**3GPP TSG RAN WG1 Meeting #104-E R1-2101860**

**e-Meeting, January 25th – February 5th, 2021**

**Source: Moderator (Intel Corporation)**

**Title: Feature Lead Summary #2 for NR Positioning UL-AoA Enhancements**

**Agenda item: 8.5.2**

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

# Introduction

In this document, we provide summary of contributions [1]-[19]submitted for the AI 8.5.2 on enhancements for UL-AOA positioning method as a part of the Rel.17 NR Positioning Enhancements work item. In addition, we provide initial set of proposals for RAN WG1 discussions/decisions at the RAN1#104E meeting.

# Summary of Proposed Enhancements

In this section, we provide summary of the major topics that have been identified based on review of the submitted contributions:

* Reporting and measurements enhancements for UL-AOA NR Positioning
	+ [OPPO, [1]], [Huawei, [2]], [ZTE, [3]], [CATT, [4]], [vivo, [5]], [Futurewei, [6]], [InterDigital, [11]], [Sony, [12]], [CMCC, [13]], [Qualcomm, [17]], [DOCOMO, [18]], [[Ericsson, [19]]](#_Toc61904130)
* Support of different antenna array configurations (e.g. ULA, different antenna spacing)
	+ [Huawei, [2]], [vivo, [5]], [Futurewei, [6]], [Intel, [9]], [Ericsson, [19]]
* Calibration of gNB angle error and reference UE
	+ [Huawei, [2]], [vivo, [5] - FFS], [CATT, [4], [BUPT,[7]]
* LOS/NLOS identification for UL-AOA measurements
	+ [OPPO, [1]] (by implementation), [CATT, [4]], [Futurewei, [6]], [Intel, [9]]
* Assistance signaling for UL-AOA measurements (LMF assistance to gNB)
	+ [CATT, [4]], [Nokia, [8]]
* SRS physical structure enhancements (sequence, RE mapping, multi-port SRS)
	+ [LGE, [10]], [Fraunhofer, [14]]
* Power control enhancements of SRS for positioning
	+ LGE, [10]], [Samsung, [15]]
* gNB/UE beamforming related aspects
	+ [Nokia, [8]], [Samsung, [15]]
* SRS for positioning transmission priority
	+ [InterDigital, [11]]
* Enhancements for UE timing advance
	+ LGE, [10]]
* DL PRS-RSRP measurements enhancements
	+ [Apple, [16]]

# Discussion on Proposed Enhancements

## Reporting and measurements enhancements

There are a lot of various proposals for gNB reporting and measurements enhancements as listed below:

* Study implementation based solution vs reporting of multiple AOA, associated UL-RTOA, associated SRS-RSRP [OPPO, [1]]
	+ Motivation:
		- Improve the performance of UL AOA
* Per path UL AOA measurements/reporting [Huawei, [2]]
	+ Motivation:
		- Positioning via reflections and spatial consistency checks
* Additional beam information reporting [ZTE, [3]] (e.g. antenna layout, beam width, beam vectors and corresponding gains etc.)
	+ Motivation:
		- LMF can search for a right direction in an angle range, handling of sidelobes
* AOA & RTOA measurements associated to multi-paths to LMF for AOA positioning [CATT, [4]]
	+ Motivation:
		- Discriminate AOA measurements corresponding to the LOS path from AOA measurements corresponding to the NLOS path
		- Use of advanced algorithms potentially to achieve a higher positioning accuracy
* Additional angle information of multiple paths [vivo, [5]] (RSRP, timing information per each angle)
	+ Motivation:
		- Helps LMF to decide which angle is better for accurate positioning
* Detailed Tx/Rx beam information [Futurewei, [6]]
	+ Motivation:
		- LMF to decide which angle is better for accurate positioning
* Reporting of UE orientation information from the UE [InterDigital, [11]
	+ Motivation:
		- Network may be able to determine angle of transmission of SRSp depending on the UE orientation information and configured SRSp resource set and resource ID
* Uncertainty of the AOA and SRS Resource ID [Sony, [12]]
	+ Motivation:
		- Helps to filter out some unreliable AOA measurements
		- Filter out undesired report from certain gNB
* Multiple UL AOA with associated ToA measurements [CMCC, [13]]
	+ Motivation:
* Report multiple tuples (UL-AOA, UL-RSRP, RTOA/gNB Rx-Tx) within a single report [Qualcomm, [17]]
	+ Motivation:
		- Helpful in advanced fusing algorithms
* Reporting multiple UL-AOAs w/ timing measurements [DOCOMO, [18]]
	+ Motivation:
		- Single UL-AOA reporting may be insufficient to achieve a certain positioning accuracy for especially for NLOS
* Velocity of the UE should be reported to the network [Ericsson, [19]]
	+ Motivation:
		- For estimation of AOA at TRPs

### Round – 1 (Closed)

**Proposal 1-1**

* NR supports combination of {UL-AOA, UL-RTOA or gNB Rx-Tx time difference, UL-RSRP} gNB/TRP measurements defined per channel path
	+ FFS reporting details etc.

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| Company Name | Comments |
| CATT | Are we planning to introduce new “per channel path” definition of UL-AOA, UL-RTOA or gNB Rx-Tx time difference, UL-RSRP measurements? If not, suggest make the following wording change “NR supports combination of {UL-AOA, UL-RTOA or gNB Rx-Tx time difference, UL-RSRP} gNB/TRP measurements per channel path” |
| Qualcomm | Support |
| Nokia/NSB | Two questions for clarification: 1) is the intention that these measurement combinations would be mandatory or optional for different positioning techniques? E.g., does UL-TDOA now require UL-RSRP and UL-AoA to be reported by TRP? 2) Is the decision to report on multiple channel paths left to the measuring TRP, similar to additional path reporting for RSTD? Or is it configured by LMF and required?  |
| Fraunhofer | Do not support.We do not see an improvement in terms of accuracy for the UL-AoA method by the above proposal. The additional reporting, depending on the “per channel definition”, is already supported in NRPPa.  |
| ZTE | Not support. This proposal is unclear to us.1. Is the combination means different positioning methods defined in Rel-16? In our understanding, this is already supported by implementation.
2. What does “per channel path” means? Is it similar to additional paths defined in Rel-16?
 |
| China Telecom | This proposal may need further clarified.In our understanding, the motivation of this proposal is to provide more information of other beams or paths, so that the estimation of UL-AOA accuracy can be improved. What does the ‘combination’ and ‘per channel path’ mean is not clear for us, which may need be further clarified.  |
| vivo | Firstly, same view as Nokia, it needs to be clarified whether the enhancement is for AoA only or for other methods too (such as TDOA, RTT).Secondly, ‘per channel path’ reporting is for the first path only or for multiple paths?In the last, if the proposal is for reporting multiple path or additional path, we propose to discuss it along with the discussion of multipath mitigation in WID. |
| Huawei/HiSilicon | Support. |
| InterDigital | We support the FL’s proposal. |
| CMCC | In our views, this proposal intends to support multiple UL-AoA measurements of multiple paths reporting associated with corresponding timing and RSRP information. If the understanding is correct, then we support this proposal. |
| Intel  | Do not support. At this stage, we are OK to support the UL-AOA reporting per channel path only.We believe that this proposal is not a pure UL-AOA proposal and it requires discussion along with the multipath reporting. Therefore, we think that the rest of metrics, including the {UL-RTOA, gNB Rx-Tx, UL-RSRP} can be discussed when NLOS/multipath mitigation is in the WID scope. |
| Apple | If the intention is to have UL measurements and reports associated to path then it is OK but the current version of proposal as of now is too broad. Needs further details/clarifications. |
| Sony | We need for discussion / clarification, particularly we share Intel’s view that this type of enhancements may not only be applicable to UL-AoA. This can be discussed further when NLOS/Multipath mitigation is in WID.We would need firstly to agree (or not) whether to support gNB reporting and measurements enhancements. FFS the details. |
| Ericsson | By implementation, first-path based AOA reports can be sent to the LMF already in rel16. It is unclear to us what could be gain by specifying the new measurements proposed.  |
| DOCOMO | OK to support, however, some clarifications may be needed. |
| Samsung  | It seems the key part of the proposal is to make the report to be path-specific, then a “path index” type of thing will be needed? so that LMF can identify the report values is useful or not?  |
| LG | Combination of {UL-AOA, UL-RTOA or gNB Rx-Tx time difference, UL-RSRP} gNB/TRP measurements is ambiguous to us. It seems to support hybrid technique, which might not be the original intention. In addition, as other companies said, it seems necessary to define “per channel definition” more clearly. |
| OPPO | Support in principle.One question is what is “channel path”. Does it mean the path in a multi-path channel or per SRS resource for positioning?**Proposal 1-1*** NR supports combination of {UL-AOA, UL-RTOA or gNB Rx-Tx time difference, UL-RSRP} gNB/TRP measurements defined per ~~channel path per~~ SRS resource~~.~~
	+ FFS reporting details etc.
 |

### Round – 2

Based on provided comments, it seems the following observations can be drawn:

* 6 companies either **do not support Proposal 1-1** or prefer not to discuss it this meeting as WID objectives are not finalized yet (Fraunhofer, ZTE, Intel, Sony, Ericsson, LGE)
* 3 companies **support** the Proposal 1-1 (Qualcomm, InterDigital, Huawei)
* 10 companies request for further clarification:
	+ Whether new per channel path definitions of UL-AOA, UL-RTOA or gNB Rx-Tx time difference, UL-RSRP measurements is to be introduced (CATT)
	+ Whether it is mandatory or optional for different positioning techniques? E.g., does UL-TDOA now require UL-RSRP and UL-AoA to be reported by TRP? (Nokia, vivo)
	+ Whether decision to report on multiple channel paths left to gNB/TRP implementation? (Nokia, vivo)
	+ What is the definition of “combination” and “per cannel path”? (China Telecom)
	+ Whether path specific measurement is defined for first arrival path or multiple paths (vivo, CMCC)
	+ Proposal is too broad (Apple)
	+ Clarifications may be needed (DOCOMO)
	+ Whether “path index” type of thing will be needed so that LMF can identify the report values is useful or not? (Samsung)
	+ Is the intention to support hybrid technique and what is the definition for “per channel path” (LGE)
	+ What is “channel path”. Does it mean the path in a multi-path channel or per SRS resource for positioning? (OPPO)

Based on received comments, it is proposed to simplify discussion and discuss revised Proposal 1-2:

**Proposal 1-2**

* Report of path-specific UL-AOA measurements is supported for
	+ Alt.1: the first arrival path
	+ Alt 2: the first arrival path and $N\geq 0$ additional paths
* For each path, report of multiple $M\geq 1$ path-specific UL-AOA values is supported
* FFS further reporting details
	+ e.g. reporting format, number of additional paths - *N*, number of path-specific UL-AOA values - *M*, additional measurements, positioning method

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| Company Name | Comments |
| ZTE | To our understanding, the current spec has already supported TRP to report multiple AOAs, normally smart TRP will forward the AOA of the first path or the AOA received with highest power. So it’s up to LMF to select the right AOA for positioning computation. |
| Huawei/HiSilicon | We understand that current spec allows TRP to provide multiple AoA values, and the multiple AoA values may correspond to a single path due to angle ambiguity (e.g. larger antenna spacing, front-side/back side), or to multiple paths, or to multiple occasion (associated with time stamp).However, we still think some clarification may be helpful either via stage-2 description, or adding the LMF request information, or adding the identification of the purpose of the multiple AoA, so that the information provided by TRPs will not be misused by the LMF. |
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## Support of different antenna array configurations

The following issues were raised for specific antenna configurations, e.g. Unilateral Linear Arrays (ULA):

* Ambiguity of angle measurements (e.g. due to different antenna spacings)
* Bias in angle measurements when gNB/TRP antenna array and UE are located at different heights

In order to address these issues, the following was proposed

* Firstly the use cases and scenarios for ULA antenna array should be discussed and confirmed [vivo, [5]]
* Reporting of multiple angle values per path or indication of the TRP antenna array orientation in the local coordinate system [Intel, [9]]
* Angle measurement defined with respect to the ULA antenna direction [Huawei, [2]]
* Enhanced AOA measurement with respect to the ULA antenna orientation [Futurewei, [6]]
* Reporting of the true AOA for ULA antenna configuration is supported by rel17 NR positioning enhancements [Ericsson, [19]]

### Round – 1 (Closed)

**Proposal 2-1**

* In case of UL-AOA measurements ambiguity,
	+ gNB reports multiple values of UL-AOA measurements per path
* In case of ULA,
	+ gNB reports UL-AOA measurement which is a function of the actual azimuth and zenith angles of arrival
* FFS details

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| Company Name | Comments |
| CATT | We would like to understand a little more about this proposal. 1. “In case of UL-AOA measurements ambiguity,
	1. gNB reports multiple values of UL-AOA measurements per path”

it is unclear to us what it means with the condition “in case of UL-AOA measurements ambiguity”, and it is also unclear to us why “gNB reports multiple values of UL-AOA measurements per path” assume the gNB receives a UL SRS resource from multipaths. For example, if gNB detects 4 paths when receives a UL SRS resource, does it means the gNB may report N UL-AOA measurements per path, i.e., total 4N UL-AOA measurements to LMF?1. “gNB reports UL-AOA measurement which is a function of the actual azimuth and zenith angles of arrival”. It is also unclear the intention of the proposal. gNB already support reporting UL-AOA measurement, which include both azimuth of angles of arrival.

  |
| Qualcomm | First bullet is related to Section 3.1.1: The framework in 3.1.1 can be general enough for a gNB to report multiple UL-AoAs, no need to discuss it separately in this proposal. For the 2nd bullet, for ULA, the proposal focuses on a specific way of enhancing the ULA scenario. As it was noted in today’s GTW discussion, the identified problem could potentially be solved by having AoA reporting to be optional; (reference from Huawei/HiSilicon paper R1-2100237):Our understanding of the problem that some companies identify is that, with a single ULA, it is more natural to think of the ULA axis as the z-axis in LCS and thus the measured phi-prime should be ZoA and not A(zimuth)oA – whereas the signaling makes ZoA optional and AoA mandatory; or in other words, in the current NRPPa specification, a gNB might not be able to report an LCS & an AoA that is consistent with the measurement. However, in this case, the network should define the LCS such that the z-axis is along the ULA direction, and then report only the ZoA relative to that z-axis (which based on our understanding, is the single angle that the network should report; aka it is not, strictly speaking a function of the azimuth and zenith angles as suggested in the proposal). The X and Y axes can be chosen in any manner (any 2 perpendicular lines in the plane perpendicular to the z-axis), and LCS-to-GCS mapping would be well defined. If such a simple change in NRPPa specification does not solve the identified problem, then there needs to be additional technical discussion to understand better the issue that companies bring up for discussion. Could the supporters of a different solution clarify why the above solution would not address their concerns?  |
| Nokia/NSB | We tend to agree with the comments from QC and would like to better understand the problem at hand.  |
| ZTE | For the first bullet: agree with Qualcomm.For the second bullet.:In our understanding, current spec supports AoA as mandatory but ZoA as optional. Therefore, if TRP is deployed with ULA, only AoA (azimuth) report is enough. In this case, the ULA axis should be regarded as x-axis in LCS. |
| China Telecom | We agree with Qualcomm’s comments. But we still confuse about what the second bullet’s intention, is it mean that in ULA case, both AOA and ZOA should be mandatory? |
| Vivo | Before discussing, we would like to align the understanding about AoA reporting. Based on the [9.2.37,TS 38.455], one TRP can report 16384 AoA for a UE. So I think multiple AoA reporting has been supported. Please let me know if there are other understanding.

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| IE/Group Name | Presence | Range | IE Type and Reference | Semantics Description |
| **Measured Result Item** |  | *1 .. <maxnoPosMeas>* |  |  |
| >CHOICE *Measured Results Value* | M |  |  |  |
| >>UL Angle of Arrival | M |  | 9.2.38 |  |
| >>UL SRS-RSRP | M |  | INTEGER (0..126) |  |
| >>UL RTOA | M |  | 9.2.39 |  |
| >>gNB Rx-Tx Time Difference | M |  | 9.2.40 |  |
| >Time Stamp | M |  | 9.2.42 |  |
| >Measurement Quality | O |  | 9.2.43 |  |
| >Measurement Beam Information | O |  | 9.2.57 |  |

For the first bullet, we agree with QC that it is overlap with Section 3.1.1.For the second bullet, we are open for the discussion. However, we think the use cases and applicable scenario for ULA should be clarified first, as far as we know, at least in current indoor or indoor factory scenarios, the ULA is not the commonly used antenna array. Can the proponents explain the main scenarios where ULA antennas are used? |
| Huawei/HiSilicon | For second bullet, we think the current proposal is not reflecting the proposal in our contribution. Suggest to modify as below.* In case of ULA,
	+ Alt.1 gNB reports UL-AOA measurement which is a function of the actual azimuth and zenith angles of arrival
	+ Alt.2 gNB reports only the “ZoA” defined with respect to the ULA axis.
	+ Note: Alt.1 and Alt.2 may result in the equivalent quantity.

For the comments from CATT/QC on Proposal 1, we think that for a single path, there exist multiple interpretation of the AoA, which is different from 3.1.1.For the comments from QC/Nokia on Proposal 2, we think the NRPPa change can be minor to allow gNB to only report ZoA without reporting AoA at all, and gNB can select a proper LCS-GCS translation function.For the comments from vivo on Proposal 2, we consider it an important feature for indoor angle-based positioning, where the antenna number is limited for indoor base stations. For 4 antenna elements, we observe the accuracy is higher for 1x4 array than 2x2 array.To vivo, we think that based on the interpretation of vivo, it should be possible. However, we would like to align the understanding that such an operation does not cause confusion at the LMF if a TRP reports multiple angles of the UE. |
| CMCC | For the 2nd bullet, as we commented during the GTW session, the scenarios and use cases of ULA deployment should be first clarified, then the AoA definition of ULA can be further enhanced if companies reach the consensus to investigate it in the WI. |
| Intel  | To Qualcomm (regarding the second bullet):The ZoA defined with respect to the ULA axis it is not supported by the current specification. This is because (as it stated by multiple companies) AoA is the mandatory and ZoA is the optional angle and reporting of ZoA only is not possible.This option requires specific orientation of the LCS with respect to the GCS and usage of the LCS-to-GCS translation function. Therefore, it does not support direct reporting in the GCS coordinates, where direction of the Z-axis is fixed and cannot be changed.In that sense, the FL proposal and the Alt. 1 in Huawei response is more general solution that allows reporting in both LCS and GCS coordinate systems without specific knowledge of the LCS orientation. From the specification perspective, the changes are similar, however, given that Alt. 1 is a more general solution (covering both reporting in LCS and GCS), we prefer to define the Alt. 1.  |
| Sony | We are not supportive of bullet 1. In our understanding, this UL-AOA measurement ambiguity in the original context is caused by the signals received from the front side and the backside of the TRP antenna panel. We don’t agree that it is a common issue in the current antenna model. Even if that is the case, it would be feasible for the TRP to distinguish which signal is from the side facing to the UE based on the UL-RSRP, since only one side is LOS.For bullet 2, we agree with the comments from QC. |
| Ericsson | For the first bullet, we agree that the report could consist of multiple value. We can leave the details to ran2. For the second bullet, we agree in principle, but we think the current report can be used with an indicator to signal that the reported zenith angle should be interpreted as being in a LCS with z-axis along the ULA, and the azimuth angle can be ignored.  |
| LG | For the first bullet, it might be related with section 3.1. So, it would be discussed in section 3.1. For the second bullet, before discussing the issue, it seems that the motivation of the issue needs to be studied clearly.  |
| OPPO | We need more discussion to better understand the problem and issues. For example. For the first sub-bullet: reporting multiple values. Is it intended for gNB to report multiple UL-AoA value for one UE? If so, it can be supported in rel16 spec already, for which we share the same understanding with QC. |

### Round – 2

Based on provided comments, it is observed that

* Companies seems believe that discussion on reporting of multiple AoA values has overlap with discussion in section 3.1 and prefer to have one common discussion. From FL perspective the topic and addressed problems are different. In section 3.1 it is discussed whether to introduce path-specific UL-AOA measurements and how many paths should be reported. In section 3.2, it is proposed to support reporting of multiple UL-AoA measurements per channel path. Anyway, if companies prefer to have single discussion, it is also fine from FL perspective. Therefore, the related revised proposal was moved to section 3.1.2.
* It seems there was misunderstanding on why in case of ULA, gNB should report UL-AOA measurement which is a function of the actual azimuth and zenith angles of arrival. The clarification was provided in responses from Huawei and Intel. Based on comments, it seems there are following alternatives to address the problem of UL-AOA measurement for ULA:
	+ In case of ULA,
		- Alt.1 gNB reports UL-AOA measurement which is a function of the actual azimuth and zenith angles of arrival
		- Alt.2 The z-axis of LCS is defined along the ULA direction. gNB report only the ZoA relative to z-axis

**Proposal 2-2**

* Select one of the following alternatives in case of ULA
	+ In case of ULA,
		- Alt.1: gNB reports UL-AOA measurement which is a function of the actual azimuth and zenith angles of arrival
		- Alt.2: The z-axis of LCS is defined along the ULA direction. gNB reports only the ZoA relative to z-axis

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| Company Name | Comments |
| ZTE | We understand the intention here. But Alt.1 is still unclear. For a ULA, there is naturally only one angle can be acquired, so what does it mean by “a function of the actual azimuth and zenith angles of arrival” ? We think Alt.1 is trying to say we should define the reference direction(e.g. ULA axis) and report the angle relative to the reference direction.  |
| Huawei/HiSilicon | We are fine with the current progress. Downselection and the specification impact may be discussed further, e.g. invalidate the AoA part for AoA+ZoA in the LCS or define a new reporting IE. |
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## Calibration of gNB angle error and reference UE

The following options were proposed to support calibration of gNB angle error measurements:

* Introduce a calibration/reference UE [Huawei, [2]], [vivo, [5] – FFS], [CATT, [4]
	+ Motivation:
		- Use known location to mitigate the gNB angle error
* Support LMF assisted angle calibration [Huawei, [2]]
	+ Motivation:
		- Calibrating the phase/amplitude error across antenna elements
* Correction of the fixed phase deviation between channels of gNB antenna [BUPT,[7]]
	+ Motivation:
		- Accurate UL AOA measurements

### Round – 1 (Closed)

**Proposal 3-1**

* Further study the following two alternatives for gNB/TRP antenna array calibration to facilitate accurate UL-AOA measurements:
	+ Alt.1: NR supports reference UE with known coordinates/orientation for UL-AOA measurement calibration
	+ Alt.2: Procedure for calibration of UL-AOA measurements is up to gNB/TRP implementation

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| Company Name | Comments |
| CATT | Support Alt.1 and suggest the following wording changes::* NR supports using the information provided by a reference UE with known coordinates/orientation for UL-AOA measurement calibration
* FFS: the details of the procedure and signaling
 |
| Qualcomm | We are supportive of Alt. 1 however, we don’t see the need of calling it a “reference UE”; it can be a gNB or some other device; these decisions can be discussed/finalized later, and there may need to have upper layer WGs included in the discussion. Suggest to change the first option by saying: “reference device or reference entity or reference node”.Additional changes over the proposal from CATT:* NR supports using the information provided by a reference ~~Ue~~node with known coordinates/orientation for UL-AOA measurement calibration
* FFS: the details of the procedure and signaling, whether the reference node can be a UE, a gNB, or another device
 |
| Nokia/NSB | In principle we are okay with Alt. 1 with update from CATT/QC. However, the general concept of reference UE is being discussed for multiple techniques and we think that we should not do a piecemeal solution but rather have a comprehensive agreement if possible.  |
| Fraunhofer | Support Alt1. |
| ZTE | Prefer Alt.2. No spec change is needed. |
| China Telecom | Support Alt1 with update from CATT/QC. |
| Vivo | Support Alt1.  |
| Huawei/HiSilicon | OK with the change from QC, but to our understanding, reference UE should be more suitable not to break the existing DL/UL behavior of gNB. |
| CMCC | Alt 1 is preferred.  |
| Intel  | Support of Alt. 2.  |
| Apple | Support Alt1 (preferred by note from QC) |
| Sony | Support Alt.2 |
| Ericsson | Prefer Alt.2. Reference UEs can be used without specification impact.  |
| Samsung  | The key question is whether using the “reference UE” or TRP to do the job can be totally up to implementation. We think this is very likely the case, and no additional measurement/report is needed, alt2 seems natural.  |
| LG | Support Alt.2 |
| OPPO | Support Alt2. The calibration shall be TRP implementation issue. |

### Round – 2

Based on provided comments, it is observed that

* 8 companies prefer Alternative 1 (introduce reference UE/node for UL-AOA measurement error calibration)
* 7 companies prefer Alternative 2 (leave calibration for UL-AOA up to gNB implementation)

It seems there no common view and it is challenging to find a common ground based on responses so far and more discussion and understanding is needed for Alt.1. Therefore, FL proposal is to continue discussion and analysis till the next meeting aiming to select one of the alternatives.

**Proposal 3-2**

* Continue discussion and select one of the following alternatives for gNB/TRP antenna array calibration at RAN1#104b:
	+ Alt.1: NR supports reference UE with known coordinates/orientation for UL-AOA measurement calibration
	+ Alt.2: Procedure for calibration of UL-AOA measurements is up to gNB/TRP implementation

## LOS/NLOS identification for UL-AOA measurements

The following proposals were discussed for with respect to LOS/NLOS identification to improve accuracy of UL-AOA positioning.

* AOA measurements associated with LOS/NLOS identifier and a confidence level [CATT, [4]]
	+ Motivation:
		- Accuracy of AOA positioning
* LOS indicators as soft values to the network or LMF [Futurewei, [6]]
	+ Motivation:
		- To improve positioning accuracy using regularization techniques
* NLOS link rejection by polarization [Futurewei, [6]]
	+ Motivation:
		- Improve accuracy, identify NLOS direction (relative changes in their polarization orientation)
* Indication of link propagation type (LOS/NLOS) and reliability metric [Intel, [9]]
	+ Motivation:
		- Improved UL-AOA positioning accuracy

### Round – 1 (Closed)

**Proposal 4-1**

* gNB/TRP reports estimate of LOS/NLOS link type identification to facilitate accurate UL-AOA positioning
	+ FFS details for LOS/NLOS link type identification and signaling

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| Company Name | Comments |
| CATT | Support and suggest the following wording changes:* NR supports gNB/TRP to reports LOS/NLOS link type identification associated with UL-AOA measurements to facilitate accurate UL-AOA positioning
	+ FFS details for LOS/NLOS link type identification and signaling
 |
| Qualcomm | Not support. Sending a discretized AoA/RTOA/RSRP as proposed in Proposal 3.1 is a more generic way to solve this problem. Let everything else up to the LMF implementation, without having to ask the gNB to derive by-product metrics; send over to the positioning engine all the information.  |
| Nokia/NSB | While we are supportive of LoS/NloS identification, we don’t feel this should be discussed during this meeting and should wait for any potential update to the WID given the discussions at RAN.  |
| Fraunhofer | Do not support.LOS/NLOS identification or mitigation is not part of the current WID objectives. |
| ZTE | Agree with Nokia. This can be discussed when NLOS/multipath mitigation is in WID. |
| China Telecom  | We support the proposal 4-1. Even though the NLOS/multipath mitigation is not included in current WID, it does help improve the UL-AOA positioning accuracy and can regard as kind of procedure and measurements. We are also OK to discuss this when the WID is updated. |
| Vivo | Do not support.Same view as Nokia, Fraunhofer and ZTE. |
| InterDigital | This issue can be dealt in the LOS/NLOS item which was not included in the WID in RAN#90. |
| CMCC | We think this discussion can be postponed to the next meeting if LOS/NLOS identification is included in the revised WID. |
| Intel  | We are supportive of this proposal.We are OK to consider it later based on the WID revision.  |
| Apple | Do not support, out of scope of current WID. |
| Sony | In principle, we support. However, this proposal can also be discussed further when NLOS/Multipath mitigation is in WID. |
| Ericsson | Agree with other companies, prefer to wait that LOS detection is in scope.  |
| DOCOMO | Agree with Nokia. |
| Samsung  | Similar view as other company, this can wait. |
| LG | We do not agree with the proposal. We think that LOS/NLOS identification issue needs to be up to implementation. Furthermore, it seems very difficult to converge to specific scheme because there is not enough time to prove each schemes. |
| OPPO | It is out of scope of current WID at least. |

### Round – 2

Based on provided comments, it seems the following proposal can be made:

**Proposal 4-2**

* Conclude that discussion on this topic is subject to further WID revision by RAN WG

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| Company Name | Comments |
| ZTE | Support FL’s suggestion. |
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## Assistance signaling for UL-AOA measurements

The following options were proposed to assist UL-AOA measurements:

* Indication of expected AOA parameters [Nokia, [8]]
	+ Motivation: Assist non-serving cell TRPs in UL-AOA measurements
* Indication of estimated UE position and the uncertainty [CATT, [4]]
	+ Motivation: Aid the UE/gNB in the reception of the DL/UL reference signals and providing reliable NR timing and angular (especially AOA) measurements

### Round – 1 (Closed)

**Proposal 5-1**

* NR supports assistance signaling from LMF to gNB/TRP to facilitate UL-AOA measurements
	+ FFS details of LMF assistance signaling

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| --- | --- |
| Company Name | Comments |
| CATT | Support. |
| Qualcomm | Support |
| Nokia/NSB | Support. Suggest the following small changes: * NR supports enhanced assistance signaling from LMF to gNB/TRP to facilitate improved UL-AOA measurements
 |
| Fraunhofer | Do not support.It is not clear what improvements are achieved if the proposal is supported. |
| ZTE | Generally fine with the proposal and leave details to next meeting. |
| China Telecom | Support. |
| vivo | In general, we are okay for the proposal, but the proposal is too broad for us. We wonder that which type of assistance signaling would be supported for UL-AoA and how it can facilitate UL-AOA measurements. |
| CMCC | The enhancements and benefits of this proposal seems not clear to us. |
| Apple | Support with note added by Nokia/NSB |
| Sony | Support. This can also facilitate to improve other positioning method. |
| Ericsson | Do not support, but we are ok to revisit this proposal if more concrete enhancements are mentioned.  |
| DOCOMO | Support |
| Samsung  | The main bullet opens a quite big window, no? generally, we needs to first see what kind of the assisted signaling it is, and check whether it is really useful, then decide to support or not. For current stage, it seems only suitable to say FFS.  |
| LG | We are wondering that RAN1 needs to discuss about it in details since the signaling between LMF and gNB/TRP is related with higher layer. |
| OPPO | We need to know more details, for example what kind of singling and information. So for the current moment, we do not support this proposal. |

### Round – 2

Based on provided comments, it seems the following observations can be drawn:

* 8 companies **support** the Proposal 5-1 (CATT, Qualcomm, Nokia, ZTE, China Telecom, Apple, Sony, DOCOMO)
* 3 companies either **do not support Proposal 1-1** or express view that benefits are not clear (Fraunhofer, CMCC, Ericsson)
* 4 companies request for further clarification:
	+ (vivo) - the proposal is too broad / which type of assistance signaling would be supported for UL-AoA
	+ (Samsung) - main bullet opens a quite big window
	+ (LGE) - RAN1 needs to discuss about it in details since the signaling between LMF and gNB/TRP is related with higher layer
	+ (Ericsson) ok to revisit this proposal if more concrete enhancements are mentioned.
	+ (OPPO) what kind of singling and information

Based on received comments, it is proposed to simplify discussion and discuss revised Proposal 1-2:

**Proposal 5-2**

* NR supports additional assistance signaling from LMF to gNB/TRP to facilitate measurements of UL-AOA
	+ Alt.1. Indication of expected AOA parameters
	+ Alt.2. Signaling of UE coordinate estimate and uncertainty
	+ Alt.3. FFS

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| Company Name | Comments |
| ZTE | We already discussed this in GTW session. So the following proposal should be the baseline for further discussion.Proposal:NR supports at least the following additional assistance signaling from LMF to gNB/TRP to facilitate measurements of UL-AOA for a UE from that gNB/TRP* Indication of expected AOA/ZOA value and uncertainty (of the expected AOA/ZOA value) range(s)
* FFS: Details of procedure for providing the assistance
 |
| Huawei/HiSilicon | We are generally fine with the proposal here. In our view, this enhancement may also help timing measurement (UL RTOA/gNB Rx – Tx time difference), similar to that SRS expected timing and uncertainty are also needed for AoA measurement.So we slightly prefer to add the following FFS based on ZTE’s version.Proposal:NR supports at least the following additional assistance signaling from LMF to gNB/TRP to facilitate measurements of UL-AOA for a UE from that gNB/TRP* 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: Whether the assistance signalling can also be used for measurement of UL-RTOA and gNB Rx – Tx time difference
 |
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## SRS physical structure enhancements

The following options were proposed to enhance SRS physical structure:

* Long ZC sequence (Length = existing sequence length \* comb size) [LGE, [10]]
	+ Motivation:
		- More cyclic shifts and root indexes can be used => cross-correlation can be improved
* Enhanced SRS sequence mapping rule [LGE, [10]]
	+ Motivation:
		- Adjustment of phase are not necessary
* Multi-port SRS for positioning [Fraunhofer, [14]]
	+ Motivation:
		- Reduced time-frequency resource overhead. TRP may take advantage of the multipath components received from multiple SRS resources coherently transmitted

### Round – 1 (Closed)

The proposed above enhancement seems to be a general one i.e. applicable to all UL NR positioning measurements.

**Proposal 6-1**

* FFS physical structure enhancements of SRS for positioning

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| Company Name | Comments |
| CATT | Not sure if this enhancement should be discussed under this AI. The enhancement of “SRS for positioning” was discussed during the SI and there was no consensus to include it in the WI scope in our understanding. |
| Qualcomm | We need to provide an update for this WI in the next plenary; we don’t think that this FFS would help updating the WI scope. Would it mean that during the WI, we are going to discuss it further, or is it FFS that needs to be finalized during this meeting? |
| Nokia/NSB | Do not support.  |
| Fraunhofer | The WID objective mentions: “Specify the procedure, measurements, reporting, and signalling for improving the accuracy of UL AoA…” Multi-port SRS transmission has a direct impact on the UL-AoA accuracy especially for multi-TRP scenarios. A TRP can measure the SRS from the multiple ports of the same UE and coherently process the measurements so that a better AoA estimate corresponding to the first arrival is achieved.In fact this in our view, this is one of the few proposals for UL-AoA improvements from RAN1 perspective. |
| ZTE | Not support. SRS enhancements were discussed during SI phase, no consensus was reached.  |
| China Telecom | We think this should not be discussed according to the current WID scope, but we are fine with the SRS physical structure enhancements. |
| vivo | Do not support. It is out of the scope in the current WID. |
| Intel | We think it is out of scope of this AI. |
| Apple | D not support, out of scope of WI. |
| Sony | Do not support |
| Ericsson | Do not support. Based on the SI outcome, we prefer to avoid discussing SRS enhancements.  |
| DOCOMO | We think it’s out of the current WI scope. |
| LG | We have similar views on Fraunhofer. We think the enhancement of SRS for positioning is not in contravention of the WID description since it can improve timing measurement performance so we believe that the proposal is worth considering. In addition, we prefer to suggest the following wording changes to cover companies view:FFS physical structure enhancements(e.g. sequence generation, mapping rule to physical resources and multiple port) of SRS for positioning |
| OPPO | It is out of WID. We do not have objective to redesign the SRS |

### Round – 2

Based on provided comments, it seems the following observation can be drawn:

* Majority of companies either **do not support Proposal 6-1** or do not see it under UL-AOA enhancements agenda / WI scope.

Based on received comments, the following is proposed

**Proposal 6-2**

* Conclude that there is no consensus on SRS for positioning physical structure enhancements (out of WID scope)

Note: There is no intention to explicitly capture above conclusion in chair notes.

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| Company Name | Comments |
| ZTE | Support FL’s suggestion. |
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## Power control enhancements of SRS for positioning

The following open-loop power control enhancements were proposed

* Multiple DL RS resources as path-loss reference to each SRS resource set. [LGE, [10]]
* Association between the multiple path-loss reference RSs and SRS resource within a SRS resource set. [LGE, [10]]
	+ Motivation:
		- Improve reception at neighbour gNBs/TRPs
* Power control enhancements [Samsung, [15]]
	+ Motivation:
		- Reliable reception at neighbour TRPs/gNBs that are far from UE

### Round – 1 (Closed)

The proposed above enhancements seem to be general ones, i.e. applicable to all UL NR positioning measurements.

**Proposal 7-1**

* FFS association of pathloss reference RSs and SRS resources for positioning within an SRS resource set
* FFS power control enhancements for SRS for positioning

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| --- | --- |
| Company Name | Comments |
| CATT | Not sure if this enhancement should be discussed under this AI. The enhancement was discussed during the SI and there was no consensus to include it in the WI scope in our understanding. |
| Qualcomm | We may need to provide an update for this WI in the next plenary; we don’t think that this FFS would help updating the WI scope. Would it mean that during the WI, we are going to discuss it further, or is it FFS that needs to be finalized during this meeting? |
| Nokia/NSB | We also brought some power control proposals in our TDoc under “Others” – R1-2100551. We are open to discussing. While we are supportive of enhancing power control in Rel-17 we also acknowledge the comments above about WI scope.  |
| ZTE | It’s out of WID scope. |
| China Telecom | We think this should not be discussed according to the current WID scope, but we are fine with the power control enhancements. |
| vivo | Agree with power control not in this AI, although we are supportive of enhancing power control and hope power control can be discussed further in WI. |
| Intel | We think it is out of scope of this AI. |
| Apple | Out of current WID scope (postpone if WID is updated in next RANP) |
| Sony | It is unclear. We have the same view as CATT |
| Ericsson | Do not support. Based on the SI outcome, we prefer to avoid discussing power control enhancements.  |
| DOCOMO | We think it’s out of the current WI scope. |
| Samsung | If the proposed power control related to method is to improving the UL-AoA accuracy, we think it should be counted as within the scope. Thus, we suggest change the second bullet to be * FFS power control enhancements for SRS for UL-AOA positioning improvement
 |
| LG | Support. The accuracy improvement of AoA positioning technique is related to SRS power control. |
| OPPO | Out of scope of WID |

### Round – 2

Based on provided comments, it seems the following observation can be drawn:

* Majority of companies either **do not support Proposal 7-1** or do not see it in WID scope.

Based on received comments, it is proposed to discuss revised Proposal 7-2:

**Proposal 7-2**

* Conclude that there is no consensus on enhancements of SRS for positioning power control (out of WID scope)

Note: There is no intention to explicitly capture above conclusion in chair notes.

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| Company Name | Comments |
| ZTE | Support FL’s suggestion. |
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## gNB/UE beamforming related aspects

The following beamforming related techniques were proposed for study to improve UL-AOA performance:

* Differential beamforming technique for UL-AOA positioning method [Samsung, [15]]
	+ Motivation:
		- Accuracy enhancements, latency reduction, overhead reduction
* Beam interpolation based AOA estimation [Nokia, [8]]
	+ Motivation:
		- Accurate measurement of UL-RSRP

### Round – 1 (Closed)

**Proposal 8-1**

* Further study performance of differential beamforming and beam interpolation-based AOA estimation for UL-AOA positioning and particular design aspects for specification work

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| Company Name | Comments |
| CATT | Support further discussion. The investigation may not be not limited to “performance” only. |
| Qualcomm | We may need to provide an update in the next plenary; we don’t think that this FFS would help updating the WI scope. Would it mean that during the WI, we are going to discuss it further, or is it FFS that needs to be finalized during this meeting? Its unclear what is the spec impact that we are going after with this proposal. Can it be clarified further what is the spec support needed? |
| Nokia/NSB | Support.  |
| ZTE | It’s unclear what spec changes are expected. |
| China Telecom | We support the proposal, and the spec impact also needs to be considered besides the performance. |
| vivo | We doubt whether the differential beamforming and beam interpolation-based AOA estimation can help improve the AOA accuracy. Before we study the particular design aspects for specification work, the performance gain of the beamforming for AOA should be fully verified. |
| Huawei/HiSilicon | We haven’t identified any specification impact for UL-AoA calculation at the TRP. |
| Intel | We do not see a specification impact. |
| Apple | As mentioned by other companies, the spec impact is not clear to us |
| Sony | Spec impact is unclear. We have a similar view as Qualcomm |
| Ericsson | The spec impact required by these proposal is unclear. A lot could be left to implementation.  |
| Samsung | For differential beamforming, first, the spec impact could be the measurement report from TRP to LMF (instead of RSRP, it should report the received signal or the ratio of the received signal), in details, what to measure, what to report and in which formation; second, the power ramping for the SRS-pos transmission might be needed since the SNR is quite important for the accuracy and the receiving TRP(cell) is relatively far, power ramping will be needed, then the related spec impact needs to be discussed. |
| LG | We are agree with QC’s view. |
| OPPO | DO not support. It seems to be system implementation issue. |

### Round – 2

Based on provided comments, it seems the following observation can be drawn:

* Majority of companies do not see the need for specification changes

Based on received comments, it is proposed to discuss revised Proposal 8-2:

**Proposal 8-2**

* Continue discussion on specification impact and performance benefits during RAN1#104e

Note: There is no intention to explicitly capture above conclusion in chair notes.

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| Company Name | Comments |
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## SRS for positioning transmission priority

The SRS for positioning prioritization was discussed:

* Prioritization of SRS for positioning with respect to other signals and channels [InterDigital, [11]]
	+ Motivation:
		- SRS for positioning transmission may be dropped when the UE has another data for UL transmission => degradation of low latency positioning services

### Round – 1 (Closed)

The proposed above enhancement seems to be a general one i.e. applicable to all UL NR positioning measurements.

**Proposal 9-1**

* Further study prioritization of SRS for positioning with respect to other signals and channels

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| --- | --- |
| Company Name | Comments |
| CATT | Not sure if this enhancement should be discussed under this AI. The enhancement was discussed during the SI and there was no consensus to include it in the WI scope in our understanding. |
| Qualcomm | SRS prioritization would be related to all UL and DL/UL methods: UL-AoA, UL-TDOA, MRTT; it will not help the AoA method only. We are supportive to be discussed, but it should be understood that it related to all UL measurements.  |
| Nokia/NSB | Agree with above comments.  |
| Fraunhofer | Share the view of CATT. |
| ZTE | Agree with CATT. |
| China Telecom | Agree with CATT. |
| Vivo | Agree with QC. |
| InterDigital | Support the proposal. Low priority assigned to SRS can be the bottleneck for accuracy of AoA. |
| CMCC | We share similar views as QC.  |
| Intel | Can be considered in a more general context, but not in this AI. |
| Apple | Agree with CATT |
| Sony | We have similar view as CATT. |
| Ericsson | Do not support. If WID is extended to include general enhancements to reference signals, this could be considered. But as of current WID, we think the proposed enhancement goes too far.  |
| LG | We are on the same page with QC and CATT views.  |
| OPPO | Do not support. Agree with the understanding of CATT.  |

### Round – 2

Based on provided comments, it seems the following observation can be drawn:

* Majority of companies do not see it as an objective in current WI scope

Based on received comments, it is proposed to discuss revised Proposal 9-2:

**Proposal 9-2**

* Conclude that topic is not a part of the current WID and is a part of a broader discussion for all UL positioning measurements

Note: There is no intention to explicitly capture above conclusion in chair notes.

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| Company Name | Comments |
| ZTE | Support FL’s suggestion. |
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## Enhancements for UE timing advance

The following enhancements were proposed with respect to the SRS for positioning transmission timing:

* SRS resource-specific TA configuration [LGE, [10]]
	+ Motivation:
		- For transmission intended to a neighbour cell, TA of the SRS resource should also be intended to the target neighbour cell.

### Round – 1 (Closed)

The proposed enhancements were discussed in Rel.16 and there was no consensus to introduce such functionality for NR SRS for positioning.

**Proposal 10-1**

* FFS support of SRS resource-specific TA configuration

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| --- | --- |
| Company Name | Comments |
| CATT | Not sure if this enhancement should be discussed under this AI. The enhancement was discussed during the SI and there was no consensus to include it in the WI scope in our understanding. |
| Qualcomm | We don’t see the technical need to reopen this issue. Benefits have been unclear, especially if we are talking about InH/inF scenarios where the distances are small.  |
| Nokia/NSB | As this would not improve the accuracy we don’t think this is in the scope of the WI.  |
| ZTE  | It’s out of WID scope. |
| China Telecom | Agree with CATT. |
| Intel | We think it is out of scope of this AI. |
| Apple | Agree with QC, besides, it is out of scope. |
| Sony | Do not support (out of scope of WI) |
| Ericsson | Do not support. We agree with other companies that the enhancements is out of scope. |
| Samsung  | Again, if this is targeting for UL AOA improvement, it can be discussed, some clarification is needed. |
| LG | We understand the consideration of other companies above, however, we think that the enhancement of SRS is linked to AoA performance. And then, for QC’s comment, since we need to consider not only indoor case but also out door case in accordance with WID and TS 22.261, we think that the enhancement can be helpful even though the effect is unclear in InH/inF scenarios. So, we support FL’s proposal. |
| OPPO | Do not support. |

### Round – 2

Based on provided comments, it seems the following observation can be drawn:

* Majority of companies either **do not support Proposal 10-1** or do not see it under UL-AoA agenda item / WI scope.

Based on received comments, it is proposed to discuss revised Proposal 10-2:

**Proposal 10-2**

* Conclude that there is no consensus to define UE timing advance enhancements

Note: There is no intention to explicitly capture above conclusion in chair notes.

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| Company Name | Comments |
| ZTE | Support FL’s suggestion. |
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## DL PRS-RSRP measurements enhancements

* Association of DL-PRS-RSRP measurements with a time window, determined by UE [Apple, [16]]
	+ Motivation:
		- PRS for DL-AoD, is not tied with the first detected path in time. Report may be often biased toward the NLOS path
	+ NOTE: Proposal relates to DL-AoD enhancement and thus should be covered under another AI 8.5.3

### Round – 1 (Closed)

**Proposal 11-1**

* Discuss proposal under AI 8.5.3 unless the same approach is suggested for UL-AOA by proponent

|  |  |
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| Company Name | Comments |
| Qualcomm | The proposal above seems to be Dl-AoD, unless there was a typo.  |
| Nokia/NSB | Agree with FL view. Seems that Apple may have flipped their DL-AoD and UL-AoA Tdocs.  |
| vivo | Agree with FL view. |
| Intel  | Agree with FL view. |
| Apple | Agree with FL (it was a last minute typo… our contributions flipped in 8.5.2 and 8.5.3)  |
| Ericsson | Support. Note from 8.5.3 FL that AOD-related contributions filed under 8.5.2 are included in the 8.5.3 summary.  |
| LG | We also think that there is mistake in the submission. We agree with FL’s proposal. |

It seems group supports Proposal 11-1.

Note: There is no intention to explicitly capture Proposal 11-1 in chair notes.

# Conclusions

In this contribution, we have provided review of the submitted contributions for NR Positioning UL-AOA enhancements and prepared initial and revised set of proposals (based on initial feedback from companies) to facilitate further discussion/decision.

# References

1. R1-2100129 Enhancements for UL AOA Positioning OPPO
2. R1-2100237 Enhancement for UL AOA positioning Huawei, HiSilicon
3. R1-2100294 Accuracy improvement for UL-AOA positioning solutions ZTE
4. R1-2100386 Discussion on accuracy improvements for UL-AOA positioning solutions CATT
5. R1-2100446 Discussion on potential enhancements for UL-AOA method vivo
6. R1-2100488 Discussion on improving the accuracy of UL AOA positioning solutions FUTUREWEI
7. R1-2100497 Accuracy improvements for UL-AOA positioning solutions BUPT
8. R1-2100549 Initial views on enhancing UL AOA Nokia, Nokia Shanghai Bell
9. R1-2100658 NR positioning enhancements for UL-AOA method Intel Corporation
10. R1-2100709 Discussion on accuracy improvement for UL-AOA positioning LG Electronics
11. R1-2100753 Discussions on techniques to improve accuracy for UL-AOA positioning solutions InterDigital, Inc.
12. R1-2100863 Discussion on accuracy improvements for UL-AOA positioning method Sony
13. R1-2101047 Discussion on UL-AOA enhancement CMCC
14. R1-2101132 UL-AOA positioning enhancements Fraunhofer IIS, Fraunhofer HHI
15. R1-2101211 Discussion on accuracy improvements for UL-AOA positioning solutions Samsung
16. R1-2101388 Accuracy enhancements for DL-AoD positioning technique Apple
17. R1-2101469 Potential Enhancements on UL-AOA positioning Qualcomm Incorporated
18. R1-2101617 Discussion on UL-AOA positioning enhancements NTT DOCOMO, INC.
19. R1-2101755 Enhancements of UL-AOA positioning solutions Ericsson