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

**Toulouse, France, August 22nd – 26th, 2022**

**Source: Moderator (vivo)**

**Title: FL summary #1 of other aspects on AI/ML for positioning accuracy enhancement**

**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 #110.

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, Huawei] | 1. ***: For direct AI/ML positioning, AI/ML-based fingerprint positioning should be studied.*** 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*** |
| [2, vivo] | 1. AI/ML based positioning shows significant accuracy improvement compared to conventional RAT-dependent positioning methods in a heavy NLOS scenario. 2. AI/ML based positioning accuracy enhancement for heavy NLOS scenario is selected as a representative sub use case. |
| [3, ZTE] | ***Proposal 1:*** *For further sub-use case classification, at least considering following high level principles:*   * *The intention is 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 inputs are path timings and RSRPPs from single port PRS*   + *Sub-use case 1-2: AI model inputs are path timings, RSRPPs and path phases (i.e., CIR)from single port PRS*   + *Sub-use case 1-3: AI model inputs are path timings and RSRPPs (or CIR) from multi-port PRS* * *AI/ML assisted positioning*   + *Sub-use case 2-1: AI model outputs are DL PRS RSTD values*   + *Sub-use case 2-2: AI model output is LOS/NLOS indicator*   + *Sub-use case 2-3: AI model outputs are RSRPP values to the first detected path in time* |
| [4, Sony] | [**Observation 1: The multiple paths reporting from UE/TRP to LMF as a feature in rel-17 could assist LMF to make its own decision on LOS path selection.**](#_Toc111023505)  [**Observation 2: The procedure of ML for positioning can be at least divided in three phases:**](#_Toc111023506)   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 the input for AI/ML Positioning.**](#_Toc111023507)  **Proposal 1: Consider supporting LMF to create and train AI/ML model for NLOS mitigation.**  Proposal 2: Support channel observation input for AI/ML Positioning from UE and gNB for downlink and uplink-based positioning, respectively.  **Proposal 3: Support the usage of PRU for AI/ML Positioning.**  **Proposal 4: Study the inference model (e.g., contents, structure, size) to be provided from LMF to UE/gNB** |
| [5, Fujitsu] | ***Observation 1 The current collaboration level Z takes the model transfer as its criterion, which has no relation to the sub use case selection.***  ***Proposal 1 The sub use cases for AI positioning are confined to AI model collaboration level X and Y. Level Z cases will not be considered at this stage.***  ***Proposal 2 Both direct and indirect AI/ML Positioning methods are worthwhile to study, and only one sub use case is selected for each category.***  ***Proposal 3 Companies are suggested to report the input/output of their selected AI/ML models for reference only.*** |
| [6, 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.***  ***Proposal 4: The AI/ML model training and indication should be transparent.*** |
| [7, Ericsson] | 1. Categorize sub use cases for the positioning use case based on functionality that the AI/ML model is intended to fulfill. 2. Focus on one-sided ML functionality for the positioning use case. 3. Deprioritize two-sided ML functionality, which requires joint training and inference.   **Observation 1 For a CIR based ML fingerprinting solution, using UL CIR can be done 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 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 Collaboration details (e.g., the assistance information details) of the evaluated AI/ML model is reported by participating companies.**  **Proposal 7 Study fingerprinting solutions that are robust to propagation environment changes and limit the required number of trained models that need to be supported.**  **Proposal 8 Prioritize solutions where the intermediate feature output from AI/ML assisted models can directly be used as input to legacy positioning calculations.**  **Proposal 9 Prioritize solutions where the intermediate feature input to AI/ML assisted models uses existing channel observations, for example channel impulse response (in time or frequency domain), RSRP measurements and/or angular measurements.** |
| [8, Rakuten Mobile] | **Proposal 1: Study and evaluate both direct and assisted AI/ML based positioning techniques.**  **Proposal 2: Prioritize single sided AI/ML operation for positioning study.** |
| [9, OPPO] | ***Principle 1: Down-select a limited number of sub use cases to keep a manageable workload.***  ***Principle 2: The selected typical sub use case(s) should be able to show potential advantages and performance gain of AI/ML-based scheme over traditional positioning algorithms.***  ***Principle 3: At least one non-AI-based traditional scheme should be chosen as the baseline.***  ***Principle 4: The sub use cases should be as diversified as possible to facilitate the study of potential impacts on various aspects of NR system.***  ***Proposal 1: For AI/ML-based positioning accuracy improvement, down-select one out of the existing NR positioning methods to investigate the integration with AI/ML.***   * ***Our preference is DL-TDOA***   ***Proposal 2: For the justification of any potential spec enhancement, a sub use case with AI/ML replying on UE/NW implementation and having no spec impact should be selected as a baseline:***   * ***E.g., LMF deployed AI model(s) to calculate the*** ***location of a given UE based on the existing RSTD measurement results reported by UE***   ***Proposal 3: For direct AI/ML positioning, study the sub use case based on CIR feedback with corresponding RSRP and inference of AI model at LMF:***   * ***E.g., UE estimates the channel impulse response (CIR) and reports the normalized versions. LMF deployed AI model(s) to calculate the*** ***location of a given UE based on CIR/RSRP measurement results.***   ***Proposal 4: For AI/ML assisted positioning, study the sub use case based on existing types of measurement results and some new types of measurement.***  ***Proposal 5: 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 a later phase of Rel-18 or in later release(s)***   ***Proposal 6: For both direct AI/ML positioning and AI/ML assisted positioning, only consider one-side model for all sub use cases in Rel-18***   * ***Note: Whether AI/ML or non-AI scheme is used in Stage 2 of AI/ML assisted positioning is a separate issue.***   ***Proposal 7: 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***   * ***Note: model transfer can be studied in later release(s).*** |
| [10, CATT] | **Proposal 1: The sub use cases for AI/ML-based positioning is defined by the functionality that the AI/ML model is intended to fulfill.**  **Proposal 2: 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.**   **Observation: Training AI/ML model for positioning at network side is more feasible due to easier data collection.**  **Proposal 3: For AI/ML-based positioning, both one-sided AI/ML model and two-sided AI/ML model can be considered.** |
| [11, NEC] | **Proposal 1:**   * *Categorize the clarification of sub-use case by the scenario that positioning accuracy can be enhanced by AI/ML model.*   **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.*   **Proposal 4:**   * *The predicted measurement and movement information of the UE can be* *served as the output of AI model for AI/ML assisted positioning.* |
| [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 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, 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 fulfil.**  **Proposal 5: Sub use cases for AI/ML based positioning based on functionality include:**   * **Fingerprinting** * **LOS/NLOS classification** * **Other use cases are not precluded** |
| [14, Spreadtrum] | ***Observation 1: Two sub use cases have been identified, and further classification is not needed.*** |
| [15, Xiaomi] | **Proposal 1: Prioritize the study of offline training on single node for positioning accuracy enhancement** |
| [16, CAICT] | ***Proposal 1: The following two sub use cases should be at least included:***   1. ***Direct AI/ML positioning with fingerprinting(CIR) in heavy NLOS scenario*** 2. ***AI/ML assisted positioning with LOS/NLOS identification***   ***Observation 1: Generalization capability of AI model for positioning could be evaluated by configurations changing with fixed gNB positions.*** |
| [17, 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: RAN1 supports to identify the sub use cases for AI in positioning by the functionality that the AI/ML model is intended to fulfil.***  ***Proposal 2: both positioning location estimation and intermediate measurement estimation can be considered as candidate sub use-cases;*** |
| [18, 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).**  **Proposal #1: Consider assistant information including LOS probability and/or reliability information for the AI/ML based LOS/NLOS identification.**  **Proposal #2: Consider PRS priority configuration based on AI/ML based LOS/NLOS indication.**  **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 #3: Consider PRU prediction on NW-/UE-side based on measurement report in addition to PRU identification and/or assistance information utilized for PRU determination.**  **Observation #3: Consider the metric for AI/ML based positioning in terms of efficiency and power saving as in Rel-17.** |
| [19, CMCC] | ***Proposal 1:* For AI/ML enabled positioning accuracy enhancement, the sub use cases of AI/ML based positioning can be defined by the functionality of the AI/ML model.**  ***Proposal 2:* For AI/ML enabled positioning accuracy enhancement, select one or two sub use cases for characterization and baseline performance evaluations.**  ***Proposal 3:* For AI/ML enabled positioning accuracy enhancement, all the collaboration levels (Level x/y/z) defined in AI 9.2.1 should be considered.** |
| [20, Nokia] | **Observation-4: Sub-use case definition Options 1 and 2 might have overlaps in terms of how the options are defined – for e.g., considering scenario as a problem space addressed as part of the study, however from the standards perspective it is important to define the input and output parameters of the AI/ML model.**  **Proposal-5:** **Option 2 may provide a useful categorization for standardization of the AI/ML model elements, where element may mean: training procedure, collaboration level, deployment, etc. If option 2 is adopted, then various sub-cases similar to the ones mentioned below can be defined:**   1. **Sub-use case 1:**    1. **Input:**        1. **raw received P/SRS signal samples and**       2. **raw transmitted P/SRS signal samples**       3. **(optional) TRP location**    2. **Output (soft or hard):**        1. **Selected (by the LMF) positioning measurements or**       2. **UE location. Note that in this case, an additional input (iii) consisting of the TRPs locations should be provided.** 2. **Sub-use case 2:**    1. **Input:**       1. **Post-processed received P/SRS signal samples, where post-processing is done autonomously by the positioning receiver (UE in DL, TRP in UL positioning).**       2. **(optional) TRP location**    2. **Output (soft or hard):**        1. **selected positioning measurements or**       2. **UE location. Note that in this case, an additional input (ii) consisting of the TRPs locations should be provided.** 3. **Sub-use case 3:**    1. **Input:**       1. **Post-processed received P/SRS signal samples, where post-processing is done by the positioning receiver (UE in DL, TRP in UL positioning) with help from the LMF. Specifically, the LMF indicates a preferred list of input features (e.g., CIR, CFR, LOS, etc.) which can be used by the model.**       2. **(optional) TRP location.**    2. **Output (soft or hard):**        1. **selected positioning measurements or**       2. **UE location. Note that in this case, an additional input (ii) consisting of the TRPs locations should be provided.**   **Observation-5:It is expected that *A. direct AI/ML vs. B. AI/ML-assisted* positioning has different standardization requirements. For example, the two approaches have different requirements in terms of necessary and sufficient inputs: the latter may require that the TRP location is known, whereas the former typically does not. Similarly, the levels of collaboration between the UE and the NW (e.g. who defines and controls the inputs), and the model training and deployment aspects are also specific to the A vs. B.**  **Proposal-6: RAN1 to study the radio environment and scenario dependence of using direct AI/ML vs. AI/ML-assisted positioning approaches.** |
| [21, InterDigital] | **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**  **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** |
| [22, 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.**  **Proposal 1: Support signaling and reporting enhancements on LPP / NRPPa to enable ML measurement approaches for accuracy improvements.**  **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.**  **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 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**   **Proposal 5: Prioritize the two sub use case of timing and/or angle of measurement and ML based positioning with heavy NLOS conditions.** |
| [23, Qualcomm] | ***Proposal 1: Study primarily the one-shot positioning use case in Rel-18. Additional enhancements for tracking and smoothing algorithms can be considered later.***  ***Proposal 2: Study UE-based, UE-assisted, Network-based, and Network-assisted positioning methods for performing AI/ML based inference.***  ***Proposal 3: For the positioning use case, the data is collected by the UE and/or the network and the training is performed offline.***  ***Proposal 4: The overall scope of enhancements include:***   * ***Direct AI/ML method (ex. RFFP) and AI/ML assisted positioning method (ex. Likelihood fusion)*** * ***Assistance data and signaling for model generation, inference and life cycle management*** * ***ML enhanced reports mapping to existing report parameters and new parameters (interpretable and non-interpretable features).*** |
| [24, 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***     - ***Output: actual UE position*** * ***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 TDOA-based positioning***      - ***Potential spec impact: indication of LOS/NLOS probability. This may already be supported in Rel-17***   + ***Sub-Use case 3: TOA estimation for input into TDOA-based positioning***     - ***Potential spec impact: Possible signaling of the TOA rather than the TDoA to LMF***   ***Proposal 2: RAN1 should the following scenarios:***   * ***Training and inference at the UE*** * ***Training and inference at the LMF*** |

## AI/ML model training and inference

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 training and inference are copied below.

Working Assumption

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| Terminology | Description |
| Online training | TBD - need more discussion |
| Offline training | TBD - need more discussion |
| On-UE training | Online/offline training at the UE |
| On-network training | Online/offline training at the network |
| 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. |
| Model transfer | Delivery of an AI/ML model over the air interface, either parameters of a model structure known at the receiving end or a new model with parameters. Delivery may contain a full model or a partial model. |

Several companies discussed aspects related to AI/ML model training and inference.

[1, Huawei] proposed that for AI/ML-based positioning, single-sided model should be considered as a starting point. [6, Google] proposed that the study of AI/ML based positioning should focus on 1-side AI/ML model. [7, Ericsson] proposed to focus on one-sided ML functionality for the positioning use case and deprioritize two-sided ML functionality, which requires joint training and inference. [8, Rakuten Mobile] proposed to prioritize single sided AI/ML operation for positioning study. [9, OPPO] proposed that for both direct AI/ML positioning and AI/ML assisted positioning, only consider one-side model for all sub use cases and the AI model training and inference are assumed to be done in the same side in Rel-18.

[10, CATT] proposed that for AI/ML-based positioning, both one-sided AI/ML model and two-sided AI/ML model can be considered. [14, Spreadtrum] proposed that for both sub use cases, AI/ML model can be delivered or not. It is observed in [20, Nokia] that while there are clear benefits of training the model at the NW side (in terms of model robustness and complexity), the disadvantages of such approach should be considered before choosing or prioritizing one option as compared to the other. [20, Nokia] further proposed that selecting entities for model training and inference should be decided jointly, and should be at least use-case specific. For example, if the inference is done by the NW, then the training should also be realized by the NW. Conversely, if the inference is done at the UE side, the model training may be done at the UE or NW side, depending on the use-case, approach (A/B) and UE capability. [23, Qualcomm] proposed to study UE-based, UE-assisted, Network-based, and Network-assisted positioning methods for performing AI/ML based inference. Note that for UE-assisted positioning methods, these AI/ML models may be one-sided or two sided depending on the function at the UE. [24, Apple] proposed to consider training and inference at the UE as well as training and inference at the LMF.

Regarding online/offline training, [15, Xiaomi] proposed to prioritize the study of offline training on single node for positioning accuracy enhancement. [23, 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.

Moderator’s observations and comment:

It is observed by the moderator that some companies may have broader and inaccurate interpretation of one-sided and two-sided model. 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. However, some companies have wrongly interpreted that one-sided model means both model training and inference are performed entirely either at the UE or at the network.

There’re views to focus on model training and inference at the same entity to avoid model transfer. While there’re also views to study methods when model training and inference are not performed at the same side. Furthermore, there’re views to study further on two-sided model with joint inference. Given model transfer is in the scope of study for the AI/ML general framework, it seems pre-mature to exclude that for AI/ML based positioning for now.

Although there’re views to not support online training for AI/ML positioning, it is moderator’s understanding that the definitions of online/offline training have not been agreed in agenda 9.2.1 general framework yet. Therefore, it seems pre-mature to rule out online training especially when companies may have different understanding on what is online training (e.g., whether data collection/training for model updating/fine-tuning is part of online training or not).

With the above, suggest the following proposal to align understanding and as a guidance for future meeting(s).

##### Proposal 1-1

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 On-UE or On-network training
  + Note 1: whether On-UE training includes outside-UE options and whether On-network training includes non-3GPP-entity are subject to discussion/decision in AI 9.2.1
* One-sided or two-sided model for inference
* Note 2: companies are encouraged to clarify aspects of their proposed AI/ML approaches when AI/ML model training and inference are not performed at the same entity

Companies are encouraged to provide comments.

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| Company Name | Comments/Views |
| CAICT | We think at least on-UE and on-network training could be considered for AI/ML-based positioning. One-side model should be baseline and the mechanism of two-side model is not clear. |
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Furthermore, regarding inference entity, it seems beneficial to align the terminologies used among companies. Suggest the following proposal to align understanding and as a guidance for future meeting(s).

##### Proposal 1-2

Support to include the following positioning methods for further study on AI/ML for positioning accuracy enhancement

* UE-based: UE derives the final positioning estimate based on UE measurement
* UE-assisted: network derives the final positioning estimate based on UE report
* Network-based: network derives the final positioning estimate based on network measurement
* Network-assisted: UE derives the final positioning estimate based on network feedback
* Note: companies are encouraged to align the terminology when describe their proposed AI/ML approaches/sub use case(s) of AI/ML for positioning accuracy enhancement

Companies are encouraged to provide comments.

|  |  |
| --- | --- |
| Company Name | Comments/Views |
| CAICT | In general, we are fine to have UE-based and network-based positioning. UE-assisted and Network-assisted needs further discussion. |
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## Sub use case(s)

In RAN1#109-e, the following were agreed regarding categorization of 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

There’s also a discussion on how to categorize sub use case(s) for AI/ML based positioning where 4 options were listed in RAN1#109-e.

* Option 1: by scenario
* Option 2: by {input, output} of an AI/ML model
* Option 3: for estimation, tracking, and prediction etc. as different sub use cases
* Option 4: by functionality that the AI/ML model is intended to fulfil where LOS/NLOS classification and Fingerprinting to directly estimate UE’s position as different sub use cases

Many companies expressed their views on this issue of sub use case categorization and/or sub use cases for further study.

[2, vivo] proposed that AI/ML based positioning accuracy enhancement for heavy NLOS scenario is selected as a representative sub use case. [11, NEC] proposed categorize the clarification of sub-use case by the scenario that positioning accuracy can be enhanced by AI/ML model. [13, NVIDIA] proposed that high accuracy positioning in heavy NLOS scenarios should be the target of using AI/ML for positioning enhancement. [22, Fraunhofer] proposed to prioritize the two sub use case of timing and/or angle of measurement and ML based positioning with heavy NLOS conditions.

[3, ZTE] propsoed 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. It is observed in [20, Nokia] that Sub-use case definition Options 1 and 2 might have overlaps in terms of how the options are defined – for e.g., considering scenario as a problem space addressed as part of the study, however from the standards perspective it is important to define the input and output parameters of the AI/ML model. Therefore, [20, Nokia] proposed that Option 2 may provide a useful categorization for standardization of the AI/ML model elements, where element may mean: training procedure, collaboration level, deployment, etc.

[7, Ericsson], [10, CATT] proposed to categorize sub use cases for the positioning use case based on functionality that the AI/ML model is intended to fulfill. [13, NVIDIA] proposed that sub use cases for AI/ML based positioning are described by functionality that the AI/ML model is intended to fulfil. [17, Samsung] proposed that RAN1 supports to identify the sub use cases for AI in positioning by the functionality that the AI/ML model is intended to fulfil. A similar proposal is made by [19, CMCC].

It is observed in [14, Spreadtrum] that two sub use cases have been identified, and further classification is not needed.

Some companies didn’t explicitly state how they define/classify different sub use cases but rather directly made proposals of sub use case(s) for further study. [1, Huawei] proposed AI/ML-based fingerprint for direct AI/ML positioning and AI/ML-based LOS/NLOS identification for AI/ML assisted positioning. [3, ZTE] also proposed to study direct AI/ML positioning and AI/ML assisted positioning. [5, Fujitsu] proposed that both direct and indirect AI/ML Positioning methods are worthwhile to study, and only one sub use case is selected for each category. [6, Google] proposed that direct AI/ML positioning should be prioritized compared to AI/ML assisted positioning. [7, Ericsson] proposed to study fingerprinting solutions that are robust to propagation environment changes and limit the required number of trained models that need to be supported and to prioritize solutions where the intermediate feature output from AI/ML assisted models can directly be used as input to legacy positioning calculations. [8, Rakuten Mobile] proposed to study and evaluate both direct and assisted AI/ML based positioning techniques. [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 and 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, NVIDIA] listed fingerprinting and LOS/NLOS classification as sub use cases for AI/ML based positioning. [16, CAICT] proposed to consider at least two sub use cases: Direct AI/ML positioning with fingerprinting (CIR) in heavy NLOS scenario and AI/ML assisted positioning with LOS/NLOS identification. [17, Samsung] proposed that both positioning location estimation and intermediate measurement estimation can be considered as candidate sub use-cases. [21, 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. [24, Apple] also proposed to study specification impact of both Direct AI/ML based positioning model and AI-assisted positioning with output of AI model serving as input to traditional positioning.

Moderator’s observation and comment:

Companies still have somewhat different understanding of what is a ‘sub use case’. The difference is mainly on the level of details for AI/ML based positioning accuracy enhancement. Furthermore, there’re different views on whether further categorization of sub use cases is needed. Some companies proposed second level of details (e.g., input and/or output to AI/ML model) to further classify sub use cases. While others do not think that’s necessary.

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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:   + 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. |

Moderator’s understanding of the task stated in the SID (relevant part copied above) to “finalize representative sub use cases for characterization and baseline performance evaluations by RAN#98” is that selection of representative sub use cases are meant to showcase the performance benefits of AI/ML approaches for positioning with complexity and potential specification impact identified such that a framework to apply AI/ML to the air-interface can be formulated.

Based on 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. Given the SID also stated that “the AI/ML approaches for the selected sub use cases need to be diverse enough”, it seems not necessary to further select between direct AI/ML positioning and AI/ML assisted positioning or to further categorize sub use cases based on different input/output for the purpose of baseline performance evaluations and specification impact study by RAN#98. After all, the important task as stated in the SID is the actual performance, complexity, and potential specification impact study.

Moderator observed that there’s a vast majority view from companies on what to study further. Other than [6, Google], many other companies all proposed to study further of performance evaluations and potential specification impact for both direct AI/ML positioning and AI/ML assisted positioning.

With the above reasoning, the following proposal is formulated for discussion so that companies in RAN1 can concentrate on actual performance/specification impact study of schemes rather than debating on which scheme to study/evaluate before any performed study.

##### Proposal 1-3

For characterization and baseline 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

Companies are encouraged to provide comments.

|  |  |
| --- | --- |
| Company Name | Comments/Views |
| CAICT | Fine with the proposal. |
|  |  |
|  |  |

# Collaboration levels and 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.

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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.  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, Huawei] | ***Proposal 4: Study potential specification impact for AI/ML-based positioning, including feedback of channel measurements (e.g., CIR, CFR, PDP) to LMF.***  ***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.***  ***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 a 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 AI/ML-based positioning, it is simpler to perform the model training/updating/inference of AI/ML models at Network side.*** |
| [2, vivo] | **Proposal 2: Support time domain CIR as one model input for training of AI/ML model for positioning.**  **Proposal 3: Study signaling, procedures and assistance information for data collection for both cases where measurement is conducted at UE side and at the network.**  **Proposal 4: When AI/ML model is deployed at UE side, network side should transfer the model information to the target UE.**  **Proposal 5: The process of model activation and deactivation is needed to flexibly control the model's lifecycle, so as to ensure positioning performance.**  **Proposal 6: 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.**  **Proposal 7: The assistance information from network side is required to support model monitoring at UE side.**  **Proposal 8: The assistance information from UE side is required to support model monitoring at network side.**  **Proposal 9: When fine-tuning is conducted at UE side, UE capability corresponding to fine-tuning is required.**  **Proposal 10: 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.**  **Proposal 11: Training data collection request for model fine-tuning and feedback from the target UE is required to support model fine-tuning at network side.**  **Proposal 12: Support time domain CIR as one model input for AI/ML based positioning.**  **Proposal 13: 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.**  **Proposal 14: 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.**  **Proposal 15: 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.**  **Proposal 16: A general model management procedure should be specially studied for AI/ML based positioning accuracy enhancement.**  **Proposal 17: Support to study the detailed assistance signaling configuration when the model management procedure for AI/ML based positioning is agreed.** |
| [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.*  ***Observation 1:*** *AI/ML assisted positioning is more appropriate to be implemented at UE/TRP side since the motivation is to increase reliability and accuracy of UE/TRP measurement based on AI/ML techniques.*  ***Proposal 7:*** *For AI/ML assisted positioning, accessibility to ground-truth labels should be considered to get an intermediate output of an AI/ML model. .*  ***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.*  ***Proposal 10:*** *Study and support an AI/ML based DL PRS-RSRPP estimation to increase accuracy and reliability.* |
| [5, Fujitsu] | ***Proposal 4 For the sub use cases of collaboration level X, the potential specification impacts can be limited to lifecycle-related such as model generalization, selection, and monitoring.***  ***Proposal 5*** ***For the sub use cases of collaboration level Y, the potential specification impacts can be lifecycle-related and additional assistance information.***  ***Proposal 6 Study the fine-tuning procedures and related specification impact which requires online interactions via air interface.*** |
| [6, Google] | ***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.*** |
| [7, Ericsson] | **Observation 4 It is expected that AI/ML solutions will impact 3GPP specifications related to inference and testing phase. Procedures and protocols might be differently impacted depending on what positioning related enhancements are specified.**  **Proposal 10 Study enhancements of LPP and NRPPa protocols to support the NW side direct AI/ML approach.**  **Proposal 11 Study enhancements of LPP and NRPPa protocols to support the NW side assisted AI/ML approach.** |
| [9, OPPO] | ***Proposal 8: 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 9: 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”)***  ***Proposal 10: 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 11: 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 12: 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”)*** |
| [10, CATT] | **Proposal 4: For AI/ML-based positioning, all collaboration levels defined in AI 9.2.1 can be considered.** |
| [11, NEC] | **Proposal 5:**   * *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.* |
| [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 5: Study the use of assistance information signalling related to positioning data set construction and collection to enhance the accuracy of the training and inference models at each node.***  ***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, NVIDIA] | **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.**  **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.**  **Proposal 8: 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 9: For AI/ML based positioning enhancements, study potential specification impact related to assistance signalling and procedure for model performance monitoring and model update/tuning.**  **Proposal 10: 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.**  **Proposal 11: For AI/ML based positioning enhancements, study potential specification impact related to report/feedback of model inference output and post-processing.**  **Proposal 12: 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.** |
| [14, Spreadtrum] | ***Proposal 1: For both sub use cases, AI/ML model can be delivered or not.***  ***Proposal 2: New measurement metric and reporting, depending on the input/output and the location of AI/ML model, can be studied.***  ***Proposal 3: Whether/How to define/reflect the complexity of the AI/ML operation in the specification can be studied.***  ***Proposal 4: The integrity mechanism can be considered as one tool to evaluate/monitor the performance of AI/ML model.***  ***Proposal 5: The better generalization of AI/ML model should be strived, to avoid frequent AI/ML model updating.*** |
| [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, CAICT] | ***Observation 2: AI/ML based positioning should be considered for both gNB side and UE side.***  ***Proposal 2: UE should consider to use the AI model for positioning from gNB side.***  ***Proposal 3: Datasets with partial coordinate labels should be considered.*** |
| [17, Samsung] | ***Proposal 3: 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.***  ***Proposal 4: RAN1 to study the training data acquisition criteria, e.g., the qualified training device determination.***  ***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.*** |
| [19, CMCC] | ***Proposal 3:* For AI/ML enabled positioning accuracy enhancement, all the collaboration levels (level x/y/z) defined in AI 9.2.1 should be considered.**  ***Proposal 4:* For AI/ML based positioning, the potential spec impact of CIR report should be studied.**  ***Proposal 5:* For AI/ML based positioning, the relationship between model monitoring and positioning integrity should be considered.** |
| [20, Nokia] | **Observation-1: Collaboration levels NW-UE may be specified in relation to approaches A or B and whether the deployment of A or B is exclusively one-sided or not, i.e., if the full model resides only at the UE or NW side, or whether different parts of the model may reside at different sides.**  **Proposal-1: Collaboration levels may be defined in relation to approaches A/B and specifically in relation to how A/B are deployed. For example, a set of collaboration levels may be considered:**   * **Approach A, Model-0 at UE: collaboration level a1;** * **Approach A, Model-0 at NW: collaboration level a2;** * **Approach A, partial Model-0 at NW, partial Model-0 at UE: collaboration level a3; and so on;** * **Approach B, Model-1 at NW, Model-2 at UE: collaboration level a4; and so on;**   **Observation-2: While there are clear benefits of training the model at the NW side (in terms of model robustness and complexity), the disadvantages of such approach should be considered before choosing or prioritizing one option as compared to the other.**  **Proposal-2: To decide whether model training should happen at the NW side, RAN1 may consider assessing if said model is scalable and robust i.e., can be deployed, performs well, and can be maintained simultaneously at multiple UEs.**  **Proposal-3: Selecting entities for model training and inference should be decided jointly, and should be at least use-case specific.**   * **For example, if the inference is done by the NW, then the training should also be realized by the NW. Conversely, if the inference is done at the UE side, the model training may be done at the UE or NW side, depending on the use-case, approach (A/B) and UE capability.**   **Observation-3: If the model training and inference is done by the UE, it would be challenging to ensure that the model performance is consistent across the UEs, even in scenarios where the same data is used for model training, validation, and testing.**  **Proposal-4: Investigate mechanisms that enable the network to ensure that there are mechanisms to ensure consistent model performance across UEs.**  **Proposal-7: Model training, retraining or finetuning can be triggered when the model detects LOS/NLOS estimation uncertainty and subsequentially new data are labelled on-demand.**  **Proposal-8: RAN1 to study further solutions for estimating accurate labels or ground truth for important intermediate features such as LOS/NLOS indicator in a real-world, dynamic environment using PRUs without manual intervention / labelling.**  **Observation-6: The AI/ML model deployed at UE used for positioning could be vendor specific or proprietary algorithm (e.g., black box).**  **Observation-7: 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.**  **Proposal-9: RAN1 to study further data augmentation solutions and related impact on AI/ML model performance.**  **Observation-8: The AI/ML model deployed at UE used for positioning could be implementation-specific.**  **Observation-9: Labelled data is required to test/validate the AI/ML model to increase the confidence of the model.**  **Proposal-10: RAN1 to study further solutions for the test and validation of UE-based AI/ML model by employing PRU labelled measurement.**  **Observation-10: 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-11: RAN1 to study further solutions 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.**  **Proposal-12: For LOS/NLOS classification, study solution considering network assistance to determine suitable set of inputs for UE-based AIML model for given setting, scenario and UE -capabilities.**  **Proposal-13: Study reinforcement learning based methods for the anchor selection problem for AI/ML based positioning.**  **Observation-11: The current procedure for collecting data from the UEs for AI/ML purposes is not optimized, potentially incurring significant amount of signalling overhead and latency.**  **Proposal-14: Study mechanisms to enable efficient data collection in terms of signaling overhead and latency, by exploiting the sidelink interface.** |
| [21, InterDigital] | **Observation 1: During training of an AIML model, exchange of assistance information may be required**  **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)** |
| [22, 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.**  **Proposal 1: Support signaling and reporting enhancements on LPP / NRPPa to enable ML measurement approaches for accuracy improvements.**  **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.**  **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 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** |
| [23, Qualcomm] | ***Proposal 4: The overall scope of enhancements include:***   * ***Direct AI/ML method (ex. RFFP) and AI/ML assisted positioning method (ex. Likelihood fusion)*** * ***Assistance data and signaling for model generation, inference and life cycle management*** * ***ML enhanced reports mapping to existing report parameters and new parameters (interpretable and non-interpretable features).***   ***Proposal 5: Study both supervised and semi-supervised/unsupervised positioning methods for the purpose of defining the AI/ML framework in Rel-18.***  ***Proposal 6: Study RFFP based methods with various architecture flavours: UE-based, UE-assisted, Network-based and Network-assisted methods.***  ***Proposal 7: Study the specification impact needed to support machine learning based likelihood fusion techniques for positioning.***  ***Proposal 8: Study the procedures needed for the network to enable training data collection at the UE and the TRPs***  ***Proposal 9: Study meta-data assistance for UE’s training data collection for ML model development.***  ***Proposal 10: Study (noisy) ground truth and measurement error feedback for UE’s training data collection***  ***Proposal 11: Study providing beneficial assistance data to the UE for improved training and inference.***  ***Proposal 12: Study mechanisms to activate, switch, and deactivate registered ML models for UE-based, network-based and X-node models.***  ***Proposal 13: 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 14: Study ML enhanced feature reporting including features relevant to new ML based and ML assisted positioning algorithms and enhancements to existing algorithms.***  ***Proposal 15: 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 16: 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.*** |
| [24, Apple] | ***Proposal 3: The following table discusses the specification impact of different elements of the AI-based positioning:***   |  |  | | --- | --- | | *AI/ML model training* | * ***training data type/size:*** *RAN1 should down-select to a fixed set of sub-use cases with specific training data types. The size may be dependent on (a) sub-use case (b) Neural Network Model and can be signaled.* * ***training data source determination (e.g., UE/PRU/TRP):*** *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.* | | *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 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 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.* | |

## Collaboration levels

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

Several companies discussed collaboration levels between nodes for AI/ML positioning.

[5, Fujitsu] proposed that the sub use cases for AI positioning are confined to AI model collaboration level X and Y. Level Z cases will not be considered at this stage. [9, OPPO] proposed that collaboration level x and y are prioritized for various UE-based and UE-assisted positioning methods with direct AI/ML or AI/ML assisted positioning.

While [10, CATT] proposed that all collaboration levels defined in AI 9.2.1 can be considered in Rel-18 SI for AI/ML-based positioning. [19, CMCC] made the same proposal that for AI/ML enabled positioning accuracy enhancement, all the collaboration levels (level x/y/z) defined in AI 9.2.1 should be considered. Similarly, [12, Lenovo] proposed to study positioning capability support of AI/ML-based positioning depending on the supported network-UE collaboration levels. [21, 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).

Moderator’s comment:

It is moderator’s understanding that general collaboration levels and their details are to be discussed in agenda 9.2.1 general framework. Note that it was agreed that “collaboration levels x, y and z is one aspect for defining collaboration levels ” and “other aspect(s), for defining collaboration levels is not precluded and will be discussed in later meetings”. Furthermore, no prioritization has been agreed among collaboration level x, y and z in agenda 9.2.1. It seems pre-mature to rule out and/or prioritize an AI/ML positioning approach purely based on current definition of collaboration level x, y and z.

With the agreement made in RAN1#109-e, moderator thinks the discussion of prioritization of AI/ML positioning based on collaboration level can be de-prioritized in this meeting.

##### Discussion point 2-1

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.

Companies are encouraged to provide comments.

|  |  |
| --- | --- |
| Company Name | Comments/Views |
| CAICT | Support. |
|  |  |
|  |  |

## Potential specification impacts

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

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

As summarized in above section 3.1, most of the proposals from the submitted contributions are high level suggestions of areas for further study on potential specification impact, which have already been reflected in the agreement made in RAN1#109-e above. Note that there’re some detailed aspects identified by companies worth study in addition to those agreed in RAN1#109-e.

### Data collection

[1, 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.

[3, ZTE] proposed that for AI/ML assisted positioning, accessibility to ground-truth labels should be considered to get an intermediate output of an AI/ML model.

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

[16, CAICT] proposed that datasets with partial coordinate labels should be considered.

[17, Samsung] proposed RAN1 to study the training data acquisition criteria, e.g., the qualified training device determination.

[20, Nokia] proposed that RAN1 to study further solutions for estimating accurate labels or ground truth for important intermediate features such as LOS/NLOS indicator in a real-world, dynamic environment using PRUs without manual intervention / labelling. It also proposed to study further data augmentation solutions and related impact on AI/ML model performance and to study mechanisms to enable efficient data collection in terms of signaling overhead and latency, by exploiting the sidelink interface. Furthermore, [20, Nokia] observed that labelled data is required to test/validate the AI/ML model to increase the confidence of the model and proposed to study further solutions for the test and validation of UE-based AI/ML model by employing PRU labelled measurement.

[23, Qualcomm] proposed to study the procedures needed for the network to enable training data collection at the UE and the TRPs as well as to study (noisy) ground truth and measurement error feedback for UE’s training data collection. 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.

Moderator’s comment:

Multiple companies proposed to study further on where and how to obtain ground truth label in AI/ML model training.

The following proposal is formulated for discussion.

##### Proposal 2-2

Regarding data collection for AI/ML model training, companies are encouraged 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
* Efficiency (e.g., overhead and latency) of signaling for data collection
* Other aspects are not precluded

Companies are encouraged to provide comments.

|  |  |
| --- | --- |
| Company Name | Comments/Views |
| CAICT | Support FL’s Proposal. |
|  |  |
|  |  |

### Model monitoring and update

[2, 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.

[14, Spreadtrum] proposed that the integrity mechanism can be considered as one tool to evaluate/monitor the performance of AI/ML model. [19, CMCC] made a similar proposal that for AI/ML based positioning, the relationship between model monitoring and positioning integrity should be considered.

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

[17, Samsung] proposed to study the condition/methods to recovery/update a AI/ML model for positioning.

[20, Nokia] proposed to investigate mechanisms that enable the network to ensure that there are mechanisms to ensure consistent model performance across UEs.

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

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

[23, 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.

[24, Apple] discussed and gave an example of calibration error for model monitoring and updating.

Moderator’s comment:

Multiple companies proposed to study further on some detailed aspects of model monitoring and update.

The following proposal is formulated for discussion.

##### Proposal 2-3

Regarding AI/ML model monitoring and update, companies are encouraged 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
* Integrity for AI/ML based positioning
* Reference signals and measurement feedback/report
* Other aspects are not precluded

Companies are encouraged to provide comments.

|  |  |
| --- | --- |
| Company Name | Comments/Views |
| CAICT | Support FL’s proposal in general. The definition of integrity of AI/ML based positioning needs further clarification. |
|  |  |
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# Conclusion

TBD

# Reference

1. [R1-2205895](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_110/Docs/R1-2205895.zip) Discussion on AI/ML for positioning accuracy enhancement Huawei, HiSilicon
2. [R1-2206037](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_110/Docs/R1-2206037.zip) Other aspects on AI/ML for positioning accuracy enhancement vivo
3. [R1-2206073](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_110/Docs/R1-2206073.zip) Discussion on other aspects for AI positioning enhancement ZTE
4. [R1-2206116](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_110/Docs/R1-2206116.zip) Considerations on AI/ML for positioning accuracy enhancement Sony
5. [R1-2206169](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_110/Docs/R1-2206169.zip) Discussions on sub use cases and spec impacts for AIML for positioning accuracy enhancement Fujitsu
6. [R1-2206200](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_110/Docs/R1-2206200.zip) On Enhancement of AI/ML based Positioning Google
7. [R1-2206249](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_110/Docs/R1-2206249.zip) Other Aspects of AI/ML Based Positioning Enhancement Ericsson
8. [R1-2206253](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_110/Docs/R1-2206253.zip) Other aspects on AI/ML based positioning Rakuten Mobile, Inc
9. [R1-2206320](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_110/Docs/R1-2206320.zip) On sub use cases and other aspects of AI/ML for positioning accuracy enhancement OPPO
10. [R1-2206396](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_110/Docs/R1-2206396.zip) Other aspects on AI/ML for positioning CATT
11. [R1-2206477](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_110/Docs/R1-2206477.zip) Discussion on AI/ML for positioning accuracy enhancement NEC
12. [R1-2206515](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_110/Docs/R1-2206515.zip) AI/ML Positioning use cases and Associated Impacts Lenovo
13. [R1-2206525](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_110/Docs/R1-2206525.zip) AI and ML for positioning enhancement NVIDIA
14. [R1-2206607](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_110/Docs/R1-2206607.zip) Discussion on other aspects on AIML for positioning accuracy enhancement Spreadtrum Communications
15. [R1-2206640](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_110/Docs/R1-2206640.zip) Views on the other aspects of AI/ML-based positioning accuracy enhancement Xiaomi
16. [R1-2206680](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_110/Docs/R1-2206680.zip) Discussions on AI-ML for positioning accuracy enhancement CAICT
17. [R1-2206825](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_110/Docs/R1-2206825.zip) Representative sub use cases for Positioning Samsung
18. [R1-2206879](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_110/Docs/R1-2206879.zip) Other aspects on AI/ML for positioning accuracy enhancement LG Electronics
19. [R1-2206907](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_110/Docs/R1-2206907.zip) Discussion on other aspects on AI/ML for positioning accuracy enhancement CMCC
20. [R1-2206973](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_110/Docs/R1-2206973.zip) Other aspects on ML for positioning accuracy enhancement Nokia, Nokia Shanghai Bell
21. [R1-2207093](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_110/Docs/R1-2207093.zip) Designs and potential specification impacts of AIML for positioning InterDigital, Inc.
22. [R1-2207122](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_110/Docs/R1-2207122.zip) On potential specification impact of AI/ML for positioning Fraunhofer IIS, Fraunhofer HHI
23. [R1-2207229](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_110/Docs/R1-2207229.zip) Other aspects on AI/ML for positioning accuracy enhancement Qualcomm Incorporated
24. [R1-2207333](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_110/Docs/R1-2207333.zip) Other aspects on AI/ML for positioning accuracy enhancement Apple