **Comment** |
| Nokia/NSB | Support |
| CATT | Support the proposal.  And we are also fine if the number of PRS RSRP is extended into 64 from current 16 in the proposal. |
| ZTE | The agreement in last meeting only includes DL PRS RSRP. We prefer to only agree DL PRS RSRP in this proposal. The first path RSRP can be settled after we decide whether the path RSRP measurement is normalized with PRS RSRP. |
| OPPO | The maximal number (beyond 8) shall be a UE capability.  **Proposal 2.1 b**  **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~~ N DL PRS RSRP and/or first path PRS RSRP measurements per TRP, where N is UE capability and candidate values include 16.** * **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.** |
| Qualcomm | Does the proposal mean: up to N across both path-RSRP & RSRP, or up to N for each one. Our understanding is that it is up to N for each one.  Also, for FR2 UEs with 3 panels, for each panel, the UE could send 8 RSRPs, so having 24 would be preferred as a UE capability.  Furthermore, the capability of the maximum number of first-path-RSRP is a new one, so it makes sense to write all the potential candidate values.  Finally, a UE may have both panels ON simultaneosuly, so the timestamp may be the same. I dont see the need to say only „different timestamps“.  Suggest the following change:  **Proposal 2.1 b**  **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~~ N DL PRS RSRP measurements per TRP, where N is UE capability and candidate values include {16,24}.** * **For UE-A DL-AOD, support reporting ~~more than 8~~ up to ~~16~~ M first path PRS RSRP measurements per TRP, where M is UE capability and candidate values include {2,4,8,16,24}.** * **Note: Multiple RSRPs corresponding to same or different Rx Beam index should be able to be reported for a given PRS resource for same or different timestamps.** * **Note: the maximum number of DL PRS RSRP associated with the same Rx beam index is up to the UE implementation.** |
| Nokia/NSB | We are fine with extending the number greater than 16. However, we prefer to explicitly mention that "candidate values are {16, 24}" rather than "include" to avoid another discussion to determine the maximum number. |
| NTT DOCOMO | We are supportive of Qualcomm’s proposal. |
| LGE | Sorry for late response. We missed nokia’s comment in the previous round. regarding the current description as ‘and/or’ in the first main bullet, does it means that UE reports both DL PRS-RSRP and first path PRS RSRP?, we can not understand the intention since reporting either DL PRS-RSRP or first path PRS RSRP depending on UE capability seems sufficient. To Nokia, coulud you explain the intention for it?, if there is no clear reason, we prefer to delete the ‚and‘ in the first main bullet.  Regarding the Note, we also prefer to add 'same or' considering simultaneous usage of different pannel at the same time. So, we are agree to QC’s revision. |
| Lenovo, Motorola Mobility | Support FL’s proposal, although first path RSRP can be FFS based on the conclusion of aspect#1. |
| CATT | We are fine with QC’s latest updated proposal. |
| Nokia/NSB | To LGE: Thanks for the clarification question. What we have in mind is that the first path RSRP may be defined as a normalized value, which is captured as FFS of Proposal 1.1d. Then the UE needs to report both first path RSRP and DL PRS RSRP for a PRS resource so that the LMF can compare multiple RSRPs for the first path. |
| Samsung | Okay with QC’s update |
| ZTE | One question for clarification,  If UE provides different values for DL PRS RSRP and first path PRS RSRP in UE capability , how UE can report the DL PRS RSRP and first path PRS RSRP when we agree that UE should report the first path RSRP along with the DL PRS RSRP (i.e. path RSRP measurement is normalized with PRS RSRP)?  For the number of first path RSRP, we prefer to decide in next meeting after we finalize the Proposal 1.1.e. |

### 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. |
| OPPO | We are supportive of the proposal. |
| Xiaomi | As for the second sub-bullet of the second bullet, we think the subset associated with a PRS resource can be in a same PRS resource set as the PRS resource, so we suggest to add “same or“ before “different“ |
| Vivo 2 | To QC, the subset method can be seen as a generic solution, it can be applied to all kinds of beams and should be adopted first rather than the expected AoD+boresight angle method which is a specific solution (it may only apply to some beam shapes). For example, based on the response of the following beams, it can be easily observed that the expected AoD+boresight angle method may not applied in the multiple beam response cases and may lead to missing of the best resource. But the subset method can apply in all the beam shapes easily given the shape similarity between resources.    Beam response with 2 antenna spacing  In addition, for the overhead, we think the mechanism of associated-dl-PRS-ID as a way of signaling that 2 TRPs have the same adjacent beam relation. But it is difficult to use to reduce the overhead of boresight angle since the TRP direction is different. The overhead can be listed in the following table, it can be found the overhead of the subset can be significantly reduced by the mechanism of associated-dl-PRS-ID, and smaller than the boresight angle.   |  |  |  |  |  | | --- | --- | --- | --- | --- | |  | TRP number | Resource number | bit | total | | Boresight angle | 64 | 64\*8 | Per angle:28  Set ID=3bit  AOA=13bit  ZOA=12bit | 64\*64\*8\*28bit | | subset | 64 | 64\*8 | Per subset:  (6)bit\*N=24bit  Resource ID=6 bit  N=4 | 64\*64\*8\*24bit  64\*8\*24bit if associated-dl-PRS-ID can be used for other 63 TRPs |   And we propose to come back the online version in the 106-e meeting  For UE-assisted 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, 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. * FFS: Details on the subset of PRS resources * FFS: the impact of processing the subset of PRS resources * Note: This does not imply any restriction on UE measurement * Note: The subset associated with a PRS resource may be in a same or different PRS resource set with the PRS resource. |
| Fraunhofer | Support.  We have concerns about UE behavior for measuring and reporting RSRPs when signaling the boresight directions. |
| Lenovo, Motorola Mobility | Support FL’s revised proposal, however a separate proposal may be needed for boresight directions in order to converge. |
| LGE | We are generally fine with the current version of FL’s proposal and we also do not support indicating boresight direction since the target functionality is the same. |
| Sony | We still have some concerns with the proposal. However, as compromise, we can take boresight direction + expected AoD |
| InterDigital | We propose to agree as a package, i.e., separate the subset proposal and boresight proposal and agree both of them as a compromise. Inclusion of boresight information for UE-assisted positionig is helpful for alignment/refinement of UE Rx beam. |
| Nokia/NSB | This proposal contains two options for similar functionality and we are not sure if it is really necessary to support both of them.  For now, we are considering that, depending on the configuration, a subset of PRS resources associated with a PRS resource may be in a different PRS resource set. And they may be transmitted by more narrow beams within a wide beam range of the associated PRS resource. In this case, we are thinking that the UE does not necessarily need to report PRS measurement for the wide beam PRS. We suggest adding one more FFS point.  FFS: UE may report PRS measurements only for the subset of PRS resources. |
| Samsung | Support. |

#### second round of discussion

Based on the received comments, it seems that the proposal for reporting of a subset of beams is mostly acceptable except for two companies. 4 companies think that the option of boresight+expected AoD is not useful, but 2 companies explicitely expressed support for it.

For the sake of progress, it seems necessary for the proposal to include both the reporting of PRS subsets and inclusion of boresight information in AD. We can use the rewording from CATT as a basis for the next round of discussion:

**Proposal 3.1b**

**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.**
* **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**

Companies are encouraged to provide comments in the table below.

**Proposal 3.1b**

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| **Company** | **Comment** |
| Qualcomm | We still dont understand what the expression „which indicates the beam inforamtion“ means. I thought that this proposal will just be a list of PRS resources for each PRS resource; no beam information. Either way, for the sake of progress, we could accept to keep both options in the specification and have separate UE capabilities for each proposed AD enhancement. It will be up to LMF, what to include in the AD.  **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 may indicate in the assistance data (AD), one or both the following:**   * **Case 1: subject to UE capability, 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:**   + **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.**   + **Note: The subset associated with a PRS resource can be in a same or different PRS resource set than the PRS resource** * **Case 2: subject to UE capability, for each PRS resource, the boresight direction information, together with the expectedDLAoD for each TRP.** * **Note: Either case does not imply any restriction on UE measurement** * **FFS: prioritization of the PRS resources and resource subsets to be measured** |
| vivo | Okay with QC proposal |
| Nokia/NSB | We have the same comment as the above. Suggest adding an FFS as follows:  FFS: UE may report PRS measurements only for the subset of PRS resources. |
| CATT | We think the two cases included in QC’s proposal is a good way forward to make the progress in this topic. Maybe the word of case can be changed into option. |
| ZTE | We think the proposal from Qualcomm is a good compromise to move forward. |
| OPPO | We are ok with case 2 if the expectedDLAoD is removed from case 2 because the indicating expectedDLAoD does not work for UE-assisted DL AoD considering the location of TRP is not avaibale for the UE in UE-assisted method.   * **Case 2: subject to UE capability, for each PRS resource, the boresight direction information~~, together with the expectedDLAoD for each TRP~~.** |
| Qualcomm | To OPPO: The UE does not need the location of the TRPs.   * UE gets the boresight of each PRS resource, e.g., 0, 15, 30,45, 60,75 degrees for PRS resoruces 1,2,3,4,5 respectively. * The UE also gets that the expected AOD is 50 degrees.   Then a, example of a good UE implemetnation is to do the processing/reporting in the following order: the PRS resources that have 45, 60, 30, 75.  In the above, there was NO need of a location of the TRP to be known. |
| Lenovo, Motorola Mobility | Support way forward by QC as a means to decouple the 2 cases and support both options. |
| Samsung | Same view as OPPO. It is not clear how LMF can get the information on expectedDLAoD. If the accurate expectedDLAoD is available, why not ask gNB to sweep the beams around the expected angle? |
| InterDigital | We support the proposal from Qualcomm. |
| vivo2 | We also think QC’s proposal is a good way forward to make the progress on this topic.  For the expected AOD, we think it is “expected AoD/ZoD value and uncertainty range(s)”, is more like a expected RSTD in angle domain. That is a angle range other than a accurate value. |
| Xiaomi | We are fine with QC’s proposal. |
| ZTE | We think case 2 should also include **an expected AOD uncertainty value**. LMF might know UE’s coarse location, so LMF can provide a search window to UE.  To Samsung,  The expected AOD and expected AOD uncertainty is UE-specific message. However, DL PRS is normally cell-specific, we cannot ask gNB to sweep the beams around the expected angle for a single UE. |

### 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.*** |
|  |  |

#### 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**

|  |  |
| --- | --- |
| **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. |
| Xiaomi | We share same view as Nokia/NSB that we need to first select a option for beam antenna information to be provided to the LMF by gNB, and then consider the information from LMF to UE. |
| Huawei, HiSilicon | Again, we have strong concern to consider only Option 2.1.  The drawbacks of Option 2.1 are   * It requires normalization of power across spatial domain and across all PRS resources * It reveals the TRP antenna element radiation pattern * It is not aligned with the UE reporting, i.e. LMF needs to recalculate radiation power difference across different PRS resources in each angle.   We disagree with argument brought up in [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 1 is not correct, for Option 2.2, there is no need to signal normalization vector, since Option 2.2 only cares about relative power between PRS resource on each angle, so that the PRS resources that has the peak power can be assigned with the reference power, e.g. 0dBm.  Observation 1 is not correct, on different angles, the PRS resources selected could be different. In fact, for each angle, only up to 8 PRS resources from the up to 64 PRS resources can be signaled. There is also no restriction on the set of angle, and it can be up to network implementation. When LMF/UE calculates the DL-AoD, it only needs to find the best matches within the set of angles based on (first path) PRS RSRP measurement. |
| ZTE | For simplicity, we support Option 2.2. We don’t need to normalize beam gains across all angles per resource. In addition, the Option 2.2 doesn’t require the following FFS,   * + **FFS: use of a reference value per TRP, where all other resources power is reported relative to this reference value.**   From our understanding, all the proposals above assume the beam information form gNB to LMF is supported. We don’t need to care about the overhead issue since the signaling between gNB and LMF is via NRPPa. If we need to extend to UE-based positioning, we need to consider the overhead. |
| CATT | We prefer to firstly discuss the Proposal 4.1-1, if we can achieve the consensus on Proposal 4.1-1, then discuss the details on the quantization methods on the beam power/angle information(i.e., Proposal 4.1-2 and 4.1-3).  And once we achieved the consensus, we prefer to send an LS to RAN2&RAN3 to inform them on the option and detailed quantiztion methods, since RAN2&RAN3 are responsible to design the signaling and procedures on the transmission of the beam power/angle information from gNB to LMF.  The Proposal 4.1-1 is acceptable for us. |
| Sony | The main concern from our side is the UE signaling overhead. As written in the proposal, one use case is UE based positioning. To use this information in UE, LMF still need to report the beam information to UE eventually. The report size is expected to be large considering the number of reported power values for each spatial response and how frequent the information is reported (for each resource). |
| Qualcomm2 | We support Proposal 4.1-1.  Thank to HW for the discussion.   * For Option 2.2, we still think that normalizaiton would be useful: Imagine for example the following toy example: we have 2 PRS resources and 2 angles. In one angle, both the PRS resources are at X dBm and X-10 dBm, and in the other angle, they are X-30 dBm and X-40 dBm. In both angles, their relative ratio is -10 dB. HW’s argument is that the UE is enoguh to know that at these 2 angles the relative ratio is -10 dB. * However, from our side we argue, that is is useful to know that, at the 2nd angle the absolute received powers of each PRS resource is 30 dB lower than the absolute received powers at the 1st angle: When the UE measures the 2 PRS resources at a given angle, and gets a ratio of around -10 dB, it will have to decide whether it is the 1st angle or the 2nd. In the absense of any other side information, the UE would have to pick a value, and knowing the absolute RSRP difference would help make a choice: E.g., If RSRP values are high, the UE could give higher likelihood on being in the 1st angle, than the 2nd. * Similarly, imagine, the UE is making several measurements across time, and observes that the spread of the RSRP measurements is high. This typically is due to the low SNR of the channel. In the absense of any side information, if the average of the ratio is around -10dB, for the UE to pick which is the angle between the 2, if the spread of the RSRP measurements is high, it may be safer to weigh more that the correct angle is the one that corresponds to the lower absolute power. * A Ues could approximate the pathloss from each TRP and determine how accurate (e.g. an MSE-type of weighting) a measurement can be at a given angle. In an extreme scenario, if the UE determines that the pathloss is X, and at one angle both PRS resources are transmitted at -50 dB compared to the PRS resources at than another angle, even if the ratio eventually could correspond to either angle, the UE would likely pick that the underling correct angle is the one for which the beams are transmitted with higher power. This would not be possible if the UE doesnt know what is the relative power of the PRS resources on different angle.s   To ZTE: the above proposals are for UE-based positioning also: Going from LMF to UE as the bullet says in the agreement: „The gNB beam/antenna information can optionally be provided to the UE by the LMF “.  With regards to Observation 1: First, we actually think that „hiding a subset of PRS resources“ at different angles, which is used as an argument from HW, might be a less robust implementation. In cases of mobility, or wrong initial assumption of the expected AoD of the UE, if the network provides just a very small subset of PRS resources tailored to the assumption that a UE is in a specific AoD, there is a risk of loss in robustness. We think it is useful to get as much as complete information possible, across all the PRS resources, and having a per-PRS-resource reporting would enable this further. In either case, this can be easily done for Option 2.1 also: One PRS resource is discretized using X points, and another PRS resource is discretized using Y points, with Y>X. |
| Apple | Support 4.1-1 |
| Huawei, HiSilicon2 | Reply to Qualcomm2:   * For Option 2.2, we still think that normalizaiton would be useful: Imagine for example the following toy example: we have 2 PRS resources and 2 angles. In one angle, both the PRS resources are at X dBm and X-10 dBm, and in the other angle, they are X-30 dBm and X-40 dBm. In both angles, their relative ratio is -10 dB. HW’s argument is that the UE is enoguh to know that at these 2 angles the relative ratio is -10 dB.   HW/HiSi: If there are only two PRS resources in total, that could be the case, but it won‘t be resolved by Option 2.1 either. The understanding from our side is that on the angles that the two PRS resources has X-30 dBm and X-40 dBm, respectively, there may be another PRS resource that has higher radiation power, which will weigh in.  When calculate the DL-AoD, LMF/UE may not know the distance between UE and the TRP, which plays role in the receive power expressed in dBm. The basic assumption for DL-AoD is that  The **relative rediated/receive power** between PRS resources on a angle does NOT depend on the distance (that will affect the **asbolute receive power**).  Here is what we imagine how DL-AoD angle calculation works.   * + UE receives multiple PRS resources with different (first path) RSRPs     - The PRS resource has the highest RSRP is called PRS resource X   + UE/LMF first finds the angle set Y in the beam information that PRS resource X has the highest radiated power   + Within the angle set Y, UE/LMF finds the angle value that results in the best match between the relative rediated power (in the beam information) and the received (first path) relative RSRP to PRS resource X.   The above procedure can also be applied to any additional path for additional path DL-AoD estimation.  The absolute power of the peak is not necessary, and is not useful for DL-AoD calculation, and it does not have any meaning unless the abosolute rediated power is claimed to be measure at a certain radiation sphere.   * However, from our side we argue, that is is useful to know that, at the 2nd angle the absolute received powers of each PRS resource is 30 dB lower than the absolute received powers at the 1st angle: When the UE measures the 2 PRS resources at a given angle, and gets a ratio of around -10 dB, it will have to decide whether it is the 1st angle or the 2nd. In the absense of any other side information, the UE would have to pick a value, and knowing the absolute RSRP difference would help make a choice: E.g., If RSRP values are high, the UE could give higher likelihood on being in the 1st angle, than the 2nd.   HW/HiSi: How UE would judge high/low from the measurement and rediated beam information without knowing the distance between UE and TRP, and without knowing how the rediated beam information was evaluated, e.g. at which radius for the radiated power?   * Similarly, imagine, the UE is making several measurements across time, and observes that the spread of the RSRP measurements is high. This typically is due to the low SNR of the channel. In the absense of any side information, if the average of the ratio is around -10dB, for the UE to pick which is the angle between the 2, if the spread of the RSRP measurements is high, it may be safer to weigh more that the correct angle is the one that corresponds to the lower absolute power.   HW/HiSi: This could also be the result of large distance between UE and TRP even for angle 1. This example assumes there is only two PRS over all spatial domain, which is not true for DL-AoD deployment. We do not think we should reply only on side-lobes of beams to calculate the angle, and if that is case, angle 2 will not be provided in Option 2.2 in the first place.   * A Ues could approximate the pathloss from each TRP and determine how accurate (e.g. an MSE-type of weighting) a measurement can be at a given angle. In an extreme scenario, if the UE determines that the pathloss is X, and at one angle both PRS resources are transmitted at -50 dB compared to the PRS resources at than another angle, even if the ratio eventually could correspond to either angle, the UE would likely pick that the underling correct angle is the one for which the beams are transmitted with higher power. This would not be possible if the UE doesnt know what is the relative power of the PRS resources on different angle.s   HW/HiSi: The factors impacting the pathloss (EPRE – RSRP) may include UE/TRP antenna gain, UE/TRP beamforming gain, propogation pathloss. If what Qualcomm want is allow UE to select the higher (radiated) power one, we would be open to say that if advanced beam information is provided, LMF/UE expects that the Rel-16 boresight direction is also provided. |
| ZTE2 | We tend to agree some views from Huawei above. As an example, LMF gets a bunch of DL PRS-RSRPs per TRP, which constructs a RSRP vector (e.g. [RSRP1, RSRP2, RSRP3, RSRP4]) for different DL PRS resources. Then, LMF should compare the RSRP vector with beam gain vector (e.g. [G1, G2, G3, G4], which is the relative power between the DL PRS resources for a specific angle). Finally, LMF will find an angle whose corresponding beam gain vector is the most relevant to the RSRP vector. |
| OPPO | Support.  Regarding option 2.2: since it does relative power for all PRS resources in each angle, we have to indicate which PRS resource has the highest power gain on every angle. That result in large overhead but provide no additional information compared to Option 2.1 |
| Huawei, HiSilicon3 | To OPPO  I am not sure how you gets the AoD with the advanced Option 2.1. Do you need to compare with received relative PRS-RSRP to find the best match?  Option 2.1 not only requires providing the information of the PRS resource that has the peak power on an angle (with the power value indicated), it also requires providing the peak power difference between different angles, which is absolutely unnecessary and reveals gNB antenna element radiation profile that has nothing to do with DL-AoD positioning.  With Option 2.2, the granurality of angles (spatial sampling point) can be rather flexible, and can be provided to the LMF only for the region of interest with either uniform sampling or other non-uniform sampling, or even a set of discrete values. |

**Proposal 4.1-2,**

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| --- | --- |
| **Company** | **Comment** |
| Vivo | Option 1A is preferred, and the quantization accuracy of relative power refers 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” |
| ZTE | Okay with the proposal except the first main bullet as we mentioned in Proposal 4.1-1. |
| Qualcomm | OK to support configurable. Will help for forward compatibility and different network/TRP implemenations and deployments. |
| Apple | Support |
| OPPO | Support. |
| Intel | Support option 2A |

**Proposal 4.1-3,**

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| --- | --- |
| **Company** | **Comment** |
| vivo | For the angle, we prefer to choose the fixed granularity(for example 1 degree, 0.5 degree) first other than confirm the granularity based on the bits |
| ZTE | We prefer to discuss how to determine **range of angles [*θ1, θ2*]** first,  **Range of angles [*θ1, θ2*] are determined by,**   * **For beam information provided by gNB to LMF, select at least one of the following options,** * **Option 1: the range of angles [*θ1, θ2*] is decided by gNB and provided in the beam information from gNB to LMF** * **Option 2: the range of angles [*θ1, θ2*] is requested by LMF**   + - **FFS: whether the gNB can use the AoD uncertainty window as default for [*θ1, θ2*] if the range is not configured and the uncertainty window is available.** * **For beam information provided by LMF to UE, select at least one of the following options,** * **Option 1: the range of angles [*θ1, θ2*] is explicitly indicated by LMF to UE** * **Option 2: the range of angles [*θ1, θ2*] can be implicitly indicated by AoD uncertainty window as default for [*θ1, θ2*] if the range is not configured and the uncertainty window is available.** |
| Qualcomm | We are Ok with configurable granularity, under the asusmption that the spec will allow a value as small as 0.5 degrees. |
| Apple | Support |
| OPPO | We prefer to choose a fixed granularity too. We first determine the granularity of angle, and the range of angle, then the bitwidth can be decided naturally. |
| Intel | Support option 2B |

#### Third round of discussion

there was a question from Nokia on proposal 4.1.1 regarding the “at least for UE based”. My understanding is that RAN3 is now discussing whether there should be NRPPa impact for UE assisted, based on the previous meetings agreement.

Regarding why the proposal is based on option 2.1, as explained in the summary I went with the majority support (7 contributions in support of 2.1, 3 in support of 2.2). clearly the issue needs more discussion, thus let’s put the proposals 4.1.2 and 4.1.3 on hold until 4.1.1 is resolved. The discussion can continue below.

**Proposal 4.1-1**

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

### 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:

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| **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. |
| OPPO | We do not think the proposal can work, especially for UE-A method.  To use the indicated expected AoD information, the UE at least knows the location of each TRP. Otherwise, angle information does not provide any information to the UE. But in UE-A positioning, the location of TRP is not provided to the UE. |
| Xiaomi | Support |
| Fraunhofer | We prefer to resolve Aspect#3 first. |
| ZTE | Support |
| CEWiT | Support the proposal. |
| LGE | We are also still supportive of option2 in the previous agreement. |
| InterDigital | Support |
| Samsung | Support |
| Intel | We also still prefer not to exclude the option with DL-AOA |
| FL | Regarding the support of option2, we had made a discussion and progress last meeting to the proposal that is captured in yellow above. Even if that is not a locked agreement, given that we are quite late in the release, it would be great if we did not have to reset the discussion, since I don’t believe we will get a different outcome. |

### 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. |
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#### 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. |
| OPPO | No, the association between PRS resources in different sets is not needed.  The QCL configruation can provided what is proposed here. Furthermore, provding the boresight informaiton of PRS resource can also provide similar funcationality |
| ZTE | We share the same view with vivo and OPPO. |
| Lenovo, Motorola Mobility | Supportive of the 1st aspect regarding association between different PRS resources in different resource sets. FFS details on whether the association Is dynamic or semi-static. |
| LGE | Without any additional information for two different PRS resource sets, UE cannot know which PRS resource set is used for each stage. In our understanding, LMF at least should provide whether each PRS resource set is related to which stage. So, we think that the related information for the example can be considered. Regarding whether the information is proved dynamically or not, we are open to discuss it.  In addition, as we mentioned in our contribution, we prefer to adding the consideration about enhancement of measurement reporting for 2-step beam refinement. |
| Sony | We are supportive of the proposal and agree that the association information is needed. For example, in the second step beam sweeping, the TRP needs to know the previous resource to schedule a ‘refined’ beam. |
| InterDigital | The deatils on how PRS resources in different resource sets can be associated should be discussed. For example, for dynamic association, is the on-demand framework used? |
| Samsung | We support introducing the association information between PRS resources in different resource sets. The details can be FFS. |

## 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** |
| CEWiT | We believe that UE-FAP-AoA should be discussed. It can help with in NLoS detection and mitigation. |

1. Conclusion

**TBD**

1. References
2. R1-2108732,Remaining issues of DL AoD enhancements,Huawei, HiSilicon
3. R1-2108880,Accuracy improvement for DL-AoD positioning solutions,ZTE
4. R1-2108977,Discussion on potential enhancements for DL-AoD method,vivo
5. R1-2109053,Enhancements for DL-AoD positioning,OPPO
6. R1-2109226,Further discussion on enhancements for DL-AoD positioning method,CATT
7. R1-2109284,Discussion on DL-AoD enhancements,CMCC
8. R1-2109346,Discussion on enhancements for DL-AoD positioning,CAICT
9. R1-2109365,Views on enhancing DL AoD,Nokia, Nokia Shanghai Bell
10. R1-2109413,Accuracy improvements for DL-AoD positioning solutions,Xiaomi
11. R1-2109492,Discussion on accuracy improvements for DL-AoD positioning solutions,Samsung
12. R1-2109613,Solutions for NR Positioning DL-AoD Enhancements,Intel Corporation
13. R1-2109681,Discussion on DL-AoD positioning enhancements,NTT DOCOMO, INC.
14. R1-2109792,Considerations on enhancements for DL-AoD,Sony
15. R1-2109864,DL-AoD positioning enhancements,Fraunhofer IIS, Fraunhofer HHI
16. R1-2110037,Positioning Accuracy enhancements for DL-AoD,Apple
17. R1-2110090,Discussion on accuracy improvement for DL-AoD positioning,LG Electronics
18. R1-2110148,Enhancements for DL-AoD positioning solutions,InterDigital, Inc.
19. R1-2110189,Remaining Issues on Potential Enhancements for DL-AoD positioning,Qualcomm Incorporated
20. R1-2110256,Accuracy enhancement for DL-AOD technique,MediaTek Inc.
21. R1-2110299,Discussion on DL-AoD Positioning Enhancements,Lenovo, Motorola Mobility
22. R1-2110343,Discussion on enhancements for DL-AoD positioning,CEWiT
23. R1-2110351,Enhancements of DL-AoD positioning solutions,Ericsson