**3GPP TSG RAN WG1 Meeting #110bis-e R1-22xxxxx**

**e-Meeting, October 10th – 19th, 2022**

**Source: Moderator (vivo)**

**Title: FL summary #1 of [110bis-e-R18-AI/ML-07]**

**Agenda item: 9.2.4.2**

**Document for: Discussion and decision**

# Introduction

In this contribution, we summarize issues regarding other aspects on AI/ML for positioning accuracy enhancement in RAN1 #110bis-e for the following email discussion.

[110bis-e-R18-AI/ML-07] Email discussion on other aspects of AI/ML for positioning accuracy enhancement by October 19 – Huaming (vivo)

* Check points: October 14, October 19

Note that the scope of agenda 9.2.4.2 including finalization of representative sub use cases and discussions on potential specification impact.

# Sub use case(s) and AI/ML approaches

In this section, we provide a summary of issues, observations and proposals related to sub use cases for AI/ML positioning accuracy enhancements based on the submitted contributions.

As in the SID, the related objectives are the following.

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| Study the 3GPP framework for AI/ML for air-interface corresponding to each target use case regarding aspects such as performance, complexity, and potential specification impact.Use cases to focus on: * Initial set of use cases includes:
	+ CSI feedback enhancement, e.g., overhead reduction, improved accuracy, prediction [RAN1]
	+ Beam management, e.g., beam prediction in time, and/or spatial domain for overhead and latency reduction, beam selection accuracy improvement [RAN1]
	+ Positioning accuracy enhancements for different scenarios including, e.g., those with heavy NLOS conditions [RAN1]
* Finalize representative sub use cases for each use case for characterization and baseline performance evaluations by RAN#98
	+ The AI/ML approaches for the selected sub use cases need to be diverse enough to support various requirements on the gNB-UE collaboration levels

Note: the selection of use cases for this study solely targets the formulation of a framework to apply AI/ML to the air-interface for these and other use cases. The selection itself does not intend to provide any indication of the prospects of any future normative project.  |

## Individual observations/proposals

The following are individual observations and proposals from the contributions.

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| Sources | Observations/proposals |
| [1, Ericsson] | **Observation 1 For a CIR based ML fingerprinting solution, UL CIR can be obtained using existing reference signals and does not require additional reports to be specified for the air interface.****Observation 2 For the InF-DH scenario with 60% clutter density, it is expected that site/deployment specific models with limited generalizability are required due to the low LoS probability.****Observation 3 For the InF-DH scenario with 40% clutter density, it is expected that generic models can be used.****Proposal 1 Focus on one-sided ML functionality for the positioning use case.****Proposal 2 Deprioritize two-sided ML functionality, which requires joint training and inference.****Proposal 3 Update the terminology for two-sided model so that the more generic term ‘network’ is used instead of ‘gNB’, if two-sided model for positioning is to be discussed.****Proposal 4 The study considers both UE-side and network-side AI/ML for positioning enhancement.****Proposal 5 The study considers both UE-based and network-based position estimation.****Proposal 6 The study consider the candidate AI/ML approaches in Table 1 only, with potential further down-selection.**Table 1 List of positioning methods and corresponding candidate AI/ML approaches

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| --- | --- | --- |
|  | **Corresponding legacy methods** | **Potential AI/ML model inference** |
| **UE-based** | DL-TDOA, DL-AoD | * UE-side inference, direct AI/ML positioning
 |
| **UE-assisted, LMF-based** | DL-TDOA, DL-AoD, Multi-RTT | * UE-side inference, AI/ML assisted positioning
* LMF-side inference, direct AI/ML positioning
 |
| **NG-RAN node assisted** | Multi-RTT, UL-TDOA, UL-AoA | * gNB-side inference, AI/ML assisted positioning
* LMF-side inference, direct AI/ML positioning
 |

**Proposal 7 Collaboration details (e.g., the assistance information details) of the evaluated AI/ML model is reported by participating companies.** |
| [2, Huawei] | ***Proposal 1: For direct AI/ML positioning, AI/ML-based fingerprint positioning should be studied***.* + ***RAN1 uses CIR as the model input as a starting point.***

***Proposal 2: For AI/ML assisted positioning, AI/ML-based LOS/NLOS identification should be studied.******Proposal 3: For AI/ML-based positioning, single-sided model should be considered as a starting point.**** + ***For UE-side model, the model training/updating and inference are performed all at UE side***
	+ ***For Network-side model, the model training/updating and inference are performed all at Network side***

***Observation 2: For direct AI/ML positioning such as the AI/ML-based fingerprint positioning sub use case, adopting the LMF-side operation mode (model training/updating/inference at LMF) would be an universal solution.******Observation 3: For AI/ML assisted positioning such as the LOS/NLOS identification sub use case, gNB-side operation mode (model training/updating/inference at gNB) can achieve lower latency than LMF-side operation mode.******Observation 4: For single-sided AI/ML-based positioning, it is simpler to perform the model training/updating/inference of AI/ML models at Network side.*** |
| [3, ZTE] | ***Proposal 1:*** *For further sub-use case classification, at least considering following high level principles:** *The intentions are to further clarify evaluation methodologies and corresponding specification impacts;*
* *Rel-18 AI/ML based positioning should prioritize the static positioning;*
* *Sub-use case classification should consider both AI model input/output and AI model functionalities.*

***Proposal 2:*** *Further sub-use case classification for direct AI/ML positioning and AI/ML assisted positioning should be based on AI model input and AI model output respectively.****Proposal 3:*** *For evaluations on potential specification impacts, at least include following sub-use cases for direct AI/ML positioning and AI/ML assisted positioning:** *Direct AI/ML positioning*
	+ *Sub-use case 1-1: AI model input is path timings and RSRPPs from single port PRS*
	+ *Sub-use case 1-2: AI model input is CIR (i.e., path timings, RSRPPs and path phases) from single port PRS*
	+ *Sub-use case 1-3: AI model input is path timings and RSRPPs (or CIR) from multi-port PRS*
* *AI/ML assisted positioning*
	+ *Sub-use case 2-1: AI model output is DL PRS RSTD values*
	+ *Sub-use case 2-2: AI model output is LOS/NLOS indicator*
	+ *Sub-use case 2-3: AI model output is relative RSRPP values to the first detected path in time*
 |
| [4, Spreadtrum] | ***Observation 1: For both of direct AI/ML positioning and AI/ML assisted positioning, AI/ML model can be delivered or not. It can wait for the progress of AI9.2.1.*** |
| [5, vivo] | 1. Both direct AI/ML positioning and AI/ML assisted positioning show significant accuracy improvement compared to conventional RAT-dependent positioning methods in a heavy NLOS scenario.
2. There’s no need to consider other sub use case(s) as representative or to down select between direct AI/ML positioning and AI/ML assisted positioning during this SI for performance and potential specification impact study.
 |
| [6, OPPO] | ***Proposal 1: For direct AI/ML positioning, study the following input options for the AI model inference at LMF side:*** * ***Option1: Existing UE measurement/reporting (e.g., DL RSTD and the corresponding RSRP)***
* ***Option2: New type of UE measurement/reporting (e.g., Normalized CIR and/or the corresponding RSRP)***

***Proposal 2: For AI/ML assisted positioning, study the following output options for the AI model inference at UE side**** ***Option1: Existing types of measurement (e.g., NLOS/LOS identification, RSTD)***
* ***Option2: New types of measurement (e.g., TOA)***

***Proposal 3: For AI/ML assisted positioning, the following alternative should be prioritized if the TOA-like output is used for AI/ML model**** ***The measurement results corresponding to all TRPs are used as the input for AI/ML model inference.***

***Proposal 7: For both direct AI/ML positioning and AI/ML assisted positioning, offline training of AI model(s) is prioritized in Rel-18*** * ***Study online training in the future release(s)***

***Proposal 8: For AI/ML based positioning, not support to study two-side AI/ML model within Rel-18 SI timeline.*** ***Proposal 9: For both direct AI/ML positioning and AI/ML assisted positioning, the AI model training and inference are assumed to be done in the same side in Rel-18, i.e., no model transfer*** * ***AI model training and inference at UE side, or***
* ***AI model training and inference at NW side***
* ***Note: model transfer can be studied in future release(s).***
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| [7, Google] | ***Proposal 1: Compared to AI/ML assisted positioning, direct AI/ML positioning should be prioritized.******Proposal 2: For direct AI/ML positioning, consider to use CIR and L1-SINR from each cell as the input.******Proposal 3: The study of AI/ML based positioning should focus on 1-side AI/ML model.*** |
| [9, CATT] | **Proposal 1: Consider the following sub use cases in Rel-18 AI/ML-based positioning:*** **AI/ML model is used to directly output UE’s position;**
* **AI/ML model is used to estimate timing and/or angle of measurement, e.g. ToA/AoA/AoD estimation;**
* **AI/ML model is used to identify LOS/NLOS.**

**Proposal 2: For direct AI/ML positioning, both one-sided AI/ML model and two-sided AI/ML model can be considered.****Observation 1: Training AI/ML model for positioning at network side is more feasible due to easier data collection and stronger computational resources.** |
| [10, Fujitsu] | ***Proposal 1 The selected two sub use cases are sufficient for the evaluation and related framework or specification impact study at this stage.*** |
| [12, Lenovo] | ***Observation 1: For positioning, three entities in the RAN require tight coordination and collaboration including LMF, NG-RAN nodes (serving and neighbouring gNBs) and the target-UE.******Proposal 1: Consider the following additional aspects with respect to the network-UE collaboration levels y and z including the associated sub-levels:**** ***Data collection for training/inference***
* ***Model Life Cycle Management (including model acquisition, activation/deactivation of AI/ML models, model monitoring and update at the LMF, serving and neighbouring gNBs, and target-UE)***
* ***Model inference***
* ***Interactions with communication/positioning modules via data pre-/post-processing***

***Proposal 2: Study fingerprinting as a Direct AI/ML positioning sub-use case, whereby channel observations/measurements, e.g., CIR, RSS measurements serve as input data to an AI/ML model to determine the target-UE’s location estimate.******Proposal 3: Further study scenarios for practical and feasible use of fingerprinting include indoor environments, e.g., indoor office or indoor factory settings.******Observation 2: Rel-17 focused on reporting enhancements for NLOS and multipath effects.******Proposal 4: RAN1 to consider LOS/NLOS identification as AI/ML assisted positioning sub-use case for timing-based and angular-based positioning techniques, where the input data may comprise all supported DL-based, UL-based, (DL+UL) measurements and the corresponding output comprises classification of measurements in terms of LOS and NLOS.*** |
| [13, NEC] | **Proposal 1:** *Option 4 is preferable to categorize the clarification of sub-use case.***Observation 1:** *Synchronization error between service TRP and reference TRP seriously hinders high accuracy requirement of NR positioning.***Proposal 2:** *The sub use cases of positioning accuracy enhancements should include the scenarios of existing synchronization error between service TRP and reference TRP.***Observation 2:** *Heavy NLOS condition seriously hinders high accuracy requirement of NR positioning.***Proposal 3:** *The sub use cases of positioning accuracy enhancements should include the scenarios of heavy NLOS condition.***Observation 3:** *Network side AI model cannot apply to UE based positioning combining with direct AI positioning for DL PRS based positioning.***Proposal 4:** *Collaboration level x is preferable when suppose direct AI model is deployed at UE side for UE based positioning.***Proposal 5:** *For UE based positioning combining with AI assisted positioning, only UE side AI model rather than network side mode is not supported considering the additional specification complexity. Collaboration level x is preferable for this scenario.***Observation 4:** *UE side AI model cannot apply to UE assisted positioning combining with direct AI positioning for DL PRS based positioning.***Proposal 6:** *AI fingerprint positioning can be served as a sub-use case applying UE assisted positioning combining with direct AI positioning. How to obtain CIR at network side should be further study.* |
| [14, CAICT] | ***Proposal 1: AI/ML based positioning could be considered for both NW side and UE side.******Observation 2: AI/ML based positioning should be considered for both gNB side and UE side.******Proposal 2: For direct AI/ML positioning at UE side, AI model from NW side should be considered.***  |
| [15, Xiaomi] | **Proposal 1: Prioritize the study of offline training on single node for positioning accuracy enhancement** |
| [16, CMCC] | ***Proposal 1:* For AI/ML enabled positioning accuracy enhancement, all the collaboration levels (Level x/y/z) defined in AI 9.2.1 should be considered.** |
| [17, Nokia] | **Observation-1: For each positioning use-case, different collaboration levels may be considered, depending on the task to be solved for the use-case. For example, a task may be:** * **Training data collection and labeling**
* **Model training**
* **Model refinement, etc.**

**Proposal-1: RAN1 to study use-case-based collaboration levels between gNB and UE. Furthermore, RAN1 may assess whether different collaboration levels may be needed within one use-case for e.g., use-case and task-based collaboration level.****Observation-2: For UE-based positioning where UE is also the node where the training and inference is conducted, there are two scenarios in which a new positioning method could be applied: (1) during the data collection and training phase where the training and testing/validation data has significant amount of noise; and (2) during the inference phase where the input data is noisy or there is high uncertainty related to the flags/indicators estimated by the UE (for e.g., LOS/NLOS flag).****Observation-3: From UE location privacy perspective, it is important to note that in these scenarios, since intermediate features / parameters are reported from the UE to the LMF, the network would still be unaware of the UE location.****Proposal-2: RAN1 to consider LMF-assisted/UE-based as a new positioning method.** |
| [18, InterDigital] | **Proposal 1: Study details of AI/ML models related to collaboration level x (no collaboration), y (signaling-based collaboration without model transfer) and z (model transfer from the network to the UE)****Observation 2: NW-side training allows collection of measurements from diverse UEs, potentially diversifying the training data****Observation 3: MO-LR scenarios require positioning information at the UE, requiring UE-side inference for AIML based positioning****Proposal 2: Study direct AI/ML positioning where at least RSRP, RSRPP for PRS resources and RSTD are used as inputs for AI/ML models****Proposal 3: Study AI/ML assisted positioning where timing measurements are generated based on RSRP fingerprints** |
| [19, Fraunhofer] | **Observation 1: The AI/ML model for measurement enhancements can be trained on simulated data, the AI/ML model resulting from this use case can be generalized.****Observation 2: For Positioning ML approaches trained with environment information a high accuracy is achievable, if the evaluation areas was covered by the training data.****Proposal 5: Prioritize the two sub use case of timing and/or angle of measurement and ML based positioning with heavy NLOS conditions.** |
| [20, Apple] | ***Proposal 2: For both direct AI/ML positioning and AI/ML assisted positioning, a one-sided AI model is sufficient with training and inference occurring at either the gNB/LMF or at the UE. This eliminates the need for model transfer between the UE and Network or vice-versa.*** ***Proposal 3: RAN1 should support the following options:**** ***Inference at the UE***
* ***Inference at the LMF***

***Training can occur at either side with model deployment/transfer enabled only if necessary*** |
| [21, Rakuten] | **Proposal 1: For direct positioning, inference is performed at the UE side.** **Proposal 2: For assisted positioning, inference of the intermediate feature is performed at the UE side. The position estimation is performed at the NW side using the intermediate feature.****Proposal 3: Prioritize single sided AI/ML operation for positioning study.** |
| [22, NVIDIA] | **Observation 1: AI/ML techniques can be used to learn the mapping of RF measurements to position.****Proposal 1: High accuracy positioning in heavy NLOS scenarios should be the target of using AI/ML for positioning enhancement.****Proposal 2: AI/ML techniques used to learn the mapping of RF measurements to position should be studied for positioning enhancement.****Proposal 3: AI/ML techniques used to provide intermediate estimates such as LOS/NLOS classification should be studied for positioning enhancement.****Proposal 4: Sub use cases for AI/ML based positioning are described by functionality that the AI/ML model is intended to fulfill.** **Proposal 5: Sub use cases for AI/ML based positioning based on functionality include:*** **Fingerprinting**
* **LOS/NLOS classification**
* **Other use cases are not precluded**

**Proposal 6: Agree on at least one sub use case as early as possible so that the corresponding specification impact analysis can be carried out.** |
| [23, Samsung] | ***Observation 1: the use cases in which legacy positioning methods cannot work well could be prioritized to check whether AI based methods could work.******Proposal 1: both positioning location estimation and intermediate measurement estimation can be considered as candidate sub use-cases;******Proposal 2: studying the potential spec impact with consideration on training data type/size, determination of source providing input data, measurement data or AI model related configuration exchange if any.*** |
| [24, NTT DoCoMo] | **Proposal 1:****Further study on whether/how the output of an AI/ML assisted positioning model can be applied as the input for another direct AI/ML positioning model.****Proposal 2:****Further down select sub use cases based on at least different specification impacts.****Proposal 3:****Discuss in which side the AI/ML model inference to be deployed considering the applied positioning methods and sub use cases.*** **For LMF based positioning method, AI/ML model at LMF side is preferred.**
* **For UE based positioning method, AI/ML model at UE side is preferred.**

**Proposal 4:****For AI/ML positioning, deprioritize model inference at gNB side.** |
| [25, Qualcomm]  | ***Proposal 1: For the positioning use case, the data is collected by the UE-side and/or the network-side and the training is performed offline.*** ***Proposal 2: For positioning use case, the various methods of interest can be categorized as Level-x or Level-y collaboration depending on the assistance information needed. We do not anticipate the need to study Level-z collaboration for the positioning use case in Rel-18.*** ***Proposal 3: The overall scope of enhancements include:**** ***Direct AI/ML method (ex. RFFP) and AI/ML assisted positioning method (ex. ML-based soft information reporting)***
* ***Assistance data and signaling for data collection, model generation, inference, and life cycle management***
* ***ML enhanced reports mapping to existing report parameters and new parameters (interpretable and non-interpretable features).***

***Observation 1: UE-based and NG RAN node-assisted direct AI/ML methods are already being studied in Rel-18 based on agreements in RAN1 109 and RAN1 110.******Proposal 5: Study the specification impact for the reporting of soft information associated with positioning measurements, derived using machine learning.******Proposal 18: Study multiple ML positioning methods suited to a wide variety of operating conditions as there is no single method that can improve performance in all scenarios.******Proposal 19: Study ML methods and procedures that can enable robust operation to moderate changes in environments (ex. People, furniture movement). Semi-supervised training is one example approach.*** |

## One-sided and two-sided model

In RAN1#109-e, some terminologies were agreed as working assumption to be used for RAN1 AI/ML air interface SI discussion. Some relevant to AI/ML model inference are copied below.

Working Assumption

|  |  |
| --- | --- |
| Terminology | Description |
| UE-side (AI/ML) model | An AI/ML Model whose inference is performed entirely at the UE |
| Network-side (AI/ML) model | An AI/ML Model whose inference is performed entirely at the network |
| One-sided (AI/ML) model | A UE-side (AI/ML) model or a Network-side (AI/ML) model |
| Two-sided (AI/ML) model | A paired AI/ML Model(s) over which joint inference is performed, where joint inference comprises AI/ML Inference whose inference is performed jointly across the UE and the network, i.e, the first part of inference is firstly performed by UE and then the remaining part is performed by gNB, or vice versa. |

In RAN1#110, it was agreed that

Agreement

Study aspects in terms of potential benefit(s) and requirement(s)/specification impact(s) of AI/ML model training and inference in AI/ML for positioning accuracy enhancement considering at least

* UE-side or Network-side training
* UE-side or Network-side inference
	+ Note: model inference at both UE and network side is not precluded where proponent(s) are encouraged to clarify their AI/ML approaches

Note: companies are encouraged to clarify aspects of their proposed AI/ML approaches for positioning when AI/ML model training and inference are not performed at the same entity

Several companies discussed aspects related to AI/ML model inference w.r.t. one-sided and two-sided model.

[1, Ericsson] proposed to focus on one-sided ML functionality and deprioritize two-sided ML functionality, which requires joint training and inference. [1, Ericsson] also proposed to update the terminology for two-sided model so that the more generic term ‘network’ is used instead of ‘gNB’, if two-sided model for positioning is to be discussed. [2, Huawei] proposed that for AI/ML-based positioning, single-sided model should be considered as a starting point. [6, OPPO] proposed that for AI/ML based positioning, not support to study two-side AI/ML model within Rel-18 SI timeline. [7, Google] proposed that the study of AI/ML based positioning should focus on 1-side AI/ML model. [20, Apple] proposed that for both direct AI/ML positioning and AI/ML assisted positioning, a one-sided AI model is sufficient with training and inference occurring at either the gNB/LMF or at the UE. [20, Apple] also proposed that RAN1 should support Inference at the UE and Inference at the LMF, where training can occur at either side with model deployment/transfer enabled only if necessary. [21, Rakuten] proposed to prioritize single sided AI/ML operation for positioning study.

On the other hand, [9, CATT] proposed that for direct AI/ML positioning, both one-sided AI/ML model and two-sided AI/ML model can be considered where two-sided model may be beneficial in resource overhead for transferring the compressed channel observations. [24, NTT DOCOMO] also proposed to further study on whether/how the output of an AI/ML assisted positioning model can be applied as the input for another direct AI/ML positioning model.

Moderator’s observations and comment:

There’re views from multiple companies proposing to focus on one-sided model with the reasons such as simplicity for model development and to avoid model transfer (overhead). However, regarding the latter reasoning, it is moderator’s understanding that current agreed/assumed definitions of one-sided and two-sided (AI/ML) model are only defined by where the AI/ML model inference operation is performed. As such, the definition of one-sided model (for inference) does not limit where the model training occurs.

There’re also views to consider two-sided model as it may be beneficial in resource overhead for transferring the compressed channel observations or to further study it considering potential benefits of both direct and AI/ML assisted positioning where the output of an AI/ML assisted positioning model can be applied as the input for another direct AI/ML positioning model.

It is moderator’s understanding that the discussion of one-sided and two-sided model in general is in the scope of agenda 9.2.1 general framework especially the argument against two-sided model is to avoid model transfer, which itself is again in the scope of agenda 9.2.1. Moderator suggest the following.

##### Discussion point 1-1

* Defer the discussion on prioritization of one-sided vs. two-sided model for AI/ML based positioning until more progress on one-sided and two-sided model discussion in agenda 9.2.1 general framework.
* Companies are encouraged to study and provide input of potential specification impact and other aspects for one-sided and two-sided model specific for AI/ML based positioning in agenda 9.2.4.2.

Companies are encouraged to provide comments.

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| Company Name | Comments/Views |
| OPPO | The proposal seems conflicting with the previous agreement. RAN1 agreement has prioritized one-sided model since it says “support at least UE-side or Network-side inference” and the two-sided model is not precluded.Moreover, the first bullet is quite confusing. What is “more progress” expected to be? Does this bullet indicate AI 9.2.1 to have one common agreement/conclusion on the selection of one-sided and/or two-sided model for all use cases? The selection for different cases has been different so far. For example, two-sided model is supported for CSI compression and one-sided model is supported for BM. Regarding the second bullet, the study should focus on one-sided model. As this bullet suggest to study both one-sided model and two-sided model, if agenda 9.2.1 make decision to prioritize one than the other, then some work on the deprioritized model will be wasted. Since no company oppose one-sided model, the study should focus on it as the current stage.  |
| InterDigital | The first bullet should be sufficient. Regarding the second bullet, if we are waiting for the progress in 9.2.1, we can put the study on hold for now, so the focus is more clear. |
|  |  |

## Model transfer

In RAN1#109-e, the following were agreed.

Agreement

Take the following network-UE collaboration levels as one aspect for defining collaboration levels

1. Level x: No collaboration

2. Level y: Signaling-based collaboration without model transfer

3. Level z: Signaling-based collaboration with model transfer

Note: Other aspect(s), for defining collaboration levels is not precluded and will be discussed in later meetings, e.g., with/without model updating, to support training/inference, for defining collaboration levels will be discussed in later meetings

FFS: Clarification is needed for Level x-y boundary

Agreement

Study further on sub use cases and potential specification impact of AI/ML for positioning accuracy enhancement considering various identified collaboration levels.

* Companies are encouraged to identify positioning specific aspects on collaboration levels if any in agenda 9.2.4.2.
* Note1: terminology, notation and common framework of Network-UE collaboration levels are to be discussed in agenda 9.2.1 and expected to be applicable to AI/ML for positioning accuracy enhancement.
* Note2: not every collaboration level may be applicable to an AI/ML approach for a sub use case

In RAN1#110, it concluded that

Conclusion

Defer the discussion of prioritization of AI/ML positioning based on collaboration level until more progress on collaboration level discussion in agenda 9.2.1.

In RAN1#110, it was agreed that

Agreement

Study aspects in terms of potential benefit(s) and requirement(s)/specification impact(s) of AI/ML model training and inference in AI/ML for positioning accuracy enhancement considering at least

* UE-side or Network-side training
* UE-side or Network-side inference
	+ Note: model inference at both UE and network side is not precluded where proponent(s) are encouraged to clarify their AI/ML approaches

Note: companies are encouraged to clarify aspects of their proposed AI/ML approaches for positioning when AI/ML model training and inference are not performed at the same entity

Several companies discussed aspects on model transfer and/or collaboration Level-y and Level-z.

[2, Huawei] proposed that for UE-side model, the model training/updating and inference are performed all at UE side and for Network-side model, the model training/updating and inference are performed all at Network side. [6, OPPO] proposed that for both direct AI/ML positioning and AI/ML assisted positioning, the AI model training and inference are assumed to be done in the same side in Rel-18, i.e., no model transfer. [25, Qualcomm] proposed that for positioning use case, the various methods of interest can be categorized as Level-x or Level-y collaboration depending on the assistance information needed and do not anticipate the need to study Level-z collaboration for the positioning use case in Rel-18.

[4, Spreadtrum] proposed that for both of direct AI/ML positioning and AI/ML assisted positioning, whether AI/ML model can be delivered or not can wait for the progress of AI9.2.1.

[5, vivo] proposed that when AI/ML model is deployed at UE side, network side should transfer the model information to the target UE. [9, CATT] observed that training AI/ML model for positioning at network side is more feasible due to easier data collection and stronger computational resources. [9, CATT] also proposed that for Rel-18 AI/ML-based positioning, both training and inference at same side and at different sides can be considered. [9, CATT] further proposed to study on full or partial model transfer; data size of model transfer; model transfer frequency for model deployment/update; latency and reliability requirements for model transfer; model representation format (MRF) for model transfer, e.g., ONNX or 3GPP-based model representation format. [10, Fujitsu] proposed to study the model transfer and specific capabilities report/configuration for model deployed in different entities during training and inference. [11, Sony] proposed to study the inference model (e.g., contents, structure, size) to be provided from LMF to UE/gNB. [12, Lenovo] proposed to consider the some additional aspects with respect to the network-UE collaboration levels y and z including the associated sub-levels. [12, Lenovo] also proposed to further study mechanisms to enable efficient positioning AI/ML model transfer between UE, gNB and LMF. [14, CAICT] proposed that for direct AI/ML positioning at UE side, AI model from NW side should be considered. While [16, CMCC] proposed that all collaboration levels defined in AI 9.2.1 can be considered in Rel-18 SI for AI/ML-based positioning. [18, InterDigital] proposed to study details of AI/ML models related to collaboration level x (no collaboration), y (signaling-based collaboration without model transfer) and z (model transfer from the network to the UE). [20, Apple] proposed that training can occur at either side with model deployment/transfer enabled only if necessary.

Moderator’s observation and comment:

Companies’ view on whether to study/consider further on model transfer (i.e., model trained on one side and deployed to the other side for inference) for AI/ML based positioning.

Yes: [5, vivo], [9, CATT], [10, Fujitsu], [11, Sony], [12, Lenovo], [14, CAICT], [16, CMCC], [18, InterDigital]

No: [2, Huawei], [6, OPPO], [25, Qualcomm]

Wait for progress of AI 9.2.1: [4, Spreadtrum]

It is observed that much more companies support to study/consider further on model transfer (i.e., model trained on one side and deployed to the other side for inference).

Note that with or without model transfer is the only difference between collaboration level y and z. Considering the conclusion made in RAN1#110 and the status of discussion in agenda 9.2.1, it’s not worthwhile time wise to discuss prioritization of collaboration levels (e.g., with model transfer or not) for AI/ML based positioning in AI 9.2.4.2 in this meeting. Rather, companies are encouraged to continue study and to provide input on both collaboration level y and z for AI/ML based positioning.

Moderator’s understanding is that the agreement made in RAN1#109-e (i.e., study further on sub use cases and potential specification impact of AI/ML for positioning accuracy enhancement considering various identified collaboration levels) and the conclusion made in RAN1#110 (i.e., defer the discussion of prioritization of AI/ML positioning based on collaboration level until more progress on collaboration level discussion in agenda 9.2.1) still hold and no need to have a new agreement and/or conclusion for this matter.

##### Discussion point 1-2

Companies are encouraged to provide comments.

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| Company Name | Comments/Views |
| OPPO | Agree to defer the discussion to wait for more progress in agenda 9.2.1 |
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## Online and offline training

In RAN1#110, some terminologies were agreed as working assumption to be used for RAN1 AI/ML air interface SI discussion. Some relevant to AI/ML model training are copied below.

Working Assumption

|  |  |
| --- | --- |
| Terminology | Description |
| Online training | An AI/ML training process where the model being used for inference) is (typically continuously) trained in (near) real-time with the arrival of new training samples. Note: the notion of (near) real-time vs. non real-time is context-dependent and is relative to the inference time-scale.Note: This definition only serves as a guidance. There may be cases that may not exactly conform to this definition but could still be categorized as online training by commonly accepted conventions.Note: Fine-tuning/re-training may be done via online or offline training. (This note could be removed when we define the term fine-tuning.) |
| Offline training | An AI/ML training process where the model is trained based on collected dataset, and where the trained model is later used or delivered for inference.Note: This definition only serves as a guidance. There may be cases that may not exactly conform to this definition but could still be categorized as offline training by commonly accepted conventions. |

Regarding online/offline training, [6, OPPO] proposed that for both direct AI/ML positioning and AI/ML assisted positioning, offline training of AI model(s) is prioritized in Rel-18 considering the limited timeline of Rel-18 AI study. [15, Xiaomi] proposed to prioritize the study of offline training on single node for positioning accuracy enhancement since current evaluations are almost all conducted based on offline training on single node and the other training manners are not fully studied and evaluated. [25, Qualcomm] also proposed that for the positioning use case, the data is collected by the UE and/or the network and the training is performed offline for the reason that ML models can be developed and trained in a proprietary manner based on proprietary data collection.

Moderator’s observations and comment:

Reading from the above agreed/assumed definitions of online vs. offline training, it is moderator’s understanding that the definitions of online/offline training are mainly differed by when the dataset for training is collected and used (i.e., (near) real-time or not). There’s also a note on the definition of online training where companies may have different understanding on whether data collection/training for model updating/fine-tuning can be done via online training or not. As agreed in previous RAN1 meetings, model updating/fine-tuning and associated data collection is for further study in this SI.

Furthermore, given this SI may serve as the base for multiple future releases, it is actually beneficial to study pros/cons and potential specification impact of both online and offline training for AI/ML based positioning.

Lastly, given no prioritization has been decided between online vs. offline training in agenda 9.2.1, it seems pre-mature to rule out study on online training for AI/ML based positioning for now in agenda 9.2.4.2.

With the above, moderator thinks the discussion of prioritization of online/offline training for AI/ML based positioning can be de-prioritized in this meeting in agenda 9.2.4.2.

##### Discussion point 1-3

* Defer the discussion of prioritization of online/offline training for AI/ML based positioning until more progress on online vs. offline training discussion in agenda 9.2.1.
* Companies are encouraged to study and provide input on potential specification impact and other aspects of online and/or offline training specific for AI/ML based positioning in agenda 9.2.4.2.

Companies are encouraged to provide comments.

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| --- | --- |
| Company Name | Comments/Views |
| OPPO | Fine with the first bulletRegarding the second bullet, the study should start with offline training. As this bullet suggest to study both offline and online training, if agenda 9.2.1 make decision to prioritize one than the other, then some work on the deprioritized model will be wasted. Since no company oppose offline training, the study should start with it as the current stage. |
| InterDigital | The first bullet should be sufficient. Regarding the second bullet, if we are waiting for the progress in 9.2.1, we can put the study on hold for now, so the focus is more clear. |
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## AI/ML approaches for different positioning methods

In RAN1#110, the following conclusion was reached.

Conclusion

To use the following terminology defined in TS 38.305 when describe their proposed positioning methods

* UE-based
* UE-assisted/LMF-based
* NG-RAN node assisted

Note: companies are required to clarify their positioning method(s) when their approaches do not fall in one of the above.

Several companies discussed combinations of positioning methods with AI/ML positioning approaches.

[1, Ericsson] considered both UE and network side for model inference and proposed a list of positioning methods and corresponding candidate AI/ML approaches for study. Similarly, considering node for model inference, [6, OPPO] also provided a list of positioning method combined with either direct AI/ML positioning or AI/ML assisted positioning. [9, CATT] also provided a list of combinations of positioning methods considering different node for model training and inference. [24, NTT DOCOMO] analyzed specification impact on AI/ML model inference from the perspective of different positioning methods combined with different AI/ML methods.

[24, NTTDOCOMO] thinks no specification impact for UE based positioning for either direct AI/ML or AI/ML assisted positioning. However, it is observed in [17, Nokia] that for UE-based positioning where UE is also the node where the training and inference is conducted, there are two scenarios in which a new positioning method could be applied: (1) during the data collection and training phase where the training and testing/validation data has significant amount of noise; and (2) during the inference phase where the input data is noisy or there is high uncertainty related to the flags/indicators estimated by the UE (for e.g., LOS/NLOS flag). [17, Nokia] proposed to consider LMF-assisted/UE-based as a new positioning method. On the same topic, [25, Qualcomm] proposed to study (noisy) ground truth and measurement error feedback from network for enabling UE-side training data collection for both direct AI/ML and AI/ML assisted methods. [25, Qualcomm] also proposed to study signaling enhancements to include meta data for indicating positioning resources (e.g., PRS) and their configurations that are used to derive the positioning/labels. Furthermore, [25, Qualcomm] proposed to study reusing meta data and labelling assistance used for training data collection to enable monitoring for UE-sided and network-sided monitoring.

Regarding network-side model inference, [24, NTTDOCOMO] proposed to deprioritize model inference at gNB side for its performance has not yet been observed superior to that on LMF side. However, it is observed in [2, Huawei] that for AI/ML assisted positioning such as the LOS/NLOS identification sub use case, gNB-side operation mode can achieve lower latency than LMF-side operation mode.

Moderator’s comment:

Given the possible combinations of AI/ML approaches (direct or AI/ML assisted), UE-side or Network-side model for inference and different positioning methods, it would be helpful to align companies’ understanding on the cases to study.

##### Proposal 1-4

To study and provide inputs on benefit(s) and potential specification impact for the following cases of AI/ML based positioning accuracy enhancement

* Case 1: UE-based positioning with UE-side model, direct AI/ML or AI/ML assisted positioning
* Case 2a: UE-assisted/LMF-based positioning with UE-side model, AI/ML assisted positioning
* Case 2b: UE-assisted/LMF-based positioning with LMF-side model, direct AI/ML positioning
* Case 3a: NG-RAN node assisted positioning with gNB-side model, AI/ML assisted positioning
* Case 3b: NG-RAN node assisted positioning with LMF-side model, direct AI/ML positioning

Companies are encouraged to provide comments.

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| --- | --- |
| Company Name | Comments/Views |
| Samsung | Together with the discussion point 1-5, “moderator does not feel there is sufficient study results nor see a strong motivation to further select between direct AI/ML positioning and AI/ML assisted positioning or to further categorize sub use cases based on model input/output or potential specification impact.”Do the cases listed in the proposal 1-4, further clarify the possible details for direct AI or AI assisted? Or they are served as the new sub-use cases to be down selected? |
| InterDigital | A minor comment. Probably better to include “at least” in the proposal so that we can incorporate other combinations in the future, if they are identified.Proposal 1-4(mod)~~To~~ **S**tudy and provide inputs on benefit(s) and potential specification impact **at least** for the following cases of AI/ML based positioning accuracy enhancement* Case 1: UE-based positioning with UE-side model, direct AI/ML or AI/ML assisted positioning
* Case 2a: UE-assisted/LMF-based positioning with UE-side model, AI/ML assisted positioning
* Case 2b: UE-assisted/LMF-based positioning with LMF-side model, direct AI/ML positioning
* Case 3a: NG-RAN node assisted positioning with gNB-side model, AI/ML assisted positioning
* Case 3b: NG-RAN node assisted positioning with LMF-side model, direct AI/ML positioning
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## Sub use cases

In RAN1#110, the following was agreed.

Agreement

For characterization and performance evaluations of AI/ML based positioning accuracy enhancement, the following two AI/ML based positioning methods are selected.

* Direct AI/ML positioning
* AI/ML assisted positioning
* Note 1: the selection does not intend to provide any indication of the prospects of any future normative project.
* Note 2: further discussion (including selection of other sub use cases and/or down selection of selected sub use cases) are not precluded based on performance evaluation and potential specification impact study results

Several companies expressed their views on further down selection of sub use cases.

[3, ZTE] proposed that further sub-use case classification for direct AI/ML positioning and AI/ML assisted positioning should be based on AI model input and AI model output respectively. [22, NVIDIA] proposed that sub use cases for AI/ML based positioning are described by functionality that the AI/ML model is intended to fulfil. [24, NTT DOCOMO] proposed further down select sub use cases based on at least different specification impacts.

[5, vivo] proposed that no need to consider other sub use case(s) as representative or to down select between direct AI/ML positioning and AI/ML assisted positioning during this SI for performance and potential specification impact study. [10, Fujitsu] proposed that the selected two sub use cases are sufficient for the evaluation and related framework or specification impact study at this stage. [13, NEC] proposed that the sub use cases of positioning accuracy enhancements should include the scenarios of existing synchronization error between service TRP and reference TRP and heavy NLOS scenarios. [17, Nokia] observed that the scenario dependence of AI/ML models and related specification impacts would mainly depend on whether direct or AI/ML assisted positioning is used, and the type of positioning method applied (for e.g., UE-based, UE-assisted/LMF-based or NG-RAN node assisted). [19, Fraunhofer] proposed to prioritize the two sub use case of timing and/or angle of measurement and ML based positioning with heavy NLOS conditions. [25, Qualcomm] proposed to study multiple ML positioning methods suited to a wide variety of operating conditions as there is no single method that can improve performance in all scenarios.

Moderator’s observation and comment:

Based on the available performance evaluation results of direct AI/ML positioning and AI/ML assisted positioning, both AI/ML based positioning methods show significant performance benefits in evaluated scenarios with different model input and output. In particular, evaluation results of direct AI/ML positioning and AI/ML assisted positioning showed they could be suitable for different scenarios.

There’re some high level proposals (mostly for further study of details) on potential specification impact for both direct AI/ML positioning and AI/ML assisted positioning. To the best knowledge of moderator, there’s no convincing study results of potential specification impacts showing why further down selection of sub use cases is necessary.

With companies’ contributions to this meeting, moderator does not feel there is sufficient study results nor see a strong motivation to further select between direct AI/ML positioning and AI/ML assisted positioning or to further categorize sub use cases based on model input/output or potential specification impact.

##### Discussion point 1-5

Companies are encouraged to provide comments.

|  |  |
| --- | --- |
| Company Name | Comments/Views |
| Samsung  | No issue to defer down selection, just see our comments in proposal 1-4, we want to be clear on what are to be potentially down selected from.  |
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# Potential specification Impact

In this section, we provide a summary of issues, observations and proposals related to specification impact for positioning accuracy enhancements in the submitted contributions.

As in the SID, the related objectives are the following.

|  |
| --- |
| Study the 3GPP framework for AI/ML for air-interface corresponding to each target use case regarding aspects such as performance, complexity, and potential specification impact.Use cases to focus on: * Initial set of use cases includes:
	+ CSI feedback enhancement, e.g., overhead reduction, improved accuracy, prediction [RAN1]
	+ Beam management, e.g., beam prediction in time, and/or spatial domain for overhead and latency reduction, beam selection accuracy improvement [RAN1]
	+ Positioning accuracy enhancements for different scenarios including, e.g., those with heavy NLOS conditions [RAN1]
* Finalize representative sub use cases for each use case for characterization and baseline performance evaluations by RAN#98
	+ The AI/ML approaches for the selected sub use cases need to be diverse enough to support various requirements on the gNB-UE collaboration levels

Note: the selection of use cases for this study solely targets the formulation of a framework to apply AI/ML to the air-interface for these and other use cases. The selection itself does not intend to provide any indication of the prospects of any future normative project. For the use cases under consideration:1. Assess potential specification impact, specifically for the agreed use cases in the final representative set and for a common framework:
	* PHY layer aspects, e.g., (RAN1)
		+ Consider aspects related to, e.g., the potential specification of the AI Model lifecycle management, and dataset construction for training, validation and test for the selected use cases
		+ Use case and collaboration level specific specification impact, such as new signaling, means for training and validation data assistance, assistance information, measurement, and feedback
	* Protocol aspects, e.g., (RAN2) – RAN2 only starts the work after there is sufficient progress on the use case study in RAN1
		+ Consider aspects related to, e.g., capability indication, configuration and control procedures (training/inference), and management of data and AI/ML model, per RAN1 input
		+ Collaboration level specific specification impact per use case
	* Interoperability and testability aspects, e.g., (RAN4) – RAN4 only starts the work after there is sufficient progress on use case study in RAN1 and RAN2
		+ Requirements and testing frameworks to validate AI/ML based performance enhancements and ensuring that UE and gNB with AI/ML meet or exceed the existing minimum requirements if applicable
		+ Consider the need and implications for AI/ML processing capabilities definition

Note 1: specific AI/ML models are not expected to be specified and are left to implementation. User data privacy needs to be preserved.Note 2: The study on AI/ML for air interface is based on the current RAN architecture and new interfaces shall not be introduced. |

## Individual observations/proposals

The following are individual observations and proposals from the contributions.

|  |  |
| --- | --- |
| Sources | Observations/proposals |
| [1, Ericsson] | **Proposal 8 Study potential standard impacts of introducing AI/ML models for positioning: reference signal configurations for collecting data for model training, inference and monitoring; signaling to collect assistance information; and signaling and configuration to support data logging and reporting.**  |
| [2, Huawei] | ***Proposal 4: Potential spec impact of collecting data from PRUs should be studied.**** + ***Including signaling and PRU capability.***

***Proposal 5: Study the potential spec impact of data collection from realistic network for supporting the model training and updating of AI/ML model, including at least:**** + ***Feedback of channel measurements (e.g., CIR, CFR, PDP) to LMF***
	+ ***Signaling for indicating/requesting high-quality data collection***

***Observation 1: For AI/ML-based positioning, ground-truth labels of LOS/NLOS tags or UE real coordinates for AI/ML model training can be obtained by positioning reference units.*** |
| [3, ZTE] | ***Proposal 4:*** *Support UE/TRP to report more than 8 additional path timings and RSRPPs.****Proposal 5:*** *Support UE/TRP to report path phase of a channel path in addition to path power and path timing.****Proposal 6:*** *Study and support multi-port PRS in order to provide diverse channel observations for AI model inference.****Proposal 7:*** *For AI/ML assisted positioning, the AI model for intermediate output should consider the accessibility to ground-truth labels.* ***Proposal 8:*** *Study and support AI/ML based DL-RSTD estimation to increase accuracy and reliability.****Proposal 9:*** *Study and support AI/ML based LOS/NLOS identification to increase confidence level.****Proposal 10:*** *Study and support an AI/ML based DL PRS-RSRPP estimation to increase accuracy and reliability.* |
| [4, Spreadtrum] | ***Observation 2: The integrity mechanism can be considered as one tool to evaluate/monitor the performance of AI/ML model.******Proposal 1: Support to utilize PRU to achieve ground truth label.******Proposal 2: Suggest to consider training data without labels.*** ***Proposal 3: New measurement metric and reporting, depending on the input/output and the location of AI/ML model, can be studied.******Proposal 4: Whether/How to define/reflect the complexity of the AI/ML operation in the specification can be studied.******Proposal 5: The better generalization of AI/ML model should be strived, to avoid frequent AI/ML model updating.*** |
| [5, vivo] | 1. Support time domain CIR as one model input for training of AI/ML model for positioning.
2. Study signaling, procedures and assistance information for data collection for both cases where measurement is conducted at UE side and at the network.
3. Real-time on-device model training with a large-scale dataset should be avoided at UE side.
4. When AI/ML model is deployed at UE side, network side should transfer the model information to the target UE.
5. Model information should contain meta-information indicating the physical and network environment or condition under which the model is suitable for operation.
6. The process of model activation and deactivation is needed to flexibly control the model's lifecycle, so as to ensure positioning performance.
7. Network side could send a model selection instruction to instruct the target UE to select a suitable model from the model pool, when the current model does not work well.
8. The assistance information from network side is required to support model monitoring at UE side.
9. The assistance information from UE side is required to support model monitoring at network side.
10. The possible AI/ML model monitoring performance metrics are listed as follows：
* **Forward extrapolation**
	+ **Environment monitoring, such as by visual sensors deployed at factories.**
	+ **Long-term CSI statistic**
	+ **Long-term SNR statistic**
	+ **Long-term synchronization error detection**
	+ **PRS configuration matching**
	+ **Other possible features**
* **Backward extrapolation**
	+ **Long-term inference error (location or other intermediate features)**
1. Dedicated reference signals may be required to obtain performance metrics so as to support model monitoring.
2. When fine-tuning is conducted at UE side, UE capability corresponding to fine-tuning is required.
3. To enable model fine-tuning when AI/ML model inference is at UE side, support assistance information to the target UE about pre-trained model and training configuration.
4. Training data collection request for model fine-tuning and feedback from the target UE is required to support model fine-tuning at network side.
5. The result of model monitoring and the achievability of model updating should be jointly considered as the condition of model updating.
6. Support time domain CIR as one model input for AI/ML based positioning.
7. For direct AI/ML positioning, when model inference is at network side, request to and feedback from the target UE of the necessary measurement (e.g., as the input to the AI/ML model) for model inference is needed.
8. For AI/ML assisted & UE assisted positioning, support the target UE to report the output of AI/ML model inference (intermediate feature for positioning) when model inference is at UE side.
9. For AI/ML assisted positioning, when model inference is at network side, request to and feedback from the target UE of the necessary measurement (e.g., as the input to the AI/ML model) for model inference is needed.
10. A general model management procedure should be specially studied for AI/ML based positioning accuracy enhancement.
11. Support to study the detailed assistance signaling configuration when the model management procedure for AI/ML based positioning is agreed.
 |
| [6, OPPO] | ***Proposal 4: If UE-based or UE-assisted positioning method is used, regarding the data collection for AI model training, study the feasibility/mechanism that the measurement results with associated ground-truth labels are obtained via PRU**** ***Applicable to both model training at UE side and model training at NW side***

***Proposal 5: If NG-RAN node assisted positioning method is used, regarding the data collection for AI model training, study the feasibility/mechanism that the measurement results are reported from TRP and the associated ground-truth labels are obtained via PRU**** ***Applicable to model training at NW side***

***Proposal 6: For the data collection used for AI model inference**** ***When direct AI/ML positioning is used for UE-assisted positioning method, the target UE will report the measurement results to LMF***
	+ ***FFS: type of measurement, RS configuration for measurement***
* ***When direct AI/ML positioning is used for UE-base positioning method or AI/ML assisted positioning is used for UE-assisted positioning method, the UE will collect measurement for the input of AI model***
	+ ***If the model is trained at the same side, the inputs/data collection are up to UE implementation and transparent from the perspective of air interface***
	+ ***If the model is trained at NW side and AI model inference is carried out at UE side, the size/contents of inputs will need to be pre-defined or pre-configured.***
* ***When direct AI/ML positioning is used for NG-RAN node assisted positioning method, the TRP will report the measurement results to LMF***
* ***When direct AI/ML positioning or AI/ML assisted positioning is used for NG-RAN node assisted positioning method, the TRP will collect measurement for the input of AI model***

***Proposal 10: For AI/ML based positioning,*** * ***if UE-based positioning method is used, study the following aspect on spec impact***
	+ ***whether additional information (e.g., confidence of the AI estimated location) is needed or not on top of location information (LPP signaling from UE to LMF)***
* ***if UE-based positioning method is used, study the following aspects on spec impact***
	+ ***whether/what new type of measurement /reporting (LPP signaling from UE to LMF)***
	+ ***whether/what enhancement for existing reporting (e.g., finer granularity for the measurement result quantization) (LPP signaling from UE to LMF)***
	+ ***whether/what enhancement for measurement/reporting triggering/configuration (LPP signaling from LMF to UE)***
* ***if NG-RAN node assisted positioning method is used, study the following aspects on spec impact***
	+ ***whether/what new type of measurement /reporting (NRPPa signaling from gNB to LMF)***
	+ ***whether/what enhancement for existing reporting (e.g., finer granularity for the measurement result quantization) (NRPPa signaling from gNB to LMF)***
	+ ***whether/what enhancement for measurement/reporting triggering/configuration (NRPPa signaling from LMF to gNB)***

***Proposal 11: For AI/ML based positioning, study from which side/component the data are collected for AI model monitoring*** * ***If PRU is utilized to collect data for AI model performance monitoring, further study is needed to evaluate/justify whether the performance of the same AI model for PRU and a given UE in different locations are the same or similar.***

***Proposal 12: For UE-based positioning method, collaboration level x is prioritized for direct AI/ML positioning in Rel-18**** ***FFS: level y, e.g., signaling for model monitoring***

***Proposal 13: For UE-assisted positioning method, collaboration level x is prioritized for direct AI/ML positioning if the AI model is based on existing measurement and reporting (e.g., the scheme “Direct: DL RSTD +RSRP”)******Proposal 14: For UE-assisted positioning method, collaboration level y is prioritized for direct AI/ML positioning if the AI model is based on new type(s) of UE measurement/reporting (e.g., the scheme “Direct: Normalized CIR + RSRP”)******Proposal 15: For UE-assisted positioning method, collaboration level x is prioritized for AI/ML assisted positioning in Rel-18 if the outputs of AI model are some existing type(s) of UE measurement (e.g., the scheme “Assisted: an existing type of measurement”)**** ***FFS: level y, e.g., signaling for model monitoring***

***Proposal 16: For UE-assisted positioning method, collaboration level y is prioritized for AI/ML assisted positioning if the outputs of AI model are some new type(s) of UE measurement (e.g., the scheme “Assisted: a new type of measurement”)***Table 3: Potential spec impact(s) and collaboration level(s)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **AI schemes/ sub use cases**  | **Positioning method** | **Model** | **Potential impact on NR specifications** | **Collaboration level****between NW and UE** |
| direct AI/ML positioning | UE-based | UE-side model | whether additional information (e.g., confidence of the AI estimated location) is needed or not on top of location information (LPP signaling from UE to LMF) | Level xFFS: level y |
| direct AI/ML positioning based on existing measurement/reporting (e.g., “Direct: DL RSTD + RSRP”) | UE-assisted | Network-side model | whether/what enhancement for existing reporting (e.g., finer granularity for the measurement result quantization) | Level xFFS: level y |
| direct AI/ML positioning based on new measurement/reporting (e.g., “Direct: Normalized CIR + RSRP”) | UE-assisted | Network-side model | 1. New signaling for the configuration of new type of measurement and reporting
2. New reporting format
3. New type of measurement at UE side and corresponding requirement(s)
 | Level y |
| AI/ML assisted positioning based on existing type(s) of UE measurement/reporting (e.g., “Assisted: an existing type of measurement”) | UE-assisted | UE-side model (Stage 1) | / | Level xFFS: level y |
| AI/ML assisted positioning based on new type(s) of UE measurement/reporting (e.g., “Assisted: a new type of measurement”) | UE-assisted | UE-side model (Stage 1) | 1. New signaling for the configuration of new type of measurement and reporting
2. New reporting format
3. New type of measurement at UE side and corresponding requirement(s)
 | Level y |
| Note: Any potential spec impact of life cycle management is not included here. |

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| [7, Google] | ***Proposal 4: The AI/ML model training and indication should be transparent.******Proposal 5: Study to report the CIR and L1-SINR for multiple cells as the input for AI/ML for positioning in network side.******Proposal 6: Study the CIR compression operation with regard to CIR feedback overhead.*** |
| [8, LG] | **Observation #1: In Rel-17, LOS/NLOS indication for first path can be reported but the detailed algorithm is up to UE implementation (reliability issue per UE).****Observation #2: When LMF can predict UE location with mobility, it is possible that which UE can be used as PRU, the LMF can use the UE dynamically as PRU to calculate the position of target UE.****Proposal #1: Consider AI/ML model fine-tuning or update/transfer based on model monitoring performance metric by taking into account the intermediate performance and output performance together.****Proposal #2: Consider assistant information including LOS probability and/or reliability information for the AI/ML based LOS/NLOS identification.** **Proposal #3: Consider PRS priority configuration based on AI/ML based LOS/NLOS indication.****Proposal #4: Consider PRU prediction on NW-/UE-side based on measurement report in addition to PRU identification and/or assistance information utilized for PRU determination.** |
| [9, CATT] | **Proposal 3: Regarding data collection for AI/ML model training, PRU is at least used to collect channel observations and the ground truth labels. Whether and how to use the partial and/or noisy ground truth labels to improve the performance of AI/ML model can be further studied.****Proposal 4: If AI/ML model is trained at UE/PRU/TRP side, LMF side can collect a large-scale dataset from numerous UEs/PRUs/TRPs and transmits the dataset to UE/PRU/TRP side for AI/ML model training.****Proposal 5: If AI/ML model is inferred at LMF side, the channel observation is measured at UE/gNB/TRP side and transmitted to LMF side for AI/ML model inference.****Proposal 6: For Rel-18 AI/ML-based positioning, both training and inference at same side and at different sides can be considered.****Proposal 7: Regarding the model transfer, the following aspects can be further studied in RAN1:*** **Full or partial model transfer;**
* **Data size of model transfer;**
* **Model transfer frequency for model deployment/update;**
* **Latency and reliability requirements for model transfer;**
* **Model representation format (MRF) for model transfer, e.g., ONNX or 3GPP-based model representation format.**

**Proposal 8: Regarding the model transfer, the signaling and model representation format can be further studied in RAN2 based on RAN1 progress.****Proposal 9: Regarding the model monitoring, which side takes responsibility on model monitoring, e.g. UE/PRU/TRP/LMF side, should be studied.****Proposal 10: Regarding the model monitoring for direct AI/ML positioning, the following metrics can be further studied in RAN1:*** **Positioning accuracy between UE’s position estimated by AI/ML model and ideal UE’s position.**

**Proposal 11: Regarding the model monitoring for AI/ML assisted positioning, the following metrics can be further studied in RAN1:*** **Accuracy between timing/angle of measurements estimated by AI/ML model and ideal timing/angle of measurements;**
* **Positioning accuracy between UE’s position calculated by AI/ML-based timing/angle of measurements and ideal UE’s position;**
* **Correct rate of LOS/NLOS estimated by AI/ML model and ideal LOS/NLOS identification;**
* **Positioning accuracy between UE’s position calculated by AI/ML-based LOS/NLOS identification and ideal UE’s position.**
 |
| [10, Fujitsu] | ***Observation 1: The LOS/NLOS detection/classification is essential for positioning label obtaining.******Proposal 2 Study the LOS/NLOS indication enhancement and related data collection framework details on the basis of release 17.******Proposal 3 The study of the usage/enhancement of the PRU for the label collection of AI/ML positioning may be deprioritized at this stage, otherwise a specific discussion topic should be setup for it.******Proposal 4 Study the model transfer and specific capabilities report/configuration for model deployed in different entities during training and inference.*** |
| [11, Sony] | [**Observation 1: The multiple paths reporting from UE/TRP to LMF as a feature in rel-17 could assist network-side (e.g., LMF) to make its own decision on LOS path selection.**](#_Toc115173072)[**Observation 2: The procedure of AI/ML for positioning can be at least divided in three phases:**](#_Toc115173073)1. **Data collection with data processing and validation,**
2. **Model Training and updating,**
3. **Model deployment.**

[**Observation 3: The channel observation (e.g., in a form of CIR, SNR, RSRP) is used as part of the data collection in the creation of training model**](#_Toc115173074)[**Proposal 1: Consider supporting network-side training (e.g., LMF) to create and train AI/ML model for NLOS mitigation.**](#_Toc115173058)[**Proposal 2: Support channel observation as part of the data collection from UE and gNB for downlink and uplink-based positioning, respectively.**](#_Toc115173059)[**Proposal 3: Support the usage of PRU for AI/ML Positioning.**](#_Toc115173060)[**Proposal 4: Support AI/ML Positioning with UE-side inference.**](#_Toc115173061)[**Proposal 5: Study the inference model (e.g., contents, structure, size) to be provided from LMF to UE/gNB.**](#_Toc115173062) |
| [12, Lenovo] | ***Proposal 5: In terms of data collection, further study the mechanisms to trigger and configure a PRU for ground truth data collection.******Proposal 6: RAN2/RAN3 to further study signalling exchange support for AI/ML positioning model management and inference model parameters. This does not preclude the study of the impacts of AI/ML model management and inference parameters in RAN1.******Proposal 7: Further study mechanisms to enable efficient positioning AI/ML model transfer between UE, gNB and LMF.******Proposal 8: Study positioning capability support of AI/ML-based positioning depending on the supported network-UE collaboration levels.*** |
| [13, NEC] | **Proposal 7:** *The real position-related characteristic of collected data set for model training and model monitoring aimed at positioning with synchronization error can refer to the current method of multi-RTT to obtain the RSTD without synchronization through transformation.* |
| [14, CAICT] | ***Proposal 3: For LMF-Based direct AI/ML positioning, PRU could be considered to assist NW to make AI model training and update.*** ***Proposal 4: Some assistant information could be considered from NW side to assist UE side AI/ML model updating.*** ***Proposal 5: In order to support the monitoring of AI model, positioning results exchanging between UE and NW could be considered.*** |
| [15, Xiaomi] | **Observation 1:*** **If model generation is on the network side, the following specification impact is potentially involved for training phase**
* **UE capability for the data collection**
* **Data collection configuration**
* **Collected data report**
* **If model generation is on the UE side or UE’s external server, no specification impact is foreseen for training phase**

**Observation2: when AI models are provided by the network and the inference node is LMF, interaction to assist the AI model selection may be needed** **Observation 3: AI model is pre-deployed on the UE and the inference node is UE*** **Interaction to assist the AI model selection may be needed**
* **Model registration may be needed**

**Observation 4: When AI model is provided by the network and the inference node is UE*** **Interaction for the AI model selection may be needed**
* **Model transfer is needed**

**Observation 5: When inference is on the UE side and the positioning RS is PRS , no specification impact is foreseen for the inference phase****Observation 6: When inference is on the network side and the positioning RS is PRS, new signalling to feedback the input of the inference may be needed for the inference phase****Observation 7: When inference is on the network side and the positioning RS is SRS , no specification impact is foreseen for the inference phase****Proposal 2: Discuss the metrics for performance monitoring first**  |
| [16, CMCC] | ***Proposal 2:* For AI/ML based positioning, the potential spec impact of CIR report should be studied.*****Proposal 3:* For AI/ML based positioning, whether it is feasible to obtain the ground-truth labels via PRUs is related to the required training dataset size.** ***Proposal 4:* For AI/ML based positioning, the following two different options can be considered for model monitoring.*** **Option1: The metrics of performance monitoring is based on the ground-truth labels**
* **Option2: The metrics of performance monitoring is based on non-ideal results, e.g, the results of traditional positioning techniques, or the previous results of AI/ML model**

***Proposal 5:* For AI/ML based positioning, the relationship between model monitoring and positioning integrity should be considered.**  |
| [17, Nokia] | **Observation-4: For ML model training, the data has different value or importance in improving an AI/ML model’s estimation accuracy.****Proposal-3: RAN1 to study further potential impacts on data quality and on demand data labelling and selection.****Observation-5: in ML model training, training efficiency in terms of accuracy climbing versus training data is sensitive to the training dataset quality.** **Proposal-4: Model training, retraining or finetuning can be triggered when the model detects LOS/NLOS estimation uncertainty and subsequentially new data is labelled on-demand.** **Observation-6: Answering the noisy label problem is expected to be use-case dependent and may require some assistance from the network. For example, the network may provide a set of rules for label quality evaluation, where the network may indicate one or more rules to reject/accept a sample with one or several noisy labels.** **Observation-7: The potential specification impact from noisy ground truth labels during the data collection and model training phase could depend on whether UE-side or network-side training is considered.****Observation-8: For network-side training, label correction/modification could be done without any specification impacts, as long as the network has sufficient information related to the location of the PRUs.****Proposal-5: RAN1 to study further potential impacts from network assistance required for UE-side training with noisy labels.****Observation-9: The AI/ML model deployed at UE used for positioning could be vendor specific or proprietary algorithm (e.g., black box).****Observation-10: The challenges related to AI/ML model training related to dataset collection, quality and required network assistance could be addressed with the help of additional synthetic data or data augmentation.****Observation-11: AI/ML model generalization can be realized on the variations of the dataset on the same site/area but for unseen UE locations thanks to the use of DA technique.****Proposal-6: RAN1 to further study AIML model performance aspects considering data augmentation solutions and their possible specifications impact.****Observation-12: Considerations related to RF limitations translate into an additional phase rotation and delays of the positioning signal by the RF chain, as observed at the baseband receiver. As a result, a positioning entity (UE, TRP, etc.) hosting the ML positioning function experiences certain RF-based signal distortions which are not considered when training the model and are wrongly absorbed into the positioning measurement. Such imperfections are different for different host type devices, for example a PRU or gNB hosting the model would require adapting the model to their own RF-specific characteristics.****Proposal-7: RAN1 to consider a framework for positioning, through which the generic ML positioning model is customized to the specific NR elements host types - including target UE, PRU, or gNBs.****Proposal-8: RAN1 to consider model refinement (monitoring/update) to be coordinated by the LMF with the support of the units where inference is expected to be conducted. RAN1 to assess the necessary support information that the units may provide to the LMF, depending on where the model refinement is performed.** **Observation-13: The AI/ML model deployed at UE used for positioning could be implementation-specific.****Observation-14: Labelled Ground truth data (for e.g., provided by PRU) is required to monitor the AI/ML model to increase the confidence of the model.****Observation-15: In the scenario where the UE moves to a new network coverage area or to a different region within the same network which possibly might impact the model performance, the UE could request the LMF to share possible ML test or validation data, which is then used to monitor model performance.****Proposal-9: RAN1 to study further solutions for the monitoring and update of UE-based AI/ML model by employing PRU measurement and their corresponding labelled ground truth.** **Observation-16: There is significant scenario dependence – in terms of data used for model training as well as the overall radio environment in terms of clutter and NLOS occurrence.****Proposal-10: RAN1 to study further performance metrics and model update criteria that enable the network and the UE to determine the appropriate positioning approach, depending on KPIs such as positioning accuracy and QoS, as well as UE capabilities.****Observation-17: The scenario dependence of AI/ML models and related specification impacts would mainly depend on whether direct or AI/ML assisted positioning is used, and the type of positioning method applied (for e.g., UE-based, UE-assisted/LMF-based or NG-RAN node assisted).****Observation-18: For UE-based positioning method, the network could provide assistance information in terms of whether direct or AI/ML assisted positioning method could provide better performance in a given scenario, and in some cases where UEs have limited AI/ML capabilities, new positioning methods such as the LMF-assisted/UE-based approaches could also be considered where the AI/ML model could be hosted at the LMF, providing assistance information to the UE for localization.****Proposal-11: RAN1 to further study mechanisms for signaling model and AI/ML based positioning method update, due to various criteria such as mobility and positioning accuracy estimation quality deterioration.****Proposal-12: RAN1 to discuss and agree whether switching the AI/ML based positioning method could be considered as model update.****Observation-19**: **LOS/NLOS classification using AI/ML depends on the environmental setting as well as the bandwidth capabilities of the UE.****Observation-20: For optimal NLOS/LOS classification, the channel features used may not be static but dynamically updated based on the identified environmental conditions and UE capabilities.****Proposal-13: Network should be able to assist UE for LOS/NLOS classification by means of providing to the UE a ranked list of channel features. The ranked list should based on the UE bandwidth capabilities as well as the environmental setting.** **Proposal-14: RAN1 to consider and agree on possible extensions to LPP protocol with enhanced assistance data.****Proposal-15: Study required signaling mechanisms between the network entities (e.g., UE and LMF) to support requesting/responding for selecting anchor(s) for a positioning session, indication of a reward metric to train a reinforcement learning (RL) model for the anchor selection, as well as exchange of information required to construct the state that is input to the RL model.** |
| [18, InterDigital] | **Observation 1: During training of an AIML model, exchange of assistance information may be required****Proposal 4: For UE-based inference generation, study a framework to initiate direct AI/ML positioning where the network can trigger training and/or inference generation at the UE****Proposal 5: For UE-based/assisted positioning, study a framework to initiate AI/ML assisted positioning where the network can trigger training and/or inference generation at the UE****Proposal 6: Study a framework to monitor for possible degradation in AIML performance** **Observation 4: Ground truth label associated with UE location can be associated with quality/uncertainty of a location estimate****Proposal 7: Support different labels for information associated with PRU and non-PRU (e.g., normal UE)****Proposal 8: Support labels associated with uncertainty of the ground truth**  |
| [19, Fraunhofer] | **Proposal 1: Support signaling and reporting enhancements on LPP / NRPPa to enable ML measurement approaches for accuracy improvements of both UE-based and LMF-based positioning.****Proposal 2: Study the reporting enhancements to enable ML measurement accuracy including IQ reporting and selection criteria for the additional path reporting.** **Proposal 3: Study improvements by introducing calibration and association spots (ACS) for AI/ML model operation, maintenance and verification.****Proposal 4: Study in Rel-18 the following aspects to support AI/ML in challenging positioning environments:** * + **Additional reporting for environment information in processing and training phase**
	+ **Identification of AI/ML assisted areas**
	+ **Additional signaling needed for making use of Virtual-TRPs**
	+ **Temporal PRUs/anchors to enhance accuracy and maintain the AI/ML model**
 |
| [20, Apple] | ***Proposal 1: The following specification impacts can be seen in the use cases under consideration:*** * ***Direct AI/ML based positioning model***
	+ ***Sub-Use case 1: CIR / PDP/L1-RSRP input to UE position output***
		- ***Potential spec impact:***
			* ***Channel measurement information for multiple gNBs for training***
			* ***Channel measurement information for multiple gNBs for inference***
			* ***Calibration input and procedures to validate the AI model***
			* ***Ground truth label assistance information to the inference device***
* ***AI-assisted positioning with output of AI model serving as input to traditional positioning***
	+ ***Sub-Use case 2: LOS/NLOS tap identification for input to traditional positioning***
		- ***Potential spec impact:***
			* ***indication of LOS/NLOS probability. This may already be supported in Rel-17***
			* ***Channel measurement information for inference***
			* ***Channel measurement information for training***
	+ ***Sub-Use case 3: TOA/AoA/AoD estimation for input into TDOA-based, AoA-based or AoD-based positioning***
		- ***Potential spec impact:***
			* ***Possible signaling of the TOA rather than the TDoA to LMF***
			* ***Channel measurement information for inference***
			* ***Channel measurement information for training***

***Proposal 4: The following table discusses the specification impact of different elements of the AI-based positioning:***

|  |  |
| --- | --- |
| AI/ML model training | * **training data type/size:** Given the current sub-use cases selected, RAN1 should allow for flexibility in the data type needed e.g for direct AI/ML based positioning, the CIR, L1-RSRP and PDP can be used.
* **training data source determination (e.g. UE/PRU/TRP):** For online training, this depends on if the training/inference is at the UE or at the LMF/gNB. It may also depend on beam correspondence i.e. if channel is reciprocal and model is at the LMF/gNB. In the case of beam correspondence, the channel estimates at the gNB based on DMRS/SRS may be sufficient otherwise some feedback may be needed.
* **assistance signalling and procedure for training data collection :** This depends on if the training/inference is at the UE or at the LMF/gNB. It may need LPP/NRPPa based signaling to trigger feedback of training data to the training device. In addition, some assistance information may be needed for noisy ground truth labels.
 |
| AI/ML model indication/configuration | **Model Indication:** Signaling is needed to enable selection of AI/ML model to configure AI/ML model to be used e.g. to indicate training data needed from UE, or actual sub-use cases to be trained. Even for a specific sub-use case, multiple AI models may be trained for a a specific parameter value or value range(for example based on Doppler) and then the appropriate model is indicated based on the specifics of the UE whose position is to be estimated.**Model Configuration:** A discussion may be needed on how to configure the one or more AI models at the interference device and the associated configuration information needed in the network to provide training data. |
| AI/ML model monitoring and update | **Monitoring :** The traditional location services, PRUs or GPS-based location may be used to calibrate the AI-based location and vice versa. As an example, the calibration location [X,Y] can be based on (a) any of the RAT-independent techniques (e.g. GNSS) or (b) RAT-dependent techniques (e.g. TDOA) defined in 3GPP Rel-16 and Rel-17. **Update:** The calibration error may serve as input into AI model update rate decision and if the calibration error > **calibration error threshold** for **time > calibration time duration**, then an AI model update can be requested. The update signaling may have specification impact. |
| AI/ML model inference input | **Inference Input:** model input acquisition and pre-processing will depend on if the AI model is UE based, network based and on beam correspondence. In a simple example, for the direct method with training and inference at the gNB and beam correspondence, the LMF may indicate SRS configurations for the gNBs to transmit to the UE and request feedback of the channel measurements from the gNBs at the appropriate time.  |
| UE capability for AI/ML model(s) | **Capability Signaling:** This is necessary for the UE to indicate its capability for AI-based positioning. It can include (a) the type of AI positioning it supports i.e. direct AI/ML and AI/ML assisted positioning (and the associated feedback) (b) whether it supports UE-based AI inferencing and training or not (c) the location scenario e.g. high Doppler, high NLOS. |
| UE-side or Network-side trainingUE-side or Network-side inference | **Signaling and capability support:** If both are supported by the specification, capability signaling may be needed to help the network/LMF identify the UE preference and to configure the UE for the appropriate location and associated procedure for the training and inference.  |

 |
| [22, NVIDIA] | **Proposal 7: For AI/ML model training for positioning enhancements, study potential specification impact related to training data type/size, training data source determination, and assistance signalling and procedure for training data collection at UE side or network side.****Proposal 8: For AI/ML model training for positioning enhancements, study potential specification impact related to ground truth label determination and noisy level of the ground truth labels.** **Proposal 9: For AI/ML based positioning enhancements, study potential specification impact related to assistance signalling and procedure for model configuration, model activation/deactivation, model recovery/termination, and model selection.****Proposal 10: For AI/ML based positioning enhancements, study potential specification impact related to assistance signalling and procedure for model performance monitoring and model update/tuning, including monitored metrics, triggers for model update, dedicated reference signals, measurements, and feedback report.****Proposal 11: For AI/ML based positioning enhancements, study potential specification impact related to report/feedback of model input for inference, type of model input, and model input acquisition and pre-processing for UE side or network side inference.****Proposal 12: For AI/ML based positioning enhancements, study potential specification impact related to report/feedback of model inference output and post-processing for UE side or network side inference.****Proposal 13: For AI/ML based positioning enhancements, study potential specification impact related to UE capability for AI/ML based beam prediction including model training, model inference and model monitoring.** |
| [23, Samsung] | ***Proposal 3: RAN1 to study the training data collection criteria, e.g., the qualified training device determination.******Proposal 4: Current signaling framework of the measurement-report could be used as starting point to enable training data collection******Proposal 5: RAN1 to study the validation of the trained/obtained AI/ML model before actually apply it.*** ***Proposal 6: RAN1 to study the condition/methods to recovery/update a AI/ML model for positioning, e.g., event based condition or timer/counter based condition.*** |
| [24, NTT DoCoMo] | **Proposal 5:****The ground truth label can be UE coordinate and/or intermediate value with timing information.****Proposal 6:****Discuss how to collect ground truth data for AI-based positioning and the requirement of ground truth data, e.g., via UE report/PRU.****Proposal 7:****Discuss which node to determine the model activation/deactivation as well as other life cycle management for UE-NW collaboration level y and z.****Proposal 8:** **Consider performance metrics at least from following aspects for AI/ML model monitoring:*** **Performance**
* **Latency**
* **Complexity**

**Proposal 9:****Further discuss the UE behavior after model monitoring.**  |
| [25, Qualcomm] | ***Proposal 4: Study both supervised and semi-supervised/unsupervised positioning methods for the purpose of defining the AI/ML framework in Rel-18 with an initial focus on supervised methods.*** ***Proposal 6: Consider the existing framework of MO-LR, MT-LR and NI-LR services as a starting point to enable data collection for UE-side and network-side models.******Observation 2***: ***Ground truth determination is key factor in the training process and true ground truth may not be available always.******Proposal 7: Study (noisy) ground truth and measurement error feedback from network for enabling UE-side training data collection for both direct AI/ML and AI/ML assisted methods.******Proposal 8: Study signaling enhancements to include meta data for indicating positioning resources (e.g., PRS) and their configurations that are used to derive the positioning/labels.******Proposal 9: Study signaling enhancements for indicating accurate timing of PRS resources used for deriving location and measurement estimates.*** ***Proposal 10: Study providing beneficial assistance data to the UE for improved training and inference.*** ***Proposal 11: Study enhancements to assistance data for indicating PRS meta data that help UE map PRS resources to TRPs and beams.*** ***Proposal 12: Study mechanisms to activate, switch, and deactivate registered ML models for UE-based and network-based ML models.******Proposal 13: Study specification impacts on enabling AI/ML model zone validity, including zone definition, capability, assistance data, and model activation/deactivation & switching.******Proposal 14: Study the procedures needed to enable performance monitoring of ML models for positioning, including dedicated reference signals, information feedback, indication of performance monitoring outcome.*** ***Proposal 15: Study reusing meta data and labelling assistance used for training data collection to enable monitoring for UE-sided and network-sided monitoring.******Proposal 16: Study ML enhanced feature reporting including features relevant to new ML based and ML assisted positioning algorithms (ex. for the soft timing & angle-based likelihood fusion method).******Proposal 17: For ML based reporting of existing parameters, it may be beneficial for the network to know that an ML model was used at the UE and vice versa.*** |

## Training data collection

In RAN1#110, the following were agreed.

Agreement

Regarding data collection for AI/ML model training, to study and provide inputs on potential specification impact at least for the following aspects of AI/ML based positioning accuracy enhancement

* Ground truth label determination (e.g., based on UE/PRU/TRP measurement/report)
	+ Partial and/or noisy ground truth label
* Signaling for data collection
* Other aspects are not precluded

Multiple companies provided inputs related to data collection for training.

[1. Ericsson] proposed to study potential standard impacts of introducing AI/ML models for positioning: reference signal configurations for collecting data for model training, inference and monitoring; signaling to collect assistance information; and signaling and configuration to support data logging and reporting.

[2, Huawei] observed that for AI/ML-based positioning, ground-truth labels of LOS/NLOS tags or UE real coordinates for AI/ML model training can be obtained by positioning reference units. It then proposed to study potential spec impact of collecting data from PRUs (including signaling and PRU capability). It also proposed to study the potential spec impact of data collection from realistic network for supporting the model training and updating of AI/ML model, including at least feedback of channel measurements (e.g., CIR, CFR, PDP) to LMF and signaling for indicating/requesting high-quality data collection.

[3, ZTE] proposed that for AI/ML assisted positioning, the AI model for intermediate output should consider the accessibility to ground-truth labels.

[4, Spreadtrum] proposed to support to utilize PRU to achieve ground truth label and to consider training data without labels.

[5, vivo] proposed to study signaling, procedures and assistance information for data collection for both cases where measurement is conducted at UE side and at the network.

[6, OPPO] proposed to study the feasibility/mechanism that the measurement results with associated ground-truth labels are obtained via PRU.

[9, CATT] proposed that PRU is at least used to collect channel observations and the ground truth labels. It also proposed that if AI/ML model is trained at UE/PRU/TRP side, LMF side can collect a large-scale dataset from numerous UEs/PRUs/TRPs and transmits the dataset to UE/PRU/TRP side for AI/ML model training.

[10, Fujitsu] proposed that the study of the usage/enhancement of the PRU for the label collection of AI/ML positioning may be deprioritized at this stage, otherwise a specific discussion topic should be setup for it.

[11, Sony] proposed to support the usage of PRU for AI/ML Positioning.

[12, Lenovo] proposed to further study the mechanisms to trigger and configure a PRU for ground truth data collection.

[14, CAICT] proposed that for LMF-Based direct AI/ML positioning, PRU could be considered to assist NW to make AI model training and update.

[16, CMCC] proposed that for AI/ML based positioning, whether it is feasible to obtain the ground-truth labels via PRUs is related to the required training dataset size.

[17, Nokia] proposed to study further potential impacts on data quality and on demand data labelling and selection.

[18, InterDigital] proposed to support different labels for information associated with PRU and non-PRU (e.g., normal UE) and to support labels associated with uncertainty of the ground truth.

[23, Samsung] proposed RAN1 to study the training data acquisition criteria, e.g., the qualified training device determination. It also proposed that current signaling framework of the measurement-report could be used as starting point to enable training data collection.

[25, Qualcomm] proposed to consider the existing framework of MO-LR, MT-LR and NI-LR services as a starting point to enable data collection for UE-side and network-side models. It proposed to study (noisy) ground truth and measurement error feedback from network for enabling UE-side training data collection for both direct AI/ML and AI/ML assisted methods. It also proposed to study signaling enhancements to include meta data for indicating positioning resources (e.g., PRS) and their configurations that are used to derive the positioning/labels. Furthermore, it also proposed to study both supervised and semi-supervised/unsupervised positioning methods for the purpose of defining the AI/ML framework in Rel-18 with an initial focus on supervised methods.

Moderator’s comment:

Many companies proposed to support at least PRU to obtain labels for AI/ML model training data collection. There’re also views to take current signalling framework of the measurement-report as starting point for data collection. Multiple companies proposed several areas for further study related to ground truth label in AI/ML model training.

The following proposal is formulated for discussion.

##### Proposal 2-1

Regarding data collection for AI/ML model training for AI/ML based positioning,

* At least PRU is supported to obtain ground truth label and/or training data
	+ FFS whether and if so applicable conditions, to also support UE and/or TRP to obtain label and/or training data
	+ FFS potential specification impact on capability for the entity to obtain label and/or training data
* Take existing signalling framework of MO-LR, MT-LR and NI-LR location services as the starting point to enable data collection when the training entity is not the same entity to obtain label and/or training data
	+ FFS potential specification impact on the details of label and/or training data (e.g., quality, type, etc.)
	+ FFS potential specification impact on assistance signalling indicating reference signal configuration(s) to derive label and/or training data
	+ FFS potential specification impact of AI/ML learning methods (e.g., supervised and semi-supervised/unsupervised) on data collection

Companies are encouraged to provide comments.

|  |  |
| --- | --- |
| Company Name | Comments/Views |
| Samsung  | Generally are fine. Two different views:1. In the first bullet, we feel using “PRU” is not clear enough, since in previous R17 epos discussion, PRU was discussed but concluded as no spec impact for RAN1, and it’s also not concluded what kind of device type the PRU has to be, in which it was also mentioned that either UE or TRP or other type of device could be PRU. Thus to us, we think this “PRU” is more like a device could provide certain service under certain condition, it’s more like a device status, rather than an eternal identity. So we suggest, either we have clear definition of PRU (what it can do/should do), or we just replace PRU as “a certain entity” could provide the required service that is to support to obtain ground truth label and/or training data.
2. In the second bullet, the last FFS. What is the intention of study the impact of AI methods? Indeed, different AI methods could require different input or even need input or not. But since we have agreed the AI model will not be specified, so eventually, there will be just specification on what input type to be there, just like the first FFS in second bullet. So we feel this third FFS seems not needed.
 |
| OPPO | 1. We prefer to study whether/how PRU is used to data collection. However, it is premature to say that “PRU is supported to ….”. Thus, we suggest some modifications.2. For the 1st FFS of the 1st bullet, if a UE/TRP can obtain the label, what the difference between them and PRU?3. The existing signalling framework of MO-LR, MT-LR and NI-LR location are out of RAN1 scope. Thus, we prefer to discuss it in other WG(s). Regarding data collection for AI/ML model training for AI/ML based positioning, * Study whether and/or how ~~At least~~ PRU is ~~supported~~ used to obtain ground truth label and/or training data
	+ FFS whether and if so applicable conditions, to also support UE and/or TRP to obtain label and/or training data
	+ FFS potential specification impact on capability for the entity to obtain label and/or training data
* ~~Take existing signalling framework of MO-LR, MT-LR and NI-LR location services as the starting point to enable data collection when the training entity is not the same entity to obtain label and/or training data~~
	+ ~~FFS potential specification impact on the details of label and/or training data (e.g., quality, type, etc.)~~
	+ ~~FFS potential specification impact on assistance signalling indicating reference signal configuration(s) to derive label and/or training data~~
	+ ~~FFS potential specification impact of AI/ML learning methods (e.g., supervised and semi-supervised/unsupervised) on data collection~~
 |
| InterDigital | We are ok with the suggested proposal from OPPO. |

## Model monitoring and update

In RAN1#110, the following were agreed.

Agreement

Regarding AI/ML model monitoring and update, to study and provide inputs on potential specification impact at least for the following aspects of AI/ML based positioning accuracy enhancement

* AI/ML model monitoring performance metrics
* Condition of AI/ML model update
* Reference signals and measurement feedback/report
* Other aspects are not precluded

Many companies discussed aspects related to model monitoring and update.

[4, Spreadtrum] observed that the integrity mechanism can be considered as one tool to evaluate/monitor the performance of AI/ML model. [16, CMCC] made a similar proposal that for AI/ML based positioning, the relationship between model monitoring and positioning integrity should be considered.

[5, vivo] proposed that the assistance information from network side is required to support model monitoring at UE side and the assistance information from UE side is required to support model monitoring at network side. It also proposed a list of possible AI/ML model monitoring performance metrics: environment monitoring, such as by visual sensors deployed at factories; long-term CSI statistic; long-term SNR statistic; long-term synchronization error detection; PRS configuration matching; other possible features; long-term inference error (location or other intermediate features). It also proposed to support assistance information to the target UE about pre-trained model and training configuration when model fine-tuning is at UE side. It also proposed that training data collection request for model fine-tuning and feedback from the target UE is required to support model fine-tuning at network side.

[8, LG] proposed to consider AI/ML model fine-tuning or update/transfer based on model monitoring performance metric by taking into account the intermediate performance and output performance together.

[9, CATT] proposed to further study some metrics for model monitoring, e.g., positioning accuracy between UE’s position estimated by AI/ML model and ideal UE’s position.

[14, CAICT] proposed that in order to support the monitoring of AI model, positioning results exchanging between UE and NW could be considered.

[15, Xiaomi] proposed to discuss the metrics for performance monitoring first.

[16, CMCC] proposed to consider two options for model monitoring: the metrics of performance monitoring is based on the ground-truth labels; the metrics of performance monitoring is based on non-ideal results, e.g, the results of traditional positioning techniques, or the previous results of AI/ML model.

[17, Nokia] proposed to consider model refinement (monitoring/update) to be coordinated by the LMF with the support of the units where inference is expected to be conducted. RAN1 to assess the necessary support information that the units may provide to the LMF, depending on where the model refinement is performed. It also proposed to study further solutions for the monitoring and update of UE-based AI/ML model by employing PRU measurement and their corresponding labelled ground truth.

[18, InterDigital] proposed to study a framework to monitor for possible degradation in AIML performance.

[19, Fraunhofer] proposed to study improvements by introducing calibration and association spots (ACS) for AI/ML model operation, maintenance and verification.

[23, Samsung] proposed to study the condition/methods to recovery/update a AI/ML model for positioning, e.g., event based condition or timer/counter based condition.

[24, NTT DOCOMO] proposed to consider performance metric, latency and complexity for AI/ML model monitoring.

[25, Qualcomm] proposed to study the procedures needed to enable performance monitoring of ML models for positioning, including dedicated reference signals, information feedback, indication of performance monitoring outcome. It also proposed to study reusing meta data and labelling assistance used for training data collection to enable monitoring for UE-sided and network-sided monitoring

Moderator’s comment:

Although there’re many proposals from the submitted contributions on model monitoring and update, most of them are still high level suggestions of areas for further study on potential specification impact. Note that there’s one detailed aspect identified by companies worth study in addition to those agreed in RAN1#110.

The following proposal is formulated for discussion.

##### Proposal 2-2

Regarding AI/ML model monitoring and update, to study and provide inputs for the following aspects

* Whether the assistance signalling and procedure framework for training data collection can be reused for model monitoring and update
	+ If so, detailed potential specification impact including details for AI/ML model update
* Detailed performance metrics for model monitoring and update and their potential specification impact
	+ E.g., positioning accuracy difference between derived by AI/ML model and other methods; other associated measurements for model inference

Companies are encouraged to provide comments.

|  |  |
| --- | --- |
| Company Name | Comments/Views |
| Samsung  | A few comments:1. “the assistance signalling and procedure framework for training data collection” themselves are still under study, which we are not clear what they are, then how to reuse?
2. The second bullet could be regarded the further step for performance metric, which is fine. But is it clear that, we will eventually set the some KPI for the metric and design the monitoring/update process?
3. How about the further progress on other two aspects agreed to be studied in last meeting, i.e., “Condition of AI/ML model update” and “Reference signals and measurement feedback/report”?
 |
| OPPO | Regarding the 1st bullet, we don’t have details about the assistance signalling and procedure framework. Thus, it is premature to study whether an un-known thing can be reused or not.Regarding the 2nd bullet, the “E.g.,” part is not necessary and can be removed |
| InterDigital | The first bullet can be changed to “Required signalling and procedure framework”For the second bullet, we agree with OPPO that examples can be removed. More studies may be needed to identify examples.The modified proposal can be the following.Regarding AI/ML model monitoring and update, to study and provide inputs for the following aspects* Required signalling and procedure framework
* Detailed performance metrics for model monitoring and update and their potential specification impact
	+ ~~E.g., positioning accuracy difference between derived by AI/ML model and other methods; other associated measurements for model inference~~
 |

## Model indication/configuration

Several companies discussed detailed aspects related to model indication/configuration.

[5, vivo] proposed that model information should contain meta-information indicating the physical and network environment or condition under which the model is suitable for operation.

[17, Nokia] observed that the scenario dependence of AI/ML models and related specification impacts would mainly depend on whether direct or AI/ML assisted positioning is used, and the type of positioning method applied (for e.g., UE-based, UE-assisted/LMF-based or NG-RAN node assisted). It then proposed to study further performance metrics and model update criteria that enable the network and the UE to determine the appropriate positioning approach, depending on KPIs such as positioning accuracy and QoS, as well as UE capabilities. It also proposed to further study mechanisms for signaling model and AI/ML based positioning method update, due to various criteria such as mobility and positioning accuracy estimation quality deterioration.

[19, Fraunhofer] proposed to study additional reporting for environment information in processing and training phase as well as identification of AI/ML assisted areas.

[25, Qualcomm] proposed to study specification impacts on enabling AI/ML model zone validity, including zone definition, capability, assistance data, and model activation/deactivation & switching. It also proposed to study multiple ML positioning methods suited to a wide variety of operating conditions as there is no single method that can improve performance in all scenarios.

Moderator’s comment:

As observed by multiple companies and shown in multiple companies’ evaluation results, a single AI/ML model may not work for all scenarios. As such, an AI/ML model is likely validated and/or is suitable for an area/zone under some conditions.

The following proposal is formulated for discussion on those conditions for AI/ML model inference operation.

##### Proposal 2-3

Regarding AI/ML model indication/configuration, to study and provide inputs on potential specification impact at least for the following aspects on conditions/criteria of AI/ML model for AI/ML based positioning accuracy enhancement

* Validity of applicable area/zone/scenario/environment
* Model capability, e.g., positioning accuracy quality
* Conditions and requirements to achieve such capability, e.g., required assistance signalling and/or reference signals configurations
* Note: other aspects are not precluded

Companies are encouraged to provide comments.

|  |  |
| --- | --- |
| Company Name | Comments/Views |
| Samsung  | 1. For the first bullet, we think it’s not only the area etc impact, but there could be also some uneven knowledge between UE and gNB, so that whether a configured/indicated model is valid to use is under check, suggest changed to

“validity ~~of~~ check, e.g., applicable area/zone/scenario/environment and/or other conditions”1. For third bullet, we assume by saying “such capability”, it refers to the second bullet. Thus, we think it should be more than that, such condition/requirements are also applying to validity check, or even the configuration of model at beginning. Suggest change to

“Conditions and requirements ~~to achieve such capability~~, e.g., required assistance signalling and/or reference signals configurations to make the model valid in a given indication/configuration or achieve certain Model capability” |
| OPPO | These aspects are very general and also applicable to other use cases (e.g., CSI, BM). Thus, we think they should be studied in agenda 9.2.1.In our view, agenda 9.2.4.2 focuses on the spec impact specific to positioning, rather than the spec impact common to multiple cases. |
| InterDigital | The focus of the first bullet seems narrow. “Validity conditions (e.g., area)” may be sufficient.  |

## Model input/output for inference

In RAN1#109-e, the following were agreed regarding AI/ML based positioning approaches.

Agreement

For further study, at least the following aspects of AI/ML for positioning accuracy enhancement are considered.

* Direct AI/ML positioning: the output of AI/ML model inference is UE location
	+ E.g., fingerprinting based on channel observation as the input of AI/ML model
	+ FFS the details of channel observation as the input of AI/ML model, e.g. CIR, RSRP and/or other types of channel observation
	+ FFS: applicable scenario(s) and AI/ML model generalization aspect(s)
* AI/ML assisted positioning: the output of AI/ML model inference is new measurement and/or enhancement of existing measurement
	+ E.g., LOS/NLOS identification, timing and/or angle of measurement, likelihood of measurement
	+ FFS the details of input and output for corresponding AI/ML model(s)
	+ FFS: applicable scenario(s) and AI/ML model generalization aspect(s)
* Companies are encouraged to clarify all details/aspects of their proposed AI/ML approaches/sub use case(s) of AI/ML for positioning accuracy enhancement

Agreement

Companies are encouraged to study and provide inputs on potential specification impact at least for the following aspects of AI/ML approaches for sub use cases of AI/ML for positioning accuracy enhancement.

* AI/ML model training
	+ training data type/size
	+ training data source determination (e.g., UE/PRU/TRP)
	+ assistance signalling and procedure for training data collection
* AI/ML model indication/configuration
	+ assistance signalling and procedure (e.g., for model configuration, model activation/deactivation, model recovery/termination, model selection)
* AI/ML model monitoring and update
	+ assistance signalling and procedure (e.g., for model performance monitoring, model update/tuning)
* AI/ML model inference input
	+ report/feedback of model input for inference (e.g., UE feedback as input for network side model inference)
	+ model input acquisition and pre-processing
	+ type/definition of model input
* AI/ML model inference output
	+ report/feedback of model inference output
	+ post-processing of model inference output
* UE capability for AI/ML model(s) (e.g., for model training, model inference and model monitoring)
* Other aspects are not precluded
* Note: not all aspects may apply to an AI/ML approach in a sub use case
* Note2: the definitions of common AI/ML model terminologies are to be discussed in agenda 9.2.1

Multiple companies discussed detailed aspects related to model input/output.

[1, Ericsson] observed that for a CIR based ML fingerprinting solution, UL CIR can be obtained using existing reference signals and does not require additional reports to be specified for the air interface.

[2, Huawei] proposed RAN1 uses CIR as the model input as a starting point for direct AI/ML positioning and to study potential spec impact of feedback of channel measurements (e.g., CIR, CFR, PDP) to LMF.

[3, ZTE] proposed path timings and RSRPPs or CIR (i.e., path timings, RSRPPs and path phases) as model input for direct AI/ML positioning and DL PRS RSTD, LOS/NLOS indicator and relative RSRPP values to the first detected path in time for AI/ML assisted positioning.

[5, vivo] proposed to support time domain CIR as one model input for training and inference.

[6, OPPO] proposed two options: existing UE measurement/reporting (e.g., DL RSTD and the corresponding RSRP) and new type of UE measurement/reporting (e.g., Normalized CIR and/or the corresponding RSRP) for direct AI/ML positioning for the AI model inference at LMF side. It also proposed two options: existing types of measurement (e.g., NLOS/LOS identification, RSTD) and new types of measurement (e.g., TOA) for AI/ML assisted positioning for the AI model inference at UE side.

[7, Google] proposed for direct AI/ML positioning, consider to use CIR and L1-SINR from each cell as the input.

[11, Sony] proposed to support channel observation as part of the data collection from UE and gNB for downlink and uplink-based positioning, respectively.

[12, Lenovo] proposed to study fingerprinting as a Direct AI/ML positioning sub-use case, whereby channel observations/measurements, e.g., CIR, RSS measurements serve as input data to an AI/ML model to determine the target-UE’s location estimate. It also proposed to consider LOS/NLOS identification as AI/ML assisted positioning sub-use case for timing-based and angular-based positioning techniques, where the input data may comprise all supported DL-based, UL-based, (DL+UL) measurements and the corresponding output comprises classification of measurements in terms of LOS and NLOS.

[16, CMCC] proposed that for AI/ML based positioning, the potential spec impact of CIR report should be studied.

[18, InterDigital] proposed to study direct AI/ML positioning where at least RSRP, RSRPP for PRS resources and RSTD are used as inputs for AI/ML models and to study AI/ML assisted positioning where timing measurements are generated based on RSRP fingerprints.

[20, Apple] proposed to consider CIR / PDP/L1-RSRP as input for direct AI/ML positioning, LOS/NLOS tap identification and TOA/AoA/AoD estimation as input for AI/ML assisted positioning.

[25, Qualcomm] proposed to study the specification impact for the reporting of soft information associated with positioning measurements, derived using machine learning for AI/ML assisted positioning.

Moderator’s comment:

A couple of detailed aspects of AI/ML model input/output with potential specification impact have been identified by companies. The following proposal is formulated for discussion.

##### Proposal 2-4

Regarding input and output of AI/ML model inference, to study and provide inputs on potential specification impact at least for the following aspects for AI/ML based positioning accuracy enhancement

* Assistance signalling and procedure to derive channel measurements for both UE-side and Network-side model
* Types of channel measurement as model input for model inference
	+ new measurement, e.g., CIR/CFR/PDP
	+ existing measurement, e.g., RSTD, RSRP
* Report/feedback of channel measurements to LMF for Network-side model
* For AI/ML assisted positioning, new measurement (e.g., TOA or soft information of measurements) and/or enhancement of existing measurement as model output

Companies are encouraged to provide comments.

|  |  |
| --- | --- |
| Company Name | Comments/Views |
| OPPO | We are fine with the proposal in general. However, there is some ambiguity. Does the network-side model include both LMF-side model (direct AI/ML) and gNB-side model (AI/ML assisted)? If the study also includes gNB-side model (AI/ML assisted), some modification is needed to make it clearer. |
| InterDigital | Support |
|  |  |

# Conclusion

TBD

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