**3GPP TSG RAN WG1 #104bis-e R1-210zzzz**

**e-Meeting, April 12th – 20th, 2021**

**Source: Moderator (Intel Corporation)**

**Title: Feature Lead Summary #2 for Enhancements of UL-AOA Positioning**

**Agenda item:** **8.5.2**

**Document for:**  **Discussion and Decision**

# Introduction

In this contribution, we provide summary of the enhancements for UL-AOA positioning proposed by companies in contributions [1]-[19]. In addition, we formulate tentative proposals for RAN WG1 discussion and decision.

Enhancements for UL-AOA Positioning Solution

The following list of proposed enhancements was identified based on submitted contributions [1]-[19]:

1. UL-AOA Reporting for Linear Arrays
2. Details of UL-AOA Assistance Information
3. Reference UE for UL-AOA
4. Timestamp and Multiple UL-AOA Values for the FAP
5. Additional Paths and Multiple UL-AOA Measurements
6. UL-AOA Reporting Enhancements
7. Expected AoD
8. LOS/NLOS Identification
9. Velocity for UL-AOA Measurements
10. Multi-port SRS for Positioning
11. UE TX Beam Refinement
12. Beamforming and UL-AOA Estimation
13. Antenna Reference Points
14. SRS for Positioning Power Control

Design Aspects

## Aspect #1: UL-AOA Reporting for Linear Arrays

The following agreement was made with respect to enhancements of UL-AOA reporting in case of linear antenna array.

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| * Further study which option is used to potentially enhance signaling of UL-AOA measurement report in case of a linear array antenna * Option 1: gNB reports UL-AOA measurement which is a function of the actual azimuth and zenith angles of arrival in a given coordinate system * Option 2: The z-axis of LCS is defined along the linear array axis. gNB reports only the ZoA relative to z-axis in the LCS, and the LCS-to-GCS translation function is used to set up the specific z-axis direction * Other options are not precluded from the study |

Based on review of contributions, the following views were expressed:

* Option 1: Preferred by 4 sources: [Ericsson, [19]], [Samsung, [12]], [Intel, [9]], [InterDigital, [8]]
* Option 2: Preferred by 8 sources: [CEWiT, [18]], [Qualcomm, [11]], [Nokia, [7]], [ZTE, [4]], [vivo, [2]], [OPPO, [1]], [Huawei, [14]], [Intel, [9]]
* Option 2b: Preferred by 1 source: [Huawei, [14]]
  + The z-axis of LCS is defined along the linear array axis. gNB reports only the ZoA relative to z-axis in the LCS, and the z-axis direction is also reported via AoA and ZoA in GCS.

From feature lead perspective, all options can work and have similar impact on specification. Option 1 seems to be a more general solution. Considering the majority preference on Option 2, it is recommended to take this option.

### Proposals for Round #1

**Proposal 1-1**

* The following option is supported to enhance signaling of UL-AOA measurement report in case of a linear array
  + Option 2: The z-axis of LCS is defined along the linear array axis. gNB reports only the ZoA relative to z-axis in the LCS, and the LCS-to-GCS translation function is used to set up the specific z-axis direction
* UL-AOA signalling details for support of Option 2 are left up to RAN WG3

Companies are invited to provide comments on above proposal

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| Company Name | Comments |
| Qualcomm | Support |
| CATT | Support. We are also fine with Option 2b proposed by Huawei, which gives a little more on what to be included in the signalling. |
| Nokia/NSB | Support. |
| ZTE | Support. |
| Intel | Support |
| vivo | Support. |
| CMCC | Support |
| OPPO | The Option 2b proposed by HW is preferred. However, we can live with the proposal in principle if most of companies support it. And we also find the TRP can report a estimated range of angle of arrival in the plane that is vertical to the z-axis direction. The TRP can estimate that based on such as the antenna hardware setup and antenna beam synthesis. Thus suggest to update proposal as follows:  **Proposal 1-1**   * The following option is supported to enhance signaling of UL-AOA measurement report in case of a linear array   + Option 2: The z-axis of LCS is defined along the linear array axis. gNB reports only the ZoA relative to z-axis in the LCS, and the LCS-to-GCS translation function is used to set up the specific z-axis direction     - The TRP can also report on estimated range of angle of arrival of the UE in the plane vertical to the z-axis. * UL-AOA signalling details for support of Option 2 are left up to RAN WG3 |
| Sony | Support |
| Samsung | We can be ok with option 2. |
| LG | Support |

### Tentative Conclusion

Based on discussion it seems agreeable to take Option 2 as a way forward. Therefore Proposal 1-1 is recommended for online discussion w/o modifications.

## Aspect #2: Details of UL-AOA Assistance Information

The following agreement was made with respect to assistance signaling to facilitate UL-AOA measurements:

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| * NR supports at least the following additional assistance signaling from LMF to gNB/TRP to facilitate UL measurements of UL-AOA   + Indication of expected AoA/ZoA value and uncertainty (of the expected AoA/ZoA value) range(s)   + FFS: Details of procedure for providing the assistance   + FFS: Reference angle of expected AoA/ZoA |

Based on review of submitted contributions the following aspects were identified for discussion:

* Assistance information details
  + Expected AoA/ZoA can be the boresight information of a beam [CMCC, [6]]
  + Uncertainty range can be beam width [CMCC, [6]]
  + LMF can refer to the reported DL measurement and the associated resource index to configure the AoA search window for each TRP [CMCC, [6]]
  + gNB/TRP beam configuration can be provided as a part of assistance [Sony, [13]]
  + Define the expected range of the azimuth angle as (φ - Δφ/2, φ + Δφ/2) and the expected range for the zenith angle as (θ - Δθ/2, θ + Δθ/2) [Intel, [9]]
  + UL-AOA search window can be associated with RTOA search window [Intel, [9]]
  + Use the standard deviation associated with the expected (time average) AoA/ZoA value to indicate uncertainty associated with the expected AoA/ZoA value [InterDigital, [8]]
  + Support indication of expected and uncertainty for AoA/ZoA at least for the main path [InterDigital, [8]]
  + A reference AoA value and the range **,** and A reference ZoA value and the range [OPPO, [1]]
  + The LMF indicates to the TRP that the UL-SRS for UL-AoA measurements can be expected in the direction of an DL-PRS. [Fraunhofer, [17]]
  + The LMF indicates to the TRP that the UL-SRS for UL-AoA measurement can be expected in the direction of an UL-SRS. [Fraunhofer, [17]]
  + UE provides measurements related to the DL beams of surrounding gNB/TRPs to LMF (SSB index/CSI-RS resource (set) ID/PRS resource (set) ID /the RSRP /cell ID). Request can be triggered by UE/LMF [CATT, [3]]
  + gNB provides measurement information related to the DL beams to LMF (obtained from the RRM measurements reported from the UE). LMF to forward the measurement information related to the DL beams to the surrounding gNB/TRPs instead of sending the estimated expected UL-AoAs [CATT, [3]]
* Coordinate system for expected AoA/ZoA
  + Select either GCS or LCS: [ZTE, [4]]
  + GCS only: [Ericsson, [19]], [Huawei, [14]], [Nokia, [7]] (like the definition of UL AoA in the GCS)
  + Configurable LCS or GCS: [Qualcomm, [11]], [Intel, [9]], [CATT, [3]] (if LMF has GCS to LCS conversion relationship of the gNB/TRP antenna), [OPPO, [1]]
* Applicability of the expected AoA/ZoA to UL-TDOA and Multi-RTT
  + Applicable to UL-TDOA and Multi-RTT: [Huawei, [14]]
* Granularity of expected AoA/ZoA and uncertainty
  + Multiple values of granularities for expected and uncertainty of AoA/ZoA value [InterDigital, [8]]
  + Minimum granularity of 0.1 degree for expected angles and uncertainties. RAN3 are encouraged to optimize the granularity signaling. [Huawei, [14]]
* Assistance information for linear array
  + Reference angle with respect to the linear array axis */* range of the angle of arrival of the UE in the plane vertical to the linear antenna array axis [OPPO¸[1]]
    - This aspect has dependency with Aspect #1 (i.e. which option will be agreed for Aspect #1)
* Signaling/protocol details (message)
  + Sony, [13]
    - gNB/TRP reports the usage of assistance information together with the reported positioning measurement report
  + Ericson, [19]
    - gNB can request expected AoA/ZoA and uncertainty window
    - Assistance information can be provided to gNB during initial LMF measurement request message (as a part of SRS configuration)
    - LMF can provide updates to assistance information (part of the measurement update)
    - gNB can omit uncertainty window provided by LMF and provide update to the uncertainty window
  + Huawei, [14]
    - The signaled uncertainty should not prevent gNB from providing the measurements outside the range
  + Qualcomm, [11]
    - The LMF can include the expected AoA/ZoA information as part of the Measurement Request Message in NRPPa.
  + Nokia, [7]
    - Details of the procedure for providing expected AoA/ZoA should be discussed in RAN3.
* Validity of AoA assistance information
  + Define validity of UL-AoA assistance information [Sony, [13]]
* LS to RAN3 – Assistance information for UL AoA/ZoA has impact on NRPPa
  + [Ericsson, [19]], [Nokia, [7]]

### Proposals for Round #1

It is proposed to discuss and select:

* One option for indication of expected AoA/ZoA and uncertainty range
* One alternative for support of coordinate system for UL-AOA assistance information
* Discuss whether indication of expected AoA/ZoA and uncertainty range is applicable for UL-TDOA and Multi-RTT
* Leave other signaling details up to RAN2/RAN3

**Proposal 2-1**

* Select one option for indication of expected AoA/ZoA and uncertainty range
  + Option 1: Uncertainty range for expected AoA/ZoA is defined as follows
    - Expected azimuth angle of arrival as (φAOA - ΔφAOA/2, φAOA + ΔφAOA/2)
      * φAOA - expected azimuth angle of arrival, ΔφAOA – uncertainty range for expected azimuth angle of arrival
    - Expected zenith angle of arrival as (θAOA - ΔθAOA/2, θAOA + ΔθAOA/2)
      * θAOA - expected zenith angle of arrival, ΔθAOA – uncertainty range for expected zenith angle of arrival
  + Option 2:
    - LMF indicates DL-PRS resource for the expected AoA/ZoA and uncertainty range
      * In this case, expected AoA/ZoA is represented by boresight information of a DL-PRS resource (beam) and uncertainty range is associated with DL-PRS resource beamwidth
  + Option 3:
    - LMF indicates standard deviation associated with the expected (time average) AoA/ZoA value is used to indicate uncertainty associated with the expected AoA/ZoA value
  + Option 4:
    - UE provides measurements related to the DL beams of surrounding gNB/TRPs to LMF (SSB index/CSI-RS resource (set) ID/PRS resource (set) ID /the RSRP /cell ID)
      * LMF to forward the measurement information related to the DL beams to the surrounding gNB/TRPs instead of sending the estimated expected UL-AoAs
    - gNB provides measurement information related to the DL beams (obtained from UE RRM measurements) to LMF
      * LMF forwards the measurement information related to the DL beams to the surrounding gNB/TRPs instead of sending the estimated expected UL-AoAs
* Select one of the following coordinate system alternatives for signaling AoA/ZoA assistance information
  + Alt.1: Only GCS is supported for AoA/ZoA assistance information indication
  + Alt.2: Both GCS and LCS are supported for AoA/ZoA assistance information indication
    - LMF indicates which coordinate system is used
    - Note: LCS can be indicated if LMF has GCS to LCS conversion relationship of the gNB/TRP antenna
* Signaling of AoA/ZoA assistance information (expected value and uncertainty range) is supported for UL-TDOA and Multi-RTT positioning methods
  + Note: Signaling of AoA/ZoA assistance information does not limit gNB/TRP measurement behavior
* Other signalling details related to AoA/ZoA assistance information are discussed in RAN2/RAN3

Companies are invited to provide comments on above proposal

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| Company Name | Comments |
| Qualcomm | First main bullet:   * Opt. 1   Second main bullet:   * Alt. 2 without the subbulets for now   Third main bullet:   * I assume this bullet says that this AD will be for all methods and not just UL-AOA right?   FL: Right, it is an intention |
| CATT | For the main bullet, the sub-bullets in Option 4, the following methods:   * “UE provides measurements related to the DL beams of surrounding gNB/TRPs to LMF (SSB index/CSI-RS resource (set) ID/PRS resource (set) ID /the RSRP /cell ID” * “gNB provides measurement information related to the DL beams (obtained from UE RRM measurements) to LMF”   are related to UE and serving gNB to information to LMF in order to help LMF to obtain the expected UL-AoAs and uncertainties. These methods can be used to support other options listed in the main bullet, which describes how LMF sends the UL-AoAs and uncertainties to the gNB/TRPs. Thus, suggest list then as a separate proposal from main bullets.   * + Option 4:     - * LMF to forward the measurement information related to the DL beams to the surrounding gNB/TRPs instead of sending the estimated expected UL-AoAs   Proposal 2-1b   * + - UE provides measurements related to the DL beams of surrounding gNB/TRPs to LMF (SSB index/CSI-RS resource (set) ID/PRS resource (set) ID /the RSRP /cell ID)   Proposal 2-1c   * + - gNB provides measurement information related to the DL beams (obtained from UE RRM measurements) to LMF   FL: The revision looks like a separate topic for discussion (i.e. assistance information from UE/gNB to determine LMF assistance information for expected AOA). I think it should be discussed separately. It also has correlation with on-demand frameworks to be discussed starting from the next meeting. Given the explanation and comments from other companies, the recommendation from FL is to not pursue this topic further under this specific discussion. |
| Nokia/NSB | First main bullet:   * Option 1   Second bullet:   * Alt. 1. Anything more is over-specifying something simple. The TRP has the LCS-to-GCS translation always.   Support main bullets 3 and 4 in principle. |
| InterDigital | First main bullet:  Option 3 |
| ZTE | First main bullet: Option 1;  Second main bullet: Alt 1 for simplicity;  We can accept last two main bullets. |
| Huawei/HiSilicon | First bullet: Option 1.   * As commented during the GTW session, we think that Option 2 and Option 4 are already supported in Rel-16, as the SRS configuration for measurement also includes the spatial relation information as DL-PRS or SSB. * Option 3 is using STD, which may not be easily calculated by the location server.   Second bullet: Alt.1   * GCS can be directly calculated from based on TRP coordinates and coarse UE location. * LCS should be further calculated from the GCS, which we think is a “second hand” information. Typically the uncertainty in GCS cannot be easily translated into the uncertainty in the LCS.   Third bullet: Support |
| Intel | First main bullet: Option 1  Second main bullet: Alt. 2 |
| Fraunhofer | First main bullet: Option 2  To HW’s comment: the SRS configuration does not necessarily imply that all TRPs will have an SRS spatial relation information with the DL-PRS of these TRPs. In fact the TRP in NRPPa can provide a *Measurement Beam Information*in a measurement report associated with an PRS or SSB, so the other way indication from the LMF to TRP shall be also possible. |
| vivo | For the first bullet:  Option1 is preferred.  For the second bullet:  Alt.1.  For the third bullet:  Whether AoA/ZoA assistance information is needed for UL-TDOA and RTT method should be further clarified. And since the original proposal is to facilitate UL measurements of UL-AOA, I don’t think we should discuss this bullet here  Last, the granularity is RAN1 scope, we propose to discuss it. |
| CMCC | For the first main bullet:  Support Option 1. To our understanding, Options 2~4 can be achieved by Option 1, which provide full flexibility to LMF to configure the AoA search window.  For the second main bullet:  Support Alt 2. |
| OPPO | For the 1st bullet: Option 1 is preferred.  For the 2nd bullet: Alt.2 is preferred.  For the 3rd bullet: We are not sure that is needed. Furthermore, does it intend to say: is such assistance information supported for UL TDoA or multi-RTT positioning too, right?  FL: Right, it is an intention |
| CATT | To Huawei’s comment “Option 2 and Option 4 are already supported in Rel-16, as the SRS configuration for measurement also includes the spatial relation information as DL-PRS or SSB”: Our understanding is that the “SRS configuration for measurement also includes the spatial relation information as DL-PRS or SSB” does not necessary imply the TRP can derives the expected UL AOA from the UE, since the DL PRS/SSB beam width and UL SRS beam width can be completely different (See the following figure as an example). |
| Sony | For the definition/format of the expected AoA/ZoA (1st main bullet point), we prefer **Option 1**. It is more generic compare with option 3, since the uncertainty i.e. ΔφAOA can be further defined by the LMF which includes the std. of the historical AoA measurements.  Besides that, we think option 2 is for DL-AoD case rather than the UL-AoA.  For the coordinate system (2nd main bullet point), we prefer the **Alt.2**. The LCS can also be supported which helps the TRP (i.e, no need to compute the GCS).  One minor suggestion: The ‘uncertainty range’ doesn’t make sense to us because the uncertainty already means the range of the possible values within which the true value lies. It will be better to modify it as just ‘uncertainty’. |
| Huawei/HiSilicon | In reply to CATT:  The example used is not clear, and we do not think that the different beam width should be reason that the spatial relation of SRS should not be used as the Rx beam information for the SRS.  A simple relationship holds: if the Tx beam of PRS/SSB is pointing to the UE, the same Rx beam should be used to receive the SRS from the UE, and we may consider it as beam correspondence at gNB. |
| Samsung | For the first bullet, we support option 1  For the second bullet, we support Alt 2.  We do not support the third bullet. |
| Futurewei | Option 2 or Option 4. For option 4, with the revised wording by CATT (Proposal 2-1b or 2-1c), it is actually closer to Option 2. |
| Fraunhofer v2 | We propose that both options1 and 2 are supported.  For multi-RTT + UL-AoA the DL-PRS can provide more accurate information on the expected AoA than a one derived from a coarse UE position.  Based on the provided input, none of the companies are against Option2. Huawei has concerns that the reported information are redundant to the provided SRS configuration which cannot be generalized for all scenarios (for example a UE can be configured with SRS spatial relation for multiple DL-PRS of the same TRP). |
| CATT | In reply to Huawei:  To apply the simple relationship as mentioned by Huawei: “If the Tx beam of PRS/SSB is pointing to the UE, the same Rx beam should be used to receive the SRS from the UE”, it would be better to let the TRP to know which DL beam is poiting to the UE to avoid blind search. That is why we propose to let UE to provide the information, telling the TRPs which DL PRS/SRS beam(s) from the TRPs are pointing to the UE. |

For the first main bullet on assistance information:

* Option 1: Qualcomm, Nokia, ZTE, Huawei, Intel, vivo, CMCC, OPPO, Sony, Samsung
* Option 2: Futurewei, Fraunhofer
* Option 3: InterDigital
* Option 4: CATT (with proposed revisions)

It seems there is clear majority to take Option 1 and it seems can work in all discussed scenarios therefore it is recommended for online discussion.

For the second main bullet on coordinate system:

* Alt. 1: Nokia, Huawei, ZTE, vivo
* Alt. 2: Qualcomm, Intel, CMCC, OPPO, Sony, Samsung

It seems there is slight majority to take Alt.2. Both alternatives can work in practice. Alt.2 seems more aligned with existing UL-AOA reporting options and thus can be a natural choice. Unless there are strong arguments why Alt.2 cannot be used it can be recommended to go with majority view i.e. Alt.2 or pick one of the alternatives after some online debate.

For the third main bullet on extension of UL-AOA assistance information to other positioning methods:

Supported: Qualcomm(?), Huawei, ZTE,

Not supported: OPPO (?), Samsung

Can be further discussed: vivo

It seems there is no clear consensus at this stage and common understanding. It is worthwhile to continue debate and see if more companies can express view or whether proponents can convince opponents. Just to clarify, the intention is to support UL-AOA assistance information at least for UL-TDOA and Multi-RTT.

For the last main bullet on discussion of signaling details in RAN2/3:

No comments received. It seems acceptable to the group (?)

### Proposals for Round #2

Based on above discussion, the revised proposal is provided:

**Proposal 2-2**

* Uncertainty range for expected AoA/ZoA is defined as follows
  + Expected azimuth angle of arrival as (φAOA - ΔφAOA/2, φAOA + ΔφAOA/2)
    - φAOA - expected azimuth angle of arrival, ΔφAOA – uncertainty range for expected azimuth angle of arrival
  + Expected zenith angle of arrival as (θAOA - ΔθAOA/2, θAOA + ΔθAOA/2)
    - θAOA - expected zenith angle of arrival, ΔθAOA – uncertainty range for expected zenith angle of arrival
* Select one of the following coordinate system alternatives for signaling AoA/ZoA assistance information
  + Alt.1: Only GCS is supported for AoA/ZoA assistance information indication
  + Alt.2: Both GCS and LCS are supported for AoA/ZoA assistance information indication
* FFS whether signaling of AoA/ZoA assistance information (expected value and uncertainty range) is supported for UL-TDOA and Multi-RTT positioning methods
  + Note: Signaling of AoA/ZoA assistance information does not limit gNB/TRP measurement behavior
* Other signalling details related to AoA/ZoA assistance information are discussed in RAN2/RAN3

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| Company Name | Comments |
| Nokia/NSB | Support. For the second bullet we support Alt 1. We don’t understand the advantage of Alt 2 but if all other companies prefer that Alternative we are okay with it too. |
| Ericsson | Support first bullet  Support alt1 in second bullet. Seems to be the simplest option.  Support fourth bullet in principle. However, we think we could have an FFS on procedure which should be addressed, for example regarding what the gnodeB should/could do when the window is not giving good results. We think RAN1 could provide guidance to RAN3 by agreeing on e.g. signalling of a correction window or an indicator to signal that the window was useful. |
| NTT DOCOMO | Support first, third and fourth bullets. Regarding second bullet, we have similar view with Nokia/NSB. |
| LG | We are generally fine with the proposal. For second main bullet, we think that the decision on which option is supported or not needs to be discussed at the next meeting. |
| Huawei/HiSilicon | OK with the proposal. |
| vivo | Support first bullet.  For the second bullet, support Alt.1. For Alt.2, LMF does not always have the LCS to GCS translation information, such as before gNB/TRP reporting AoA measurement results.  For the third bullet, considering the original proposal is to facilitate UL measurements of UL-AOA, we don’t think we should discuss this bullet here. |
| CATT | Okay with the 1st bullet.  For the second bullet, we prefer Alt.2. |
| OPPO | Ok with 1st bullet and  For 2nd bullet: we prefer Alt 2 |
| ZTE | OK with the proposal. We prefer Alt.1 in second bullet. |
| Intel | Support first bullet, Alt 2 for the second bullet |
| SONY | Support the proposal. For the 2nd bullet, we prefer ALT.2 |

### Proposals for Round #3

In order to progress discussion on this topic further after GTW call let’s discuss the following proposal and please also provide views on the question below:

**Proposal 2-3**

* Signaling of AoA/ZoA assistance information (expected value and uncertainty range) is also supported for UL-TDOA and Multi-RTT positioning methods

**Question 2-3**

* Please provide your views whether RAN1 needs to provide some guidance to other WGs in terms of functionality for AoA/ZoA assistance information or all other signalling/procedure details related to AoA/ZoA assistance information can be discussed directly in RAN2/RAN?

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| Company Name | Comments |
|  | Proposal 2-3  Question 2-3 |
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## Aspect #3: Reference UE for UL-AOA

The possibility to use reference UE to facilitate precise UL-AOA measurements and positioning was discussed by multiple companies:

* Support reporting of UL-AoA measurements from the reference node for AoA error calibration [CEWiT, [18]]
* LMF sends the expected angle of the reference device to gNB for TRP antenna-element wise calibration. [Huawei, [14]]
* Support reference UE with known antenna orientation in space and coordinate [Intel, [9]]
  + Reference UE can perform the Downlink Angle of Arrival (DL-AOA) measurements and report them to LMF [Intel, [9]]
    - Measured azimuth and zenith DL-AOA (*φi-UE*, *θi-UE*) between the *i*th gNB/TRP and a reference UE
* Support the reference UE to report DL positioning measurements associated with known position coordinates of each calibrated test point to LMF [CATT, [3]]

### Proposals for Round #1

**Proposal 3-1**

* Reference UE with known antenna orientation in space and coordinates is supported
  + Reference UE reports DL positioning measurements associated with known position coordinates of each calibrated test point to LMF
  + LMF sends the expected angle of the reference UE to gNB for TRP antenna-element wise calibration
  + Reference UE with known antenna orientation performs the Downlink Angle of Arrival (DL-AOA) measurements and reports them to LMF
    - Measured azimuth and zenith DL-AOA (*φi-UE*, *θi-UE*) between the *i*th gNB/TRP and a reference UE

Companies are invited to provide comments on above proposal

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| Company Name | Comments |
| Qualcomm | We generally agree having Reference **Devices** to help with UL-AoA calibration.   * We don’t see the need to limit to a “UE”. It can be a Mobile Terminal (MT), similar to IAB-MT, which is not a “UE” strictly speaking; it doesn’t need to have a subscription. A reference device might not be a “user”; a more appropriate terminology is MT. * Either way, this is related to RAN2/Ran3 architecture, so we prefer for now to say:   + Reference Location Devices with known location at least for the purpose of UL-AoA calibration is supported. * Why is the antenna orientation need to be known? This bullet is about UL-AoA and not DL-AoA which is not within scope.   FL: It was clarified in response from Intel – it facilitates more reliable LOS/NLOS link identification |
| CATT | We has the similar question as Qualcomm about the antenna orientation of the reference UE. We think the antenna orientation of the reference UE is useful only when the calibration depends on the UE’s orientation. However, after the calibration, the TRP needs to be able to estimates the UL-AOA of the UE without the knowledge of the UE antenna orientation. |
| Nokia/NSB | Okay in principle. Suggest to discuss all reference device proposals together. |
| InterDigital | We support the proposal in principle and fine to discuss altogether in the reference device discussion. |
| ZTE | Our general view is that reference device can be spec transparent. Our preference is that this topic should discussed in AI 8.5.1, then to see if it’s applicable to other positioning methods. |
| Huawei/HiSilicon | Support the second bullet.  We think that antenna element-wise calibration is also needed, given that the phase calibration requirement for MIMO cannot be used for positioning purposes.  In real deployment, the antenna spacing may deviate from its desired location, and the phase offset may also subject to chain calibration error.  For the first and the third bullets, we think that more study is needed.  In particular,   * For the first bullet, it is not clear what the relationship is between reference device location and its ARP. * For the third bullet, we think DL-AoA (and its uncertainty) can be helpful, but it does not have to be associated with the reference UE. |
| Intel | Support the concept of reference UE and OK to keep more general notion of a reference device. We think that the calibration with a reference device is essentially the LOS-centric solution. So, calibration should be performed for the LOS links only and NLOS links may introduce significant bias. Therefore, we think that it is worthwhile to report antenna orientation.  Support the first bullet and OK to study the second and third bullets. |
| Vivo | Firstly, for the main bullet, we need more clarifications for the meaning of reference UE with known antenna orientation in space. Based on the explanation from Intel, it is for the NLOS link, but for us, the meaning of the calibration NloS link is unclear, may be needed to be further clarification.  In addition, we have the same understanding with QC and CATT, and DL-AoA is not within scope. |
| OPPO | Similar view as other company, the reference UE can be spec-transparent. The system can just implement on terminal sending UL SRS signal with known positioning. |
| Sony | Reference UE with known coordinates is supported. Why we still need antenna orientation? Is this (antenna orientation) explicitly indicated?  We think this topic is low priority in this agenda item. |
| Samsung | We support the method of reference devices with known position in general, but the details can be FFS. |
| Futurewei | Not clear what is the specs supported needed for Reference UE? Clarification on this would be much appreciated so that we know what this proposal means in terms of next step from specifications perspective. |

### Tentative Conclusion

Based on discussion it seems quite many companies prefer to discuss all topics related to reference device in one agenda item 8.5.1 so it is recommended to move it to 8.5.1.

## Aspect #4: Timestamp & Multiple UL-AOA Values for the FAP

The following agreement was made by RAN WG1 with respect to reporting of multiple UL-AOA measurement values for the first arrival path.

|  |
| --- |
| * NR supports reporting of M > 1 UL-AOA (AoA/ZoA) measurement values by gNB to the LMF at least for the first arrival path * FFS: Supporting of UL-AOA measurements for additional paths * FFS: Supporting of N >= 1 UL-AOA values per path for additional paths * FFS: Whether the multiple values can correspond to the same time stamp * FFS: Further details of measurement and reporting * Note: The reporting by gNB to the LMF is optional |

The following proposals were provided:

* Support multiple UL-AOA values that correspond to the same time stamp [CATT, [3]]
* No need to restrict the multiple values corresponding to the same time stamp [CMCC, [6]]
* Multiple values of M can correspond to the same time stamp [Fraunhofer, [17]]
* Support reporting of multiple UL-AOA (AoA/ZoA) measurement values of multiple first paths [vivo, [2]]

### Proposals for Round #1

It is proposed to clarify that multiple UL-AOA values correspond to the same time stamp.

**Proposal 4-1**

* Reporting to LMF of M > 1 UL-AOA (AoA/ZoA) measurement values associated with the first arrival path and corresponding to the same timestamp is supported

Companies are invited to provide comments on above proposal

|  |  |
| --- | --- |
| Company Name | Comments |
| Qualcomm | Support |
| CATT | Support |
| Nokia/NSB | We can accept the proposal but would like to take it together with proposal 5-1.  FL: It seems majority is supportive, and we need to close FFS for the first arrival path. Let’s not complicate discussion by mixing topics |
| InterDigital | Support |
| ZTE | Support |
| Huawei/HiSilicon | Support. |
| Intel | Support |
| Fraunhofer | Support |
| vivo | Not Support  Sorry for that, just like our online comment, if we don’t know the multiple values is for what, it is unclear for us to agree on the proposal.  From our point of view, we discuss the issue because we don’t know whether the current NRPPa can support reporting measurement results from multiple resources/Rx beams/ paths. However, we think the proposal is not enough to help us to clarify the issue. At least, for us, we still have a question for the multiple values is for what.  According to my understanding, the multiple measurement values associated with the first arrival path and corresponding to the same timestamp only occurs in the following cases:   * Case 1 NLOS case * Case 2 ambiguity between frontside and backside directions * Case 3 ambiguity because of larger antenna spacing   In my opinion, for case 1, the discussion for this proposal should be postponed to RAN1#105e.  For case 2, we think it is easy to filter the wrong angle based on the expected AoA. And for case 3, whether the larger antenna spacing is a common deployment scenario may need to be further clarified.  FL: My understanding none of the cases is precluded. Please also see comments from CMCC and Huawei. |
| CMCC | Support.  A brief reply to vivo: To our understanding, Case 3 is a valid issue to be addressed by introducing multiple AoA values corresponding to the first arrival path. Considering the outdoor deployment, commonly two or three antenna elements are mapped to one TXRU in the vertical direction, where the antenna spacing in the vertical direction is actually larger than 1 wavelength and causes ZoA ambiguity. In addition, considering the indoor case, it was discussed in the last meeting that for the ULA antenna array, the antenna spacing may be larger than 1 wavelength, since the increasing of the antenna spacing brings reduction of the aperture of the antenna, and therefore, the measurement performance of the AoA will become more accurate. |
| OPPO | The wording in the proposal is confusing. We prefer to make it clear that those M >1 AoA measurements are estimated from different SRS resources. Otherwise, how can we estimate multiple different AoA from the first path of same SRS resource with the same time stamp.  **Proposal 4-1**   * Reporting to LMF of M > 1 UL-AOA (AoA/ZoA) measurement values associated with the first arrival path in different SRS resources and corresponding to the same timestamp is supported   FL: SRS resource aspect can be further discussed |
| Sony | Do not support.  We still consider the reporting to LMF can be 1 UL-AoA measurement with the standard deviation of M measurements. This will provide a compact report and it can still improve the accuracy as shown in our contribution [13].  FL: It seems there is some misunderstanding. We are not discussing quality of UL-AOA measurement but rather try to resolve ambiguity issue. Multiple UL-AOA were already agreed and now we discuss only timestamp aspect. |
| Huawei/HiSilicon | To vivo, we agree with CMCC that larger antenna spacing provides the opportunity to enhance location accuracy especially for indoor where the antenna size may not be the same as outdoor, which justifies a valid case.  To OPPO, we do not support adding “in different SRS resources” explicitly; actually it can be from the same SRS resource, and multiple angle reporting is due to angle ambiguity originated from larger antenna spacing. Although there may be some ambiguity, but the “beam width” is reduced, and it can provide an opportunity for the LMF to increase the accuracy as long as the false angle can be ruled out, e.g. showing below. We have shown the accuracy gain from 1-wavelength antenna spacing over half-wavelength antenna spacing in our contribution R1-2100237 in RAN1#104-e. |
| Samsung | Support. |
| LG | Support. |

### Tentative Conclusion

Based on majority view, it is recommended to take original proposal 4-1 for online discussion.

## Aspect #5: Additional Paths and Multiple UL-AoA Measurements

Some companies have expressed views that additional paths should be discussed in NLOS/multipath mitigation objective. The following aspects were identified with respect to support of multiple UL-AOA measurements in contributions:

* Support of multiple UL-AOA measurements for additional paths.
* Number of UL-AOA measurements per additional path *N*. Different views are expressed by companies
  + *N* = 1
  + *N* ≥ 1
* Additional measurements
  + Timing delay for additional paths (this is discussed under Aspect #6)
  + Per path RSRP for additional path (this is discussed under Aspect #6)

### Proposals for Round #1

**Proposal 5-1**

* Discuss and select one of the following alternatives for additional paths
  + Alt.1: UL-AOA measurement for additional paths is supported
  + Alt.2: UL-AOA measurement for additional paths is not supported
  + Alt.3: UL-AOA measurement for additional paths is discussed under NLOS/multipath mitigation objective starting from the next meeting

If companies prefer to discuss/support UL-AOA measurements for additional paths in this meeting, it is also worthwhile to provide comments on one of the options below:

* Select one option for reporting to LMF multiple UL-AOA values per additional path
  + Option 1: NR supports reporting to LMF of *N* = 1 UL-AOA measurement values per additional path for the same timestamp
  + Option 2: NR supports reporting to LMF of *N* ≥ 1 UL-AOA measurement values per additional path for the same timestamp
    - Note:
      * It is up to gNB implementation whether to report *N* UL-AOA measurement values for each additional path

Companies are invited to provide comments on above proposal

|  |  |
| --- | --- |
| Company Name | Comments |
| Qualcomm | 1st bullet: Alt. 1  2nd bullet: Option 2 |
| CATT | 1st bullet: Alt. 1  2nd bullet: Option 1. Having N ≥ 1 UL-AOA measurement values per additional path seems to be over complicated. It will be difficult for LMF to use the information effectively. |
| Nokia/NSB | 1st bullet Alt. 1  2nd bullet: Option 1. Same view as CATT. How can the LMF use this information? |
| InterDigital | 1st bullet Alt. 1  2nd bullet” Option 1. Same view as CATT and Nokia. Setting N=1 for additional paths seems to be sufficient. |
| ZTE | First main bullet: Alt.1  Second main bullet: Option1. |
| Intel | Support Alt. 3. |
| Fraunhofer | Alt.3. |
| vivo | We support Alt.3 for the 1st bullet. |
| C*MCC* | For the 1st bullet, support Option 1. We are also fine to take Option 3, and further discuss it under the NLOS/multipath sub agenda. |
| OPPO | 1st bullet: Alt1  2nd bullet: Option 2. |
| Sony | Support Alt. 3 |
| SS | We support Alt 3, and additional paths for UL-AoA can be discussed under NLOS mitigation objective. |
| Futurewei | Support Alt 3 |

Based on received comments so far, the following is observed:

* Support Alt. 1: Qualcomm, CMCC, InterDigital, OPPO, ZTE, Nokia, CATT
* Support Alt. 3: Intel, Fraunhofer, Sony, vivo, Samsung, Futurewei

It seems there is no clear majority to discuss Alt.1 at this meeting.

Regarding options for Alternative:

* Support Option 1: CATT, Nokia, InterDigital, ZTE, CMCC
* Support Option 2: Qualcomm, OPPO

Based on expressed views it seems more discussion is needed on how to handle UL-AOA measurements for additional path including alternative to proceed and option on multiple UL-AOA values for additional paths.

### Proposals for Round #2

It seems useful to have more discussion to see if group can converge on multiple UL-AOA values for additional paths. Companies are invited to provide comments on proposal 5-2:

**Proposal 5-2**

* Discuss and select one of the following alternatives for additional paths
  + Alt.1: UL-AOA measurement for additional paths is supported
    - Select one of the following options
      * Option 1: NR supports reporting to LMF of *N* = 1 UL-AOA measurement values per additional path for the same timestamp
      * Option 2: NR supports reporting to LMF of *N* ≥ 1 UL-AOA measurement values per additional path for the same timestamp
  + Alt.2: UL-AOA measurement for additional paths is discussed under NLOS/multipath mitigation objective starting from the next meeting

|  |  |
| --- | --- |
| Company Name | Comments |
| Nokia/NSB | No company has so far provided a reply to our technical concern that this feature for N>1 is useful. We can only accept Option 1. |
| Ericsson | We support alt1 and option 2. |
| LG | Support. |
| Huawei/HiSilicon | Support Alt.1.  Under Alt.1 we believe Option 2 is aligned with the intention that multiple AoA measurement for the first path is introduced in the first place (to reduce angle ambiguity due to large antenna spacing), and align the additional path to the first path is our preference. |
| vivo | We support Alt.2. Reporting the measurements of additional paths seems a general issue for multipath/NLOS mitigation. So we prefer to discuss it in multipath/NLOS mitigation. |
| CATT | We support Alt.1 Option 1. |
| Qualcomm | Alt. 1. Option 2  To **Nokia**: We have provided results that show explicitly **that one can get gains by enabling N>1 for additional paths:**  To explore how such a reporting could be useful, we employ a Machine-Learning-type RTT+AoA framework which exploits such Angle/delay/Power information. We model the RTT-AoA distribution and train the neural network to extract features of the 2D channel to derive likelihood for performing likelihood fusion across measurements from different cells. For example, in the figure shown below, we plot a Power/Delay/Angle Heatmap of one of the channels. From such a heatmap it is clear that there is a lot of information that can be extracted, and reporting to the location entity multiple AoA and timing measurements would be helpful in advanced fusing algorithms.    Using the procedure described above, for the scenario of UMI 4 GHz case (with absolute time of arrival modelled), significant gains are expected when a TRP can report multiple AoAs and, for each AOA, multiple Timing measurements and their corresponding relative powers, to the LMF. Specifically, at the 90% percentile of error, NR Rel-16 reporting (single delay & single Angle) results into more the 12 meters, whereas reporting single delay with multiple Angles results into a 8.9m of error. Enabling the reporting of multiple delays and multiple angles (e.g., 8 delays with up to 8 angles per delay), it reduces the 8.9m down to 7.3m (1.6m of gain) at the 90%, and at the 80% percentile, the 4.7m is reduced down to around 4 meters. |
| Futurewei | Support Alt 1 – Option 2 |
| OPPO | Support Alt1 and Option 2 |
| ZTE | We slightly prefer Option 1, it’s might be hard for gNB to extract multiple UL-AOA for additional path since it may need high-resolution algorithm. |
| Intel | Support Alt 2 |
| LG-2 | To represent our view, we prefer Alt1 and option 2. |
| SONY | This is strongly related to Multipath/NLOS mitigation. We support ALT.2 |

## Aspect #6: UL-AOA Reporting Enhancements

The following aspects were discussed with respect to UL-AOA measurements and reporting enhancements:

* Identification of SRS resource and report of SRS resource ID with UL-AOA measurements [vivo, [2]], [Sony, [13]] (with RSRP), [OPPO, [1]]
* Support of RSRP and RTOA measurements for additional paths [OPPO,[1]], [LGE, [16]] (at least RSRP), [CEWiT, [18]] (TOA), [Qualcomm, [11]] (RSRP, RTOA, AOA tuple in single report)
* UL-SRS-RSRP is measured within a time window and relative power of the FAP [Apple, [10]]
* Reporting of statistical property (standard deviation) for UL-AOA measurements [Sony, [13]]

### Proposals for Round #1

Based on contribution, it is suggested to discuss the following proposal:

**Proposal 6-1**

* For UL-AOA positioning, select alternative for NR support of path-specific RSRP measurements based on SRS (for positioning, MIMO)
  + Alt.1: NR supports reporting of path specific RSRP measurements for the first arrival path only
  + Alt.2: NR supports reporting of path specific RSRP measurements for the first arrival path and for additional paths
  + Alt.3: NR supports reporting of RSRP measurements in a pre-configured time window
    - Power of paths outside of the window is excluded. FFS details of time window configuration
  + FFS how/whether path specific RSRP measurements are supported per SRS resource or SRS resource set (for positioning, MIMO)
* For UL-AOA positioning, select alternative for support of path-specific UL-RTOA measurements based on SRS (for positioning, MIMO)
  + Alt.1: NR supports reporting of path specific UL-RTOA measurements for the first arrival path only
    - Note: UL-RTOA for the first arrival path is supported for UL-TDOA (it is discussed in the context of UL-AOA)
  + Alt.2: NR supports reporting of path specific UL-RTOA measurements for the first arrival path and for additional paths
  + FFS how/whether path specific RTOA measurements are supported per SRS resource or SRS resource set (for positioning or MIMO)

**Observation 6-1 (Feature lead observation):**

Currently the above enhancements are discussed in the context of UL-AOA positioning enhancements, however similar (symmetrical) enhancements can be supported for UL-TDOA (e.g. path specific AOA and RSRP measurements per first arrival path or additional paths). It needs to be better clarified whether

1. Option 1: Enhancements are limited to UL-AOA positioning (i.e. only UL-AOA is enhanced with new measurements)
2. Option 2: New positioning method is to be introduced (i.e. hybrid AOA/RTOA/RSRP method)
3. Option 3: Similar enhancements are to be introduced to UL-TDOA/multi-RTT (i.e. other positioning methods UL-TDOA and multi-RTT will have similar enhancements)

Companies are invited to provide comments on initial proposal and feature lead observation:

|  |  |
| --- | --- |
| Company Name | Comments |
| Qualcomm | FL Proposal: There are 2 bullets and both have Alt.1 and Alt. 2 as options. Suggest to make it more clear to avoid confusion.   * 1st bullet: Support Alt. 2 and Alt. 3. These 2 alternatives are not really exclusive. We see Alt. 3 as an optimization over Alt. 2. * 2nd bullet: Alt. 2 which should be applied for gNB-Rx-Tx measurement also.   FL Observation: Option 3. The enhancement should be for all methods. |
| CATT | For the 1st main bullet on path-specific RSRP measurements:   * Alt.1 and Alt.2: it is unclear to us how TRP is able to separate accurately the RSRP of the 1st path and RSRP from the other paths, especially when the TOAs of the 1st path and other paths are within a few ns. * For Alt.3, it is also unclear to us how the time window is pre-configured to exclude other paths. Again, consider that the TOAs of the 1st path and other paths can be within a few ns.   For the 2nd main bullet on path-specific RTOA measurements: we support Alt. 2. |
| Nokia/NSB | We think we need some clarification on what path specific RSRP means. This is a new measurement that we will introduce into 38.215?  In general we are supportive of allowing the TRP to report multiple UL-AoA, RTOA pairs. |
| ZTE | 1st main bullet: We don’t think path-specific RSRP can really help to improve positioning accuracy.  2nd main bullet: although we think timing information may be helpful. However, this is already supported for UL-TDOA method. What we need to discuss is whether to support hybrid positioning (e.g. UL-TDOA and UL-AOA) rather than introduce new measurement in UL-AOA. |
| Intel | We do not think that the RSRP reporting per path can provide significant performance improvement, so propose to further study the benefits of this solution. |
| vivo | For the first main bullet:   * We would like clarification for how path-specific RSRP and path-specific UL-RTOA can help for AoA positioning. From the point of our view, path-specific RSRP and UL-RTOA are used for path selection or LOS identification, which should be discussed in multipath/NLOS mitigation.   For the second main bullet:   * We also found the same issue is discussed on different topics, and some companies propose to introduce more measurement value in one method, such as enhancing the AoA based on timing information and RSRP. But, if in each positioning method, the UE measures and reports all the information, what are the differences between these positioning methods? Maybe we need double thinking. |
| OPPO | For Proposal 6-1: we support Alt2 in both bullet.  For observation: Option 2 is preferred. |
| Sony | On FL Proposal: We prefer Alt.1 for both path-specified RSRP and UL-RTOA. We don’t think there is a benefit from reporting additional path.  On FL Observation: Option 3 |
| Samsung | For proposal,   * 1st bullet, support Alt 1 * 2nd bullet, support Alt 2   For observation, we support Option 1. |
| LG | For the first main bullet, we think more clarified description for path-specific RSRP should be added since the RSRP in here is not matched with the definition in the current specification 38.215. |

Regarding the 1st main bullet on path specific RSRP

* Support for Alt.1: Sony, Samsung
* Support for Alt.2: Qualcomm, OPPO
* Support for Alt.3: Qualcomm
* Clarification is needed on path specific RSRP: vivo, CATT, Nokia, LGE
* Not supported: Intel (for additional paths), ZTE

Regarding the 2nd main bullet on path specific RTOA

* Alt.1: Sony
* Alt.2: Qualcomm, CATT, Nokia, OPPO, Samsung

Regarding the FL observation

* Option 1:
* Option 2: OPPO
* Option 3: Qualcomm, Sony

It seems views are quite diverse, and more discussion is needed to converge on initial proposal. It seems initial proposal may need to be further divided into multiple parts for further discussion.

### Proposals for Round #2

Considering that views are quite diverse, it seems useful to have more discussion to establish common understanding within a group on benefits of various approaches. In order to facilitate future discussion, it is proposed to exchange additional views on the raised by companies questions.

* Q1: What is the definition of path-specific RSRP measurements and whether additional spec change is needed?
* Q2: What are the benefits of path-specific RSRP measurements for additional paths?
* Q3: What are the benefits of path-specific RTOA measurements for additional paths?
* Q4: Do you agree that path-specific RTOA measurements for first arrival path is already supported?
* Q5: What is the motivation to introduce symmetrical enhancements in terms of path-specific AOA, RTOA, RSRP to UL-AOA, UL-RTOA, Multi-RTT positioning methods vs defining new hybrid positioning method?

Companies are encouraged to exchange views on the above questions to facilitate further discussion and group decision:

|  |  |
| --- | --- |
| Company Name | Comments |
| vivo | For Q4, if for UL-AoA, we think path-specific measurements for first arrival path is not supported.  But if for UL-TDOA, we think it is supported. **9.2.39 UL RTOA Measurement** This information element contains the uplink RTOA measurement.   |  |  |  |  |  | | --- | --- | --- | --- | --- | | IE/Group Name | Presence | Range | IE Type and Reference | Semantics Description | | CHOICE *UL RTOA Measurement* | M |  |  |  | | >k0 | M |  | INTEGER (0.. 1970049) | TS 38.133 [16] | | >k1 | M |  | INTEGER (0.. 985025) | TS 38.133 [16] | | >k2 | M |  | INTEGER (0.. 492513) | TS 38.133 [16] | | >k3 | M |  | INTEGER (0.. 246257) | TS 38.133 [16] | | >k4 | M |  | INTEGER (0.. 123129) | TS 38.133 [16] | | >k5 | M |  | INTEGER (0.. 61565) | TS 38.133 [16] | | Additional Path List | O |  | 9.2.41 |  | |
| CATT | For Q1: Our understanding is that RSRP for a signal is defined as the signal power contributions of the resource elements that carry the signals and measured within the considered frequency bandwidth and time windows as defined in TS 38.215. However, It is unclear for us where and how path-specific RSRP is defined. Maybe the proponent of path-specific RSRP can explain how it can be reliably measured and the performance can tested when the same signal from different paths are overlapping together with the very small delay difference of a few ns. |
| Nokia/NSB | Q3: Path-specific RTOA is already support for UL-TDOA this would just enable the TRP to report these path-specific UL-AoA values together with the RTOA values for at least UL-AoA method.  Q4: Yes for UL-TDOA it is.  Q5: Typically 3GPP has left hybrid methods to implementation and we don’t see strong benefit to changing this approach now. Why not just allow the path specific reports to be made in both UL-TDOA and UL-AoA? Then it can be handled by implementation. |
| Qualcomm | Q1: In our understanding per-path RSRP corresponds to the following: a TRP receives an SRS and transforms the received signal in the delay domain where multiple peaks in the Channel Energy Response are observed. The strongest peak can be set to a “0” value, the rest to negative values. The TRP provides those relative absolute values, aka a discretized Power delay profile  Q2/Q3: Advanced processing can be used, include ML-type of solutions, as we shown in our paper. In our paper, we compared the scenario of having, for the earliest path one or multiple AoAs, and having, for multiple paths one or multiple AoAs. Gains are observed when allowing ful flexibility of the TRP to report “tuples” (RTOA/Rx-Tx, AoA, RSRP) compared to the case of just reporting the AoA and RSRP only for the earliest path.  Q4:There is additional path list for UL-TDOA, but no report of the correpson AoA of that path, no relateive RSRP. We support extending the additional path report for all methods, and also provide the option to the TRP to report which is the associated AoA and relative RSRP.  Q5: This goes back to a Rel-16 discussion and the decision has been made. We prefer compartmentalized solutions for easier tracking of the features, any capabilities, procedures, and enhancements as features are added across multiple releases. |
| Futurewei | Q1: Additional spec changes are needed since current specs on RSRP is not path specific.  Q4: Strictly speaking no, in our view. At least in 38.215 for UL-TDOA is not defined to be path specific |
| OPPO | Q1,Q2 and Q3: reporting the RTOA, AoA and RSRP per path can provide more information to the LMF so that the LMF can combine those information for better positioning calculation.  Q4: we only have the UL RTOA for the additional path but there is corresponding AoA measurement, RSRP measurement for the additional path. In our view, combining those multiple types of measurement per path can provide more useful information to the LMF.  Q5: In essence, they are same as long as the same measurement results are provided to the LMF. |
| ZTE | * Q1: In our understanding, the path-specific RSRP is the power/amplitude of path in delay domain. Each path may correspond to a tap in delay domain, which may include multiple taps. * Q2/Q3: What are the benefits of path-specific RSRP measurements for additional paths?   As mentioned by other companies, the information may be used for ML. For us, timing information is more important than path-specific RSRP, which may be beneficial for both traditional timing based methods and ML.   * Q4/Q5: Yes. This is already supported for UL-TDOA method. What we need to discuss is whether to support hybrid positioning (e.g. UL-TDOA and UL-AOA) rather than introduce new measurement in UL-AOA. |
| SONY | Q1: About the definition of the path-specific RSRP,  In our opinion, the path-specific RSRP is the power of path in delay/angular domain. The TRP receives the SRS signals at different antenna elements and converts the analog signals to a normalized power delay/angular profile (PDP), which is an estimate of the real delay/angular domain. Each peak in the PDP can be regarded as one of the transmission paths from UE to TRP. Yes, we consider spec change is needed.  Q2/Q3: About the benefit of using path-specfic RSRP/RTOA,  Compared with the legacy RSRP, the path-specific RSRP is more accurate in reflecting the quality of each path. The legacy RSRP is the average of all of the path-specific RSRP values within a specific time window, which only provides the statistical property of the channel paths. By having path-specific information (i.e., path-specific RSRP and RTOA), the LMF can have a better understanding of the channel and thereby more accurate to identify the LOS path.  Q4: Yes |

## Aspect #7: Expected AoD

In [Nokia, [7]], it is proposed to introduce an expectedAoD parameter to assist SRS configuration and UE transmission of SRS for positioning. This parameter could be signaled between the LMF and TRPs (e.g., using NRPPa) or LMF and UE (e.g., using LPP).

### Proposals for Round #1

To facilitate further discussion companies are invited to provide views on whether expectedAoD parameter to assist SRS configuration and UE transmission of SRS for positioning should be supported.

|  |  |
| --- | --- |
| Company Name | Comments |
| Qualcomm | We don’t think UL-AoD is within scope of this release (UE’s UL Tx Angle). |
| CATT | DL AOD is calculated in LMF. It seems no need for the LMF to send expectedAoD to gNB. However, we support UE to send the DL beam information to LMF to help LMF in the estimation of the AOD. |
| Nokia/NSB | We think that knowing an expectedAoD at the UE can be helpful for SRS configuration and improving positioning and support it. |
| ZTE | This should be discussed in DL-AOD agenda. |
| vivo | Agree with QC and ZTE. |
| OPPO | It seems DL-AoD is out of the scope of this AI. |
| Sony | Same view as ZTE. This should be applicable to DL-AoD. |
| Samsung | Not support. |
| LG | we think some companies misunderstands the intentantion because of the name ‘Expected AoD’. In our understanding, it want to say beam adjustment way to assist UE Tx beam refinement. If it is right, we support the proposal. |

The following views are expressed:

* Support: Nokia
* Out of scope: Qualcomm, vivo
* Scope of DL-AOD agenda: ZTE, vivo, OPPO, Sony
* Not support: Samsung

Based on current status of discussion it seems more efforts and time is needed to convince companies on the relevance of the proposal to this AI and work item scope.

### Tentative Conclusion

Based on discussion, it may be recommended to proponent to further explain relevance of the proposal to this AI and work item scope and come back at the next meeting.

## Aspect #8: LOS/NLOS Identification

The importance of LOS/NLOS indication for NR Positioning and especially UL-AOA positioning was mentioned in several contributions. The views on reporting soft values and use of polarization to assist LOS/NLOS identification were expressed in [Futurewei, [5]].

Based on FL understanding, the LOS/NLOS identification is equally important for timing and angle-based positioning techniques and thus it is expected to be discussed in agenda item on NLOS/multipath mitigation starting from the next meeting.

### Proposals for Round #1

Considering, the LOS/NLOS identification is equally important for timing and angle-based positioning techniques it can be recommended to discuss it under the NLOS/multipath mitigation agenda.

**Proposal 8-1**

* Discuss LOS/NLOS identification under objective of NLOS/multipath mitigation for all positioning methods

Companies are invited to express views on above proposal:

|  |  |
| --- | --- |
| Company Name | Comments |
| ZTE | Agree with FL’s proposal. |
| Futurewei | We are fine with FL proposal as well. |
| LG | Agree. |
|  |  |
|  |  |
|  |  |

### Tentative Conclusion

Continue discussion at the next meeting under NLOS/multipath mitigation agenda item.

## Aspect #9: Velocity for UL-AOA Measurements

In [Ericsson, [19]], it is proposed that for estimating AoA at TRPs, velocity of the UE should be reported to the network.

### Proposals for Round #1

It needs to be better understood, whether UE is expected to report velocity vector or gNB measurements are expected to be done to estimate UE velocity.

Companies are invited to express views on above aspect:

|  |  |
| --- | --- |
| Company Name | Comments |
| Ericsson | Our proposal is for the UE to report a velocity vector, which can in turn forwarded to the gnodeB to assis AoA computation. The velocity vector can be computed by the UE when it is tracking its own trajectory. gnodeB can in turn use the velocity vector to compute more accurate AoA. |
| Huawei/HiSilicon | We think that this needs further discussion. The vector reporting will require UE to figure out the bearing. |
| Fraunhofer | The UE can already report LPP-MotionInformation to the LMF which includes displacement infromation. The TRP might need then to report additional information such as phase measurements to enable such AoA estimates at the LMF. |
| CATT | In our view, velocity information is helpful for TRP to obtain the UL-AOA Measurements, especially for high-speed scenarios. Our question is what is the assumption for UE to obtain the velocity information. If UE can obtain velocity information from GNSS, the location of the UE may also be known. |
| ZTE | Not sure how UE can acquire velocity vector in a coordinate system that has common understanding among UE and network. |
|  |  |

## Aspect #10: Multi-port SRS for Positioning

In [Fraunhofer, [5]], it is proposed to enhance SRS for positioning and introduce support of simultaneous SRS transmission for positioning over multiple ports. It is also noted that there is no impact to RAN1 specifications, and that proposal can be enabled with RRC changes only.

### Proposals for Round #1

Multi-port SRS for positioning can be applicable for any positioning methods and thus should be discussed from general perspective (i.e. w/o focus on UL AOA – which is the main objective of this agenda).

Companies are invited to provide views on support of multi-port SRS for positioning:

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| --- | --- |
| Company Name | Comments |
| Fraunhofer | Support |
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## Aspect #11: UE TX Beam Refinement

In [LGE, [16]], it is proposed to provide additional information for UE TX beam refinement, either:

* Location of both TRPs and UE
* TRP ID and UE location

### Proposals for Round #1

In general, UE TX beam alignment can be supported through spatial relationship of SRS for positioning resource. The need for additional information was not discussed so far.

Companies are invited to provide views on LMF signaling to facilitate UE TX beam alignment: 1) location of both TRPs and UE or 2) TRP ID and UE location

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| --- | --- |
| Company Name | Comments |
| LG | To improve performance of angle based measurement, we think that beam alignment between TRP and UE is important and we believe that it can be helpful if additional information is provided for UE to adjust its Tx beam. |
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## Aspect #12: Beamforming and UL AOA Estimation

In [Nokia, [7]], it is proposed to study beam interpolation based AoA estimation method based on UL-RSRP measurements (accurate and effective AoA measurement methods based on UL-RSRP).

In [Samsung, [12]], it is proposed to support differential beamforming technique for UL-AOA positioning methods.

### Proposals for Round #1

To facilitate further discussion/decision by the group, companies are invited to provide views/feedback on beam interpolation based AoA estimation and differential beamforming.

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| Company Name | Comments |
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## Aspect #13: Antenna Reference Points

In [ZTE, [4]], it is mentioned that at least in the following cases, current specification doesn’t support gNB/TRP to report ARP information of UL measurement results:

* Measurement Beam Information is not requested by LMF. However, the gNB/TRP still expects to report measurement results from multiple ARPs.
* The gNB/TRP only supports UL based positioning, so that there is no DL PRS resources configured.
* The gNB/TRP is a reception point (RP) attached with multiple ARPs, where the RP only supports UL reception.

In contribution it is proposed that Rel-17 should be able to report UL-AOA measurement results being associated with ARP information (e.g. ARP ID and corresponding geographical coordinate).

### Proposals for Round #1

To facilitate further discussion/decision by the group, companies are invited to provide views/feedback on association of UL measurements with ARP ID / corresponding geographical coordinate.

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| Company Name | Comments |
| ZTE | As we discussed in our tDoc, if the TRP deploys with multiple ARPs, it would be good to utilize such configuration to improve positioning accuracy. Therefore, we propose a general proposal,  *Rel-17 should be able to report UL-AOA measurement results being associated with ARP (Antenna Reference Point) information*  *FFS: procedures and signallings to support above enhancement.* |
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## Aspect #14: SRS for Positioning Power Control

In [Samsung, [12]], it is proposed to consider power control enhancement for SRS-pos to improve UL-AOA based solution. It needs to be clarified which enhancement is considered by proponent.

### Proposals for Round #1

Companies are invited to provide views on SRS power control enhancements for UL-AOA solution:

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| Company Name | Comments |
| ZTE | Out of the scope of this agenda. |
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Conclusion

In this contribution, we provided review of the submitted contributions for NR Positioning UL-AOA enhancements and prepared initial set of proposals as well as intermediate status of discussion to facilitate further decisions by RAN WG1 during the RAN1#104bis–e meeting.

References

1. R1-2102400 Enhancements for UL AoA Positioning OPPO
2. R1-2102527 Discussion on potential enhancements for UL-AoA method vivo
3. R1-2102636 Discussion on accuracy improvements for UL-AoA positioning solutions CATT
4. R1-2102669 Accuracy improvement for UL-AoA positioning solutions ZTE
5. R1-2102784 Accuracy Improvement of UL-AoA Positioning FUTUREWEI
6. R1-2102887 Discussion on UL-AoA enhancements CMCC
7. R1-2103003 Views on enhancing UL AoA Nokia, Nokia Shanghai Bell
8. R1-2103006 Discussion on UL-AoA positioning solutions InterDigital, Inc.
9. R1-2103036 Enhancements of UL-AoA positioning solution Intel Corporation
10. R1-2103110 Accuracy enhancements for UL-AoA positioning technique Apple
11. R1-2103171 Potential Enhancements on UL-AOA positioning Qualcomm Incorporated
12. R1-2103244 Accuracy improvements for UL-AoA positioning solutions Samsung
13. R1-2103307 Discussion on accuracy improvements for UL-AoA positioning method Sony
14. R1-2103400 Enhancement for UL AoA positioning Huawei, HiSilicon
15. R1-2103581 Discussion on UL-AoA positioning enhancements NTT DOCOMO, INC.
16. R1-2103622 Discussion on accuracy improvement for UL-AoA positioning LG Electronics
17. R1-2103683 UL-AoA positioning enhancements Fraunhofer IIS, Fraunhofer HHI
18. R1-2103684 Discussion on potential enhancements for UL AoA positioning CEWiT, IITM, IITH
19. R1-2103736 Enhancements of UL-AoA positioning solutions Ericsson