**3GPP TSG RAN WG1 Meeting #109-e R1-22xxxxx**

**e-Meeting, May 9th – 20th, 2022**

**Source: Moderator (vivo)**

**Title: Discussion summary #1 of [109-e-R18-AI/ML-08]**

**Agenda item: 9.2.4.2**

**Document for:** [Status]

# Introduction

In this contribution, we summarize issues regarding other aspects on AI/ML for positioning accuracy enhancement for the following email discussion in RAN1 #109-e.

[109-e-R18-AI/ML-08] Email discussion on other aspects of AI/ML for positioning accuracy enhancement by May 20 – Huaming (vivo)

* Check points: May 18

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

# Sub use cases

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] | ***Proposal 1: For AI/ML-based positioning accuracy enhancements, the following two sub use cases should be studied:***   * ***AI/ML-based LOS/NLOS identification*** * ***AI/ML-based positioning in heavy NLOS scenarios***   ***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 AI/ML-based positioning, it is more convenient for gNB and LMF to perform the updating of AI/ML models which could be scenario specific.***  ***Observation 3: For the LOS/NLOS identification sub use case, gNB-oriented/UE-oriented operation mode can achieve lower latency than LMF-oriented operation mode.***  ***Observation 4: For the*** ***AI/ML-based fingerprint positioning in heavy NLOS scenario, LMF-oriented operation mode would be a universal solution.*** |
| [2, ZTE] | ***Proposal 1:*** *Focus on the following two categories during the initial evaluation for AI/ML based positioning,*   * *Cat1: AI/ML related training and inference are all conducted at one side of network or UE and is transparent to the other side* * *Cat2: AI/ML related training and inference are conducted at one side of network or UE, but requires additional signaling or procedure enhancements between two sides, potentially with existing signaling framework.* |
| [3, Ericsson] | **Proposal 1 Prioritize the sparse industrial (InF-SH scenario) and dense industrial (InF-DH scenario) use cases.**  **Observation 1 Although deployed AI/ML may likely benefit from being trained on field data, synthetically generated datasets (i.e. 3GPP channel model) is sufficient for the tasks that are within RAN1 standardization scope.**  **Proposal 2 Synthetic datasets based on 3GPP InF channel models are used for the positioning use case in the study item phase.**  **Proposal 3 Focus on single sided ML functionality for the positioning use case.**  **Observation 2 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.**  **Proposal 4 Study solutions that limit the required number of trained models that need to be supported.**  **Proposal 5 Focus on evaluation of positioning enhancements where ML models are used to improve accuracy of UE and gNB existing positioning related reports.** |
| [4, CATT] | **Proposal 1: Consider the following sub use cases in Rel-18 AI/ML-based positioning:**   * **AI/ML-based intermediate measurement estimation, e.g. ToA/AoA/AoD estimation.** * **AI/ML-based LOS/NLOS identification.** * **End-to-end positioning based on AI/ML.**   **Proposal 2: In Rel-18 AI/ML-based positioning, the following collaboration levels between UE and network can be considered:**   * **Level#0: No collaboration. AI model at one side is transparent to the other side.** * **Level#1: Inference is conducted at one side with exchanging non-AI-related assistance signal information.** * **Level#2: Inference is conducted at one side with exchanging AI-related assistance signal information.** * **Level#3: Inference is jointly conducted at both sides with exchanging AI-related assistance signal information for AI model alignment/synchronization.** |
| [5, vivo] | **Proposal 1: Depending on the role where AI technology plays in positioning, the use cases for AI/ML based positioning accuracy enhancement can be divided into two types of sub use cases, i.e., direct AI/ML positioning and AI/ML assisted positioning.**  **Observation 1: AI/ML assisted positioning has advantages in generalization capability, deployment flexibility, compatibility with existing positioning protocol framework, and possible positioning accuracy enhancement.**  **Proposal 2: Model training with large scale of dataset should be avoided at UE side. The model inference can be conducted at UE and/or network side.** |
| [6, NEC] | **Observation 1:**   * *Synchronization error between service TRP and reference TRP seriously hinders high accuracy requirement of NR positioning.*   **Proposal 1:**   * *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 2:**   * *The sub use cases of positioning accuracy enhancements should include the scenarios of heavy NLOS condition.* |
| [7, Sony] | **Observation 1: Among various indoor scenarios, InF-DL gives lowest LOS probability. InH-MO, InF-SL and InF-DH have also comparatively low LOS probability as increasing the distance.**  **Observation 2: 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.**  **Observation 3: The procedure of ML for positioning can be at least divided in three steps:**  **1. Data collection with data processing and validation,**  **2. Model Training and updating,**  **3. Model deployment.**  **Proposal 1: Consider the scenarios with channel model with rich NLOS components (e.g., InF-SL, InH-MO, InF-DL) for positioning accuracy enhancement evaluation in AI/ML topic.**  **Proposal 2: Consider to support LMF to create and train AI/ML model for NLOS mitigation.** |
| [8, Xiaomi] | **Observation2: Collaboration level Cat.2 is mainly involved if AI model is implemented on the UE side.**  **Observation4:**   * **Collaboration level Cat.3 is mainly involved if AI model is implemented on the network side and network obtain the input of the AI model from UE side** * **Collaboration level Cat.1 is mainly involved if AI model is implemented on the network side and network obtain the input of the AI model from network nodes.** |
| [9, 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;*** |
| [10, 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 either DL-TDOA or UL-TDOA***   ***Proposal 2: For AI/ML-based positioning accuracy improvement, take the traditional method of DL-TDOA as a benchmark to evaluate the potential performance gain of AL/ML:***   * ***DL-RSTD is determined by the super-resolution algorithm MUSIC*** * ***The location information is calculated by CHAN algorithm or other more advanced algorithm***   ***Proposal 3: 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 4: For AI/ML-based positioning accuracy improvement, support the sub use case based on AI model sharing and inference of AI model at UE:***   * ***E.g., UE downloads AI model from network.*** ***Upon the PRS reception, UE uses the AI model to estimate the location and reports the estimated location to LMF*** |
| [11, Futurewei] | ***Observation 1: AI/ML-based LOS / NLOS classification for scenarios with significant NLOS conditions and AI/ML-based position estimation enhancements for outdoor multipath environment can potentially improve the UE position estimation accuracy in addition to the enhancements that are currently supported in Release 17.***  ***Proposal 1: Support “AI/ML-based UE position estimation” and “AI/ML-based LOS / NLOS classification” as sub use cases for AI/ML-based positioning accuracy enhancement.*** |
| [12, 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)   + Through AI/ML algorithm, FAP (e.g. first arrival path) can be selected more accurately and then the reliable value of LoS/NLos for the path also can be obtained.   ***Observation #2:***   * Adaptive configuration of muting pattern based on AI/ML also can be useful for accuracy improvement.   ***Observation #3:***   * If the LMF can predict which UE can be used as PRU, the LMF can use the other UE dynamically as PRU to calculate the position of target UE.   + AI/ML can be a one of ways to achieve it.   ***Observation #4:***   * AI/ML can be used in terms of efficiency and power saving.   ***Proposal #1:***   * Regarding AI/ML for positioning enhancements, accuracy improvement with clear work scope can be prioritized. |
| [13, InterDigital] | **Proposal 1: Study the use cases where AIML based positioning can provide significant gain over existing methods**  **Proposal 2: Study AIML positioning can consider the following as representative sub-use cases**   * **LOS/NLOS identification** * **Fingerprinting based positioning** * **Enhancements for on-demand PRS** * **Enhancements for determination of positioning method(s)**   **Proposal 3: For each sub-use case, define inputs and outputs for the AIML model**  **Proposal 4: Study both UE-based training and network-based training of AIML models, required assistance information for each training scheme and identify specification impacts**  **Proposal 5: If UE-based training is agreed to be in scope of study, then study assistance information, at least sent from the network, needed for AIML training**  **Proposal 6: Study benefits of UE-based training and UE-based inference, and network-based training and network-based inference and identify their specification impacts** |
| [14, CAICT] | ***Proposal 1: AI/ML based algorithms could be considered for indoor scenarios.***  ***Observation 1: The relationship between channel characteristics and position of each grid could be used for AI/ML based positioning algorithm.***  ***Observation 2: AI/ML based positioning algorithms has the potential to achieve high positioning accuracy even with synchronization error among gNBs.*** |
| [15, Apple] | ***Proposal 1: The following use cases should be considered:***   * ***AI-only based positioning with UE position as output of AI model***   + ***Use case 1: CIR / L1-RSRP input to UE position output***     - ***Potential spec impact: CIR estimation/feedback for multiple gNBs*** * ***AI-assisted positioning with output of AI model serving as input to traditional positioning***    + ***Use case 2: LOS/NLOS tap identification for input to TDOA-based positioning***      - ***Potential spec impact: indication of LOS/NLOS probability***   + ***Use case 3: TOA estimation for input into TDOA-based positioning***     - ***Possible signaling of the TOA rather than the TDoA.***   ***Proposal 3: RAN1 should the following scenarios:***   * ***Training and inference at the UE*** * ***Training and inference at the LMF*** |
| [16, CMCC] | ***Proposal 1:* For AI/ML enabled positioning accuracy enhancement, select one or two sub use cases from Table I for characterization and baseline performance evaluations.**  **Table I. Different types of input and output of AI/ML model**   |  |  |  | | --- | --- | --- | | Case | Input | Output | | 1 | CIR | UE location | | 2 | CIR+RSRP | UE location | | 3 | TOA | UE location | | 4 | AOA | UE location | | 5 | CIR | TOA | | 6 | CIR | AOA | | 7 | CIR | LOS probability | | 8 | PDP | LOS probability | |
| [17, Lenovo] | ***Observation 1: Network-UE collaboration levels for positioning may assist in assessing any potential specification impact.***  ***Observation 2: Current positioning deployments may already have the flexibility to make use of Cat. 1 AI/ML Network-UE collaboration level.***  ***Observation 3: Rel-17 focused on reporting enhancements for NLOS and multipath effects.***  ***Proposal 1: Study various positioning AI/ML management and models based on network-UE collaboration levels.***  ***Proposal 2: RAN1 to prioritize the AI/ML-based study support for absolute positioning use cases and requirements.***  ***Proposal 3: RAN1 to further study the impact of AI/ML on the NLOS/multipath sub-use case for timing-based and angular-based positioning techniques.***  ***Proposal 4: RAN1 to further study the benefits of improving DL-PRS resource efficiency using AI/ML techniques.***  ***Proposal 5: Study the use of AI/ML techniques to enhance positioning methods employing fingerprinting.*** |
| [18, Nokia] | **Observation 1**: Using ML-based solutions to estimate a target UE’s location in NLOS conditions and/or using multipath information may be beneficial to the final location estimate.  **Observation 2**: There is a need for assessing whether and to what extent such LOS report may be trusted by the network - including both cases of binary LOS classification report and LOS probability report.  **Observation 3**: To strike the right balance between reporting overhead and location accuracy, the UE/TRP may assess whether it is beneficial, and how often to report all/some of the N required paths.  **Observation 4**: To decrease reporting overhead, the UE may apply an ML based method to compress the reported data e.g., sending K samples instead of N samples (with K < N).  **Proposal 1**: Study ML-based techniques for LOS detection as a representative sub use case of positioning accuracy enhancements use case, including joint ML operation between the network and UE.  **Proposal 4**: Study ML-based techniques for UE location estimation using channel information pertaining to NLOS conditions as a representative sub use case of positioning accuracy enhancements use case.  **Proposal 7**: Prioritize the study of the following sub-use cases in Rel-18:   * LOS/NLOS detection * NLOS-based localization and harnessing multipath information * Optimization of positioning related feedback and measurement reporting |
| [19, Intel] | **Proposal #1:**   * + **Study benefits of using AI/ML for timing estimation of multipath components with fractional sample delay (super resolution in time)**   **Proposal #2:**   * + **Study benefits of using AI/ML for angles estimation of multipath components with fractional spatial resolution (super resolution in space)**   **Proposal #3:**   * + **Study application of AI/ML methods to determine the coordinates of the virtual TRPs (image sources) associated with the 1st order reflections of multipath channel impulse response components**   **Proposal #4:**   * + **Study application of AI/ML methods for determination of per path reflection order (at least 0th and 1st orders)**   **Proposal #5:**   * + **Study benefits of using AI/ML methods for estimation of per path signal location parameters (feature extraction) for NR positioning, including but not limited to the following:**     - **Path timing (DL RSTD, UL RTOA, gNB/UE Rx-Tx time difference)**     - **Path angle (DL-AOD, UL-AOA)**     - **Path reflection order**     - **Path power (DL RSRPP, UL RSRPP)**     - **Path virtual TRP (image source) coordinate**   **Proposal #6:**   * + **Study benefits of the ANN architecture, where the ANN is divided into two parts, including the Feature Extraction Neural Network (FE-NN) and Coordinate Inference Neural Network (CI-NN) with the specified interface between these two parts**   **Proposal #7:**   * + **Study benefits of the ANN architecture, where coordinate inference is performed by the ANN for the input channel estimate without explicit division into the Feature Extraction Neural Network (FE-NN) and Coordinate Inference Neural Network (CI-NN) parts** |
| [21, 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 selected as one representative sub use case.** |
| [22, 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:***   * ***New ML based and ML enhanced positioning methods (ex. RFFP and 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 unsupervised positioning methods for the purpose of defining the AI/ML framework in Rel-18. For evaluations and comparison with classical methods, focus on the supervised methods.***  ***Proposal 6: Support 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 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).*** |
| [23, Fujitsu] | ***Proposal 1: On AI/ML for positioning accuracy enhancement during the SI phase, the following two sub use cases are selected:***   * ***gNB-based AI/ML without assistant information.*** * ***gNB-based AI/ML with assistant information.***   ***Proposal 2: Online training for positioning is not supported due to the difficulty on obtaining the training labels.*** |

## Collaboration levels

Several companies discussed collaboration levels between nodes for AI/ML operation. It seems most if not all of them took the categorization of collaboration levels suggested during the email discussion for approving this study item (copied below) for discussion.

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| Cat.1: AI/ML related training and inference are all conducted at one side of network or UE and is transparent to the other side  Cat.2: AI/ML related training and inference are conducted at one side of network or UE, but requires additional signalling or procedure enhancements between two sides, potentially with existing signalling framework. Additional information is not directly related to training and inference, e.g., capability, new patterns etc.;  Cat.3: AI/ML related inference is conducted at one side of network or UE, with assisted training information exchanged between two sides;  Cat.4: AI/ML related inference are conducted together at both sides of network and UE training maybe conducted at one side or both. Information related to inference need to be exchanged between both sides. |

[2, ZTE] proposed to focus on Cat.1 and Cat.2 collaboration levels during the initial evaluation for AI/ML based positioning. [3, Ericsson] proposed to focus on single sided ML functionality for the positioning use case. [23, Fujitsu] proposed to prioritize gNB-based AI/ML as sub use cases during SI.

While [4, CATT] proposed that all four collaboration levels between UE and network can be considered in Rel-18 SI for AI/ML-based positioning. [8, Xiaomi] observed that different collaboration levels may be involved depends on where AI/ML model is implemented and where the input of AI/ML model is obtained. [17, Lenovo] proposed to study various positioning AI/ML management and models based on different network-UE collaboration levels.

Moderator’s comment:

It is moderator’s understanding that collaboration levels and their categorization are to be discussed in agenda 9.2.1 general framework. Once agreed in agenda 9.2.1, terminology, notation and common framework for AI/ML are expected to be applicable to AI/ML for positioning accuracy enhancement as well. Though positioning specific aspects on collaboration levels if identified by companies are to be discussed in agenda 9.2.4.2.

Given the SID states “identify various levels of collaboration between UE and gNB pertinent to the selected use cases”, it is pre-mature to rule out and/or prioritize an AI/ML method purely based on collaboration level before the actual study being conducted.

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

##### Proposal 1-1

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

* Note: terminology, notation and common framework of collaboration levels are to be discussed in agenda 9.2.1 and expected to be applicable to AI/ML for positioning accuracy enhancement.
* Companies are encouraged to identify positioning specific aspects on collaboration levels if any in agenda 9.2.4.2.

Companies are encouraged to provide comments.

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| Company Name | Comments/Views |
| ZTE | Agenda 9.2.1 is to discuss the general framework. However, the collaboration level could be use case specific, or even sub-use case specific. So, for each sub-use case, we may need to discuss which collaboration level should be prioritized. We think it’s too early to say we should study all identified collaboration levels. In addition, it’s not clear this proposal is collaboration level for training or inference. Therefore, we prefer following revision,  Study further on sub use cases and their potential specification impact of AI/ML for positioning accuracy enhancement considering ~~all identified~~ **appropriate** collaboration levels **on training/ inference** **for each sub use case**. |
| InterDigital | Ok with the modification from ZTE |
| Apple | Prefer ZTE’s modification. Reluctant to endorse “all identified” collaboration levels at this stage. |
| OPPO | We understand the motivation. However, the definition of collaboration levels is not clear so far as different companies have different proposals in their tdoc. We can wait for more progress of the general aspect (AI 9.2.1). Thus, we support to change “all identified” to “appropriate” as suggested by ZTE.  For the new part “on training/inference for each sub use case” suggested by ZTE, we think it is premature to explicitly include “training”. As discussed in the general aspect, offline/online training are still under discussion.  In summary, we suggest the following modification:  Study further on sub use cases and their potential specification impact of AI/ML for positioning accuracy enhancement considering ~~all identified~~ **appropriate** collaboration levels |

## AI/ML model training and inference

Several companies discussed aspects related to AI/ML management for sub use cases, especially on AI/ML model training.

[3, Ericsson] proposed to focus on single sided ML functionality for the positioning use case. [5, vivo] proposed model (online) training with large scale of dataset should be avoided at UE side while model inference can be conducted at UE and/or network side. [7, Sony] proposed to support LMF to create and train AI/ML model for NLOS mitigation. [10, OPPO] proposed to support the sub use case based on AI model sharing and inference of AI model at UE. [13, InterDigital] proposed to study both UE-based training and network-based training of AI/ML models, required assistance information for each training scheme and identify specification impacts. [15, Apple] proposed to consider training and inference at the UE as well as training and inference at the LMF.

[22, Qualcomm] proposed that for the positioning use case, the (training) data is collected by the UE and/or the network and the training is performed offline. [23, Fujitsu] proposed online training for positioning is not supported due to the difficulty on obtaining the training labels. On the same topic of obtaining training labels, it is observed in [1, Huawei] 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. Using Positioning Reference Units (PRUs) with known coordinates for AI-based positioning is also proposed to be studied in [19, Intel].

Moderator’s comment:

It is moderator’s understanding that AI/ML model management in general are to be discussed in agenda 9.2.1 general framework and applicable to positioning use case. Though positioning specific aspects on AI/ML model management if identified by companies are to be discussed in agenda 9.2.4.2.

Although there’re views to not support online training for AI/ML positioning, it seems pre-mature to decide now in the first meeting of SI when the study on impacts of both online and offline training has not been conducted yet.

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

##### Proposal 1-2

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

* Training at UE and/or network side
* Offline and/or online training

Companies are encouraged to provide comments.

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| Company Name | Comments/Views |
| ZTE | Generally fine with the proposal, which can be a starting point for further discussion. |
| InterDigital | Support |
| Apple | Fine with the proposal |
| OPPO | It depends on the sub use case. For example, training at NW may be preferred for one sub use cases and training at UE may be preferred for another sub use cases. Thus, we prefer to discuss it sub use case by sub use case.  Moreover, AI inference seems missing. |

## Classification of sub use cases

Companies have some quite different ways to classify sub use cases.

[3, Ericsson] categorized sub use cases based on deployment scenarios and proposed to prioritize the sparse industrial (InF-SH scenario) and dense industrial (InF-DH scenario) use cases.

[4, CATT] categorized sub use cases based on where AI/ML function is in the process of positioning (e.g., whether to obtain intermediate measurement estimation, or end-to-end positioning). [5, vivo] also categorized sub use cases based on where AI/ML function is in positioning process and proposed to classify as direct AI/ML positioning and AI/ML assisted positioning. [9, Samsung] took a similar approach and termed as positioning location estimation and intermediate measurement estimation. [15, Apple] also took a similar categorization way and called them: AI-only based positioning with UE position as output of AI model and AI-assisted positioning with output of AI model serving as input to traditional positioning.

[10, OPPO] categorized sub use cases based on AI/ML enhancements for different existing RAT-dependent positioning methods (i.e., DL-TDOA, UL-TDOA, DL-AoD, UL-AoA and Multi-RTT positioning). It proposed to down-select DL-TDOA or UL-TDOA to study the integration of AI/ML.

[16, CMCC] categorized sub use cases based on different types of input and output of AI/ML model (e.g., CIR, or TOA, or AOA, or PDP as the input; location or TOA, or LOS probability as the output).

[22, Qualcomm] categorized the sub use cases as a function of the entity at which the inference is performed, and the information needed to perform the inference. It proposed four candidate use cases to study: UE-based, UE-assisted, Network-based, and Network-assisted positioning methods for performing AI/ML based inference. Note that, [22, Qualcomm] also categorized their proposed AI/ML enhancements as new ML based positioning methods (e.g. RFFP and Likelihood fusion) and ML enhanced reports mapping to existing report parameters and new parameters.

[23, Fujitsu] thought the sub use cases of AI/ML for positioning accuracy enhancement can be categorized by different ways: the collaboration level between network and UE, the AI/ML model deployment strategy and the property of the AI/ML model output.

Other companies either didn’t classify sub use cases or didn’t explicitly state how they classify different sub use cases but rather directly made proposals of sub use case(s) (moderator’s observation: likely based on where AI/ML may improve positioning accuracy). [1, Huawei] proposed AI/ML-based LOS/NLOS identification and AI/ML-based positioning in heavy NLOS scenarios. [11, Futurewei] also proposed to support AI/ML-based UE position estimation and AI/ML-based LOS/NLOS classification as sub use cases. [6, NEC] proposed to consider AI/ML for scenarios with synchronization error and heavy NLOS condition. [13, InterDigital] proposed LOS/NLOS identification, Fingerprinting based positioning, Enhancements for on-demand PRS and Enhancements for determination of positioning method(s) as sub use cases. [17, Lenovo] proposed to study further on AI/ML for NLOS/multipath, AI/ML for improving DL-PRS resource efficiency and AI/ML with fingerprinting. [18, Nokia] proposed to prioritize LOS/NLOS detection, NLOS-based localization and harnessing multipath information and Optimization of positioning related feedback and measurement reporting in Rel-18. [19, Intel] proposed to study AI/ML for timing/angle estimation of multipath, for determination of virtual TRP coordinate, for determination of per path reflection order and per path signal parameter estimation.

Moderator’s comment:

Indeed, there’re multiple ways to categorize sub use cases of AI/ML for positioning accuracy enhancement. At least for the purpose of understanding alignment among companies, and for discussion/description of potential specification impact, it seems beneficial to have a common categorization of sub use cases.

Regarding the categorization way, it seems more companies inclined to classify based on where AI/ML enhancement is in the positioning process and/or based on the output of AI/ML model.

##### Proposal 1-3

For further study of sub use cases and their potential specification impact, at least the following categorization of candidate sub use cases 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 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 reporting and/or enhancement of existing measurement reporting, which in turn is used to improve positioning accuracy
  + 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 sub use cases of AI/ML for positioning accuracy enhancement

Companies are encouraged to provide comments.

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| Company Name | Comments/Views |
| ZTE | Fine with the categorization. Regarding the applicable scenario(s), it’s not clear. Do you mean the collaboration levels, training procedures as shown in Proposal 1-1 and Proposal 1-2? |
| InterDigital | We are ok with the proposal. |
| Apple | We are fine with the categorization. |
| OPPO | We are ok with the categorization. Our proposed sub use cases are as below, which belongs to the first category.  Sub use case 1 (for UE assisted positioning):   * AI model is trained offline by NW * AI model inference at NW * The input is the RSTD measurement results (optionally with PRS RSRP) reported by UE * The output is the estimation of location   Sub use case 2 (for UE based positioning):   * AI model is trained offline by UE * AI model inference at UE * The input is * Alt.1: the RSTD measurement results (optionally with PRS RSRP) * Alt.2: the CIR measurement results * The output is the estimation of location |

## Representative sub use case(s)

Some companies have expressed views on how to select representative sub use case(s).

Several companies ([9, Samsung], [10, OPPO], [13, InterDigital]) have the view that representative sub use case(s) should cover the case(s) where legacy positioning methods cannot work well and be able to show significant advantages and performance gain of AI/ML-based scheme over existing positioning methods.

[3, Ericsson] prioritized sub use cases based on deployment scenarios and proposed to prioritize the sparse industrial (InF-SH scenario) and dense industrial (InF-DH scenario) use cases.

[23, Fujitsu] prioritized sub use cases based on collaboration levels and proposed to select gNB-based AI/ML without assistant information and gNB-based AI/ML with assistant information as the sub use cases.

Other companies didn’t explicitly state how they select representative sub use cases (moderator’s observation: likely based on where AI/ML may improve positioning accuracy). [1, Huawei] proposed AI/ML-based LOS/NLOS identification and AI/ML-based positioning in heavy NLOS scenarios. [11, Futurewei] also proposed to support AI/ML-based UE position estimation and AI/ML-based LOS/NLOS classification as sub use cases. [6, NEC] proposed to consider AI/ML for scenarios with synchronization error and heavy NLOS condition. [13, InterDigital] proposed LOS/NLOS identification, Fingerprinting based positioning, Enhancements for on-demand PRS and Enhancements for determination of positioning method(s) as sub use cases. [17, Lenovo] proposed to study further on AI/ML for NLOS/multipath, AI/ML for improving DL-PRS resource efficiency and AI/ML with fingerprinting. [18, Nokia] proposed to prioritize LOS/NLOS detection, NLOS-based localization and harnessing multipath information and Optimization of positioning related feedback and measurement reporting in Rel-18. [19, Intel] proposed to study AI/ML for timing/angle estimation of multipath, for determination of virtual TRP coordinate, for determination of per path reflection order and per path signal parameter estimation. [21, NVIDIA] proposed to select high accuracy positioning in heavy NLOS scenarios as one representative sub use case.

Moderator’s comment:

Given this is the first meeting of this SI where performance, complexity and specification impact of each sub use case have not been studied yet, it seems not appropriate to decide on representative sub use case(s) for now.

However, in order to select the representative sub use case(s), it’d be good to align companies’ understanding on the aspects to look into for selection of representative sub use case(s).

##### Proposal 1-4

For selection of representative sub use case(s), at least the following aspects of sub use cases of AI/ML for positioning accuracy enhancement are considered.

* Evaluation results of performance gain, and other agreed evaluation KPIs
* Potential specification impact

Companies are encouraged to provide comments.

|  |  |
| --- | --- |
| Company Name | Comments/Views |
| ZTE | The efforts need to maintain life cycle management(LCM) of AI/ML model should be specially considered as we try to design a framework that should be easily deployed in realistic system.  In addition, we should further study KPIs that can be representative enough to evaluate the benefits of a sub use case. |
| InterDigital | We are ok with the proposal |
| Apple | We are fine with the proposal |
| OPPO | In addition to the above aspects, the impact on UE/NW implementation should also be considered. |

## Other issue(s)

Companies are encouraged to provide comments if any on missed issue(s) of sub use cases.

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| Company Name | Comments/Views |
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# 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 signalling, 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 2: Study whether potential specification impact is needed for AI/ML-based positioning, including feedback of channel measurements (e.g., CIR, PDP) to LMF.*** |
| [2, ZTE] | ***Observation 1:*** *With the increase in number of paths, the AI/ML based positioning method can have excellent performances even in heavy NLOS conditions.*  ***Proposal 2:*** *Study and evaluate whether the specification needs to support UE/gNB to report more than 8 additional path timings and path RSRPs for AI/ML based positioning.*  ***Observation 2:*** *Evaluation results show that the utilization of path phases can obviously improve the performance for AI/ML based positioning in some cases.*  ***Proposal 3:*** *Study and evaluate whether UE/gNB should report path phases for AI/ML based positioning.* |
| [3, Ericsson] | **Observation 3 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.** |
| [4, CATT] | **Proposal 3: The specification impacts can be further considered after the sub use cases and the corresponding collaboration level are clear.** |
| [5, vivo] | **Proposal 3: For direct AI/ML positioning, UE capability corresponding to AI/ML model(s) is required when model inference is at UE side.**  **Proposal 4: For direct AI/ML positioning, assistance information to the target UE about AI/ML model for inference is beneficial and necessary when model inference is at UE side.**  **- Study further on the details of assistance information, which may consist of the input and output of model, the architecture of model, the weight of model, the configuration of model, the state of optimizer, and so on.**  **Proposal 5: 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 AI/ML model) for model inference is needed.**  **Proposal 6: For AI/ML assisted positioning, UE capability corresponding to AI/ML model(s) is required when model inference is at UE side.**  **Proposal 7: For AI/ML assisted positioning, assistance information to the target UE about AI/ML model for inference is beneficial and necessary when model inference is at UE side.**  **- Study further on the details of assistance information, which may consist of the input and output of model, the architecture of model, the weight of model, the configuration of model, the state of optimizer, and so on.**  **Proposal 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.**  **Proposal 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 AI/ML model) for model inference is needed.**  **Proposal 10: When fine-tuning is conducted at UE side, UE capability corresponding to fine-tuning is required.**  **Proposal 11: To assist UE performing model fine-tuning, assistance information to the target UE about pre-trained model and training configuration is beneficial.**  **Proposal 12: Training data collection request to and feedback from the target UE is required to support model fine-tuning at network side.** |
| [6, NEC] | **Proposal 3:**   * *Different reference signal resources density should be configured for different phase of AI/ML model for reference signal derived data set collection.*   **Proposal 4:**   * *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.* |
| [7, Sony] | Proposal : Consider the specification impact on these two aspects:   1. **Reporting positioning measurements to LMF for model training (e.g., the ground truth output of the model.)** 2. **Signalling and deploying the inference model in UE/gNB.** |
| [8, Xiaomi] | **Observation 1: New procedure or new signalling for the AI model management (including the initial AI model selection, AI model transfer and AI model updating) is potentially required in the specification**  **Observation3: If AI model is implemented on the network side, new signalling for the AI model input is potentially needed in the specification.** |
| [9, Samsung] | ***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.*** |
| [14, CAICT] | ***Proposal 2: It should be further studied that the way of high-precision positioning information achievement during the inference stage for AI/ML model monitoring.***  ***Proposal 3: AI/ML based positioning algorithm could be considered for both gNB side and UE side.*** |
| [15, Apple] | ***Proposal 2: The following should be considered as input to the AI model and effect on specification discussed:***   * + ***Channel Impulse Response (CIR), L1-RSRP, Power Delay Profile, Beam Index***     - ***Potential spec impact: NN inference input acquisition signals and procedures to/from multiple gNBs including the specification impact on issues such as pre-processing, signaling, measurement and feedback.*** |
| [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, the relationship between model monitoring and positioning integrity should be considered.** |
| [17, Lenovo] | ***Proposal 6: Study the use of assistance information signalling related to positioning data set construction to enhance the accuracy of the training and inference models at each node.***  ***Proposal 7: 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 8: Study positioning capability support of AI/ML-based positioning depending on the network-UE collaboration levels.*** |
| [18, Nokia] | **Proposal 2:** Study possible interactions between the UE and the network for training and deploying an ML-based LOS detector. The interactions between the respective entities (i.e., network – LMF and UE/TRP) should include the following information:   * The acquisition and transfer of training and/or inference data between relevant entities.   + This would facilitate to assess whether these require different definitions depending on whether the LOS detector resides at TRP side, LMF side, or at the UE side. * Network-based model generation and exchange. * Model activation, deactivation, update, and testing   + Including model assessment in terms of validity of output, and that the model output leads to actions/outcomes that ensures a minimal performance target.   **Proposal 3**: An additional indicator to the LOS indicator may be provided to the network along with the LOS indicator. The additional indicator should reflect the level of trust of the LOS indicator based on the utilized input features and the deployed classifier at the UE side.  **Proposal 5**: To cope with NLOS conditions and/or harness multipath information, study possible interactions between the UE and the network for training and deploying an ML-based localization method, including input feature definition, training data collection, model tuning after deployment, etc.  **Proposal 6**: For UE-assisted positioning, study possible interactions between the UE and the network for training and deploying an ML-based solution that allows for a flexible UE/TRP positioning measurement reporting including tuning the frequency, payload size and content (measurement types) of the report. |
| [19, Intel] | **Proposal #8:**   * + **Study benefits of the distributed, centralized, and federated architectures for AI/ML based positioning and identify the potential impact on RAN1 specification work**   **Proposal #9:**   * + **Study benefits of the ANN supervised learning using Positioning Reference Units (PRUs) with known coordinates for AI-based positioning**   **Proposal #10:**   * + **Study benefits of the ANN supervised learning using regular UEs with estimated coordinates for AI-based positioning**     - **The initial coordinate estimation is performed using conventional NR RAT-dependent positioning methods** |
| [20, Fraunhofer] | **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 in Rel-18 the following aspects to support AI/ML in challenging positioning environments:**   * + **Additional reporting for environment information in processing and training phase**   + **Study improvements by introducing calibration and association spots as guideline reporting of UE-A and calibration for UE-B.**   + **Additional signaling needed for making use of Virtual-TRPs**   + **Temporal PRUs/anchors to enhance accuracy and maintain the AI/ML model**   **Proposal 4: For UE-based AI/ML models may be subject of implementation. Identify requirements for the network for the maintenance of such models.** |
| [21, NVIDIA] | **Proposal 2: Study the signalling support for the training and execution of AI/ML models for positioning enhancement.**  **Proposal 3: Study the data required by AI/ML models for positioning enhancement (e.g., data reported by UE to gNB, assistance data from gNB to UE).**  **Proposal 4: Study how to deliver outputs generated by AI/ML models for positioning enhancement from gNB to UE and from UE to gNB.** |
| [22, Qualcomm] | ***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.*** |
| [23, Fujitsu] | ***Proposal 3: The potential specification impacts include assistance information and new signaling procedure for gNB-based AI/ML.*** |

## Potential specification impact

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.

Moderator’s comment:

Given this is the first meeting of this SI, a list of areas identified by companies for further study on potential specification impact is formulated below as guidance.

##### Proposal 2-1

Companies are encouraged to study and provide inputs on potential specification impact at least for the following aspects.

* AI/ML model training
  + training data type/size
  + training data source (e.g., UE/PRU/TRP)
  + assistance signalling and procedure for training data collection
* AI/ML model indication/configuration
  + assistance signalling and procedure for model configuration
  + assistance signalling and procedure for model activation/deactivation
* AI/ML model monitoring and update
  + assistance signalling and procedure for model performance monitoring
  + assistance signalling and procedure for model update/tuning
* AI/ML model inference input
  + report/feedback of model input for inference
  + model input acquisition and pre-processing
  + type/definition of model input
* AI/ML model inference output
  + report/feedback of model inference output
* UE capability for AI/ML model(s)
* Other aspects are not precluded
* Note: not all aspects may apply to a sub use case

Companies are encouraged to provide comments.

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| --- | --- |
| Company Name | Comments/Views |
| ZTE | 1. This proposal can provide a guidance for further study. Still, the procedures should be per sub use case. 2. For AI/ML model inference output, prefer to have another bullet,    * Post-processing of model inference output |
| InterDigital | We agree with the most of main bullets. However, for the details in sub-bullets, we may need more discussions and it may be too early to narrow the scope. Suggested changes are shown below.   * ….. * AI/ML model indication/configuration   + assistance signalling and procedure (e.g., for model configuration, model activation/deactivation) * AI/ML model monitoring and update   + assistance signalling and procedure (e.g., for model performance monitoring and model update/tuning) * …..   In addition, we are not clear about what “AI/ML model inference input” means. Clarification may be needed. For example, the source of “feedback” for model inference input is not clear. |
| Apple | Fine with this as a first step e.g. there may be use-case specific issues that may need to be addressed. |
| OPPO | In general, we are fine to consider these aspects. The spec impact depends on sub use cases. Thus, the detailed discussion can wait for more progress of sub use cases. |

## Other issue(s)

Companies are encouraged to provide comments if any on missed issue(s) of specification impact.

|  |  |
| --- | --- |
| Company Name | Comments/Views |
|  |  |
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# Conclusion

TBD

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