**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 |
| Samsung | We share the view as ZTE that the collaboration level should be use case specific, different use case could have totally different usage of AI.  However, we feel the wording of the main bullet from FL’s proposal is good enough, as to consider all levels for now it’s a fine starting point, since there is no clear motivation to rule out which one yet.    Study further on sub use cases and their potential specification impact of AI/ML for positioning accuracy enhancement considering all identified collaboration levels for each of the sub use cases. |
| NEC | Support generally except for the first bullet.  The collaboration levels for different use case may be specific. i.e., for the use case of CSI feedback enhancement, collaboration between NW and UE is preferred since the AI model of decoding and encoding will be deployed at different sides of NW and UE. For the use case of positioning accuracy enhancement, the necessity of deploying the coupling AI model at different sides is not apparent. Of course, we do not intend to support no collaboration for the use case of positioning, we hope to leave it at this agenda. |
| Futurewei | Support |
| Fujitsu | We agree with Ericsson that only one-sided sub use cases should be considered in the SI phase, that means, the AI/ML model should be deployed in gNB (we prefer) or UE only, the model inference can only take place in one side and no model-related information will be exchanged from one side to another. Therefore, we do not suggest having collaboration CAT4 studied at this stage.  CAT1, CAT2 and CAT3 are all worthy of study. CAT1, which will not introduce specification impact, can be used as a baseline for comparison. CAT2 and CAT3 have the AI model deployed in one side but need additional signaling from the other side for monitoring (procedure) and training (such as enhanced input data) respectively. They will introduce two sorts of specification impact which corresponds to the proposal 3.  Anyway, we agree with the moderator that the selection of sub use cases should not purely based on the collaboration level, it also depends on the performance improvement and other factors. It will be helpful to discuss in detail after fixing the definition of the framework, terminology and collaboration level in agenda 9.2.1. |
| NVIDIA | ZTE’s suggestion on changing “all identified collaboration levels” to “appropriate collaboration levels” is a reasonable way forward at this stage, considering the discussion on collaboration levels has not progressed yet. |
| Fraunhofer | Support |
| Nokia, NSB | We are not entirely sure about the intent of this proposal. If the intent is to not limit the sub use cases and their impact to any particular type of collaboration, we would propose the following rewording:  Study further on sub use cases and their potential specification impact of AI/ML for positioning accuracy enhancement considering possible collaboration levels identified for the study item. |
| LG | We have a similar view with ZTE and OPPO that it needs to be discussed further for the collaboration level for each AI/ML positioning-specific sub-use case |
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| Moderator | To ZTE, Apple, OPPO, LG: I don’t see how the wording of this proposal could be interpreted as all collaboration levels are applicable to an AI/ML approach in a sub use case. Anyway, a note is added to address your concern.  To ZTE, Apple, OPPO, NVIDIA: on the suggested wording of “**appropriate”.** I think it is still debatable what is **appropriate**. I took the wording “various” from the SID instead.  To ZTE, Fujitsu, Nokia: as I mentioned “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.”. The intention of this proposal is to set the scope clear that no prioritization on collaboration level for now.  To all: I also took the wording “AI/ML approaches for sub use cases” from the SID to align the understanding here as companies have different interpretation on sub use case.  Wording update into Proposal 1-1a below. |

##### Proposal 1-1a

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.
* 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.
* Note2: not every collaboration level may be applicable to an AI/ML approach for a sub use case

Companies are encouraged to provide comments.

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| Company Name | Comments/Views |
| Spreadtrum | Generally we are fine |
| CATT | Fine with the proposal. Similar view as Samsung, all identified collaboration levels can be a good starting point for further discussion, and it is too early to exclude some collaboration levels without enough research and discussion. |
| CAICT | Fine with the proposal. |
| HW/HiSi | Positioning does not only involve UE and gNB, but also LMF, which is out of RAN1 scope.  For the study of potential specific aspects on collaboration levels for positioning, we would like to clarify whether this only focuses on collaboration levels between the UE and the gNB or also between gNB and LMF.  Specific for positioning, we suggest to study the specification impact for single-sided AI models. The two-sided AI model may involve joint training and model exchange which will be addressed and 9.2.1 or in 9.2.2.1. |
| ZTE | Fine with the proposal. The entities involved in collaboration may need to be clarified, i.e., AI inference may reside at UE/gNB/LMF. |
| Ericsson | We are fine with the proposal.  Regarding the nodes involved, we think UE/gNB/LMF should be included. Depending on the sub-use case and positioning method, the inference may reside in UE or gNB or LMF. We don’t agree LMF is excluded in the discussion. Positioning use case is different from other use cases in that LMF is in the picture by nature. It’s preferred to use “network node” so that it can refer to gNB and/or LMF. |
| NEC | We are fine with the proposal. We agree to discuss collaboration levels of positioning specific aspects in agenda 9.2.4.2 and discuss terminology, notation and common framework of collaboration levels in 9.2.1. |
| Moderator | To Huawei: my understanding is collaboration between UE and gNB/LMF as well as between gNB and LMF are in the scope of RAN1. This is the same treatment as in Rel-16/17 positioning SI/WI where measurement reporting/signaling from UE to LMF and from gNB to LMF for DL-TDOA/UL-TDOA/M-RTT/UL-AOA etc. were studied and agreed in RAN1.  To Huawei: as I mentioned before “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.”. The intention of this proposal is to set the scope clear that no prioritization on collaboration level for now. When more input/study is available, prioritization and even observation/conclusion/recommendation can be done at later stage of SI. |
| LG | Fine with the current proposal. |
| vivo | Support |
| Sony | Generally, we should reuse the progress in AI9.2.1 for AI/ML for positioning.  We are fine with the suggested text by ZTE, perhaps we can fine tune as follows:  Study further on sub use cases and their potential specification impact of AI/ML for positioning accuracy enhancement considering ~~all identified~~ **appropriate** collaboration levels (e.g., **on training/ inference** **for each sub use case)**. |
| Samsung | We are fine to the proposal. |
| InterDigital | We support the proposal. |
| OPPO | Support. Regarding the nodes, we think UE, gNB and LMF should be included |
| Lenovo | Fine with proposal |
| CMCC | Fine with the proposal |
| Xiaomi | We support FL’s proposal. As for the collaboration, it may involve the collaboration between UE and gNB or between UE and LMF or between gNB and LMF. In our opinion, we could identify the involved entities clearly. Maybe the specification impact for some collaboration case is up to RAN2/RAN3. In this case RAN1 could figure out the situation clearly and leave RAN2/RAN3 to study the spec impact. That is also workable.. |
| Nokia/NSB | We are fine with the proposal and agree with the view of Ericsson that LMF should be included in the discussion due to its importance for positioning. |
| Moderator | To Sony: your comment seems is for proposal 1-1. Please check current wording of proposal 1-1a, which I think already addressed your concern. |
| Qualcomm | We support the updated proposal. The discussion on collaboration level for positioning sub use case can be decided once the agreed-on collaboration levels in 9.2.1 are clear and finalized. |
| Futurewei | Just to be clear, the order of decisions/preferences should be first decisions/agreements from 9.2.1 and then it is not precluded by companies to identify any adjustments needed that arise from 9.2.4.2. If so, then the first bullet should be a sub-bullet of the second bullet. |
| Apple | We are fine with the proposal. As mentioned by many companies, the decisions in 9.2.1 should serve as inputs to this agenda item. |
| Intel | We are okay with the proposal |

## 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.

|  |  |
| --- | --- |
| 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. |
| Samsung | Generally fine, just to clarify, does the online training here includes the online finetuning or updates? |
| NEC | Support |
| Futurewei | Support |
| Fujitsu | Considering the rapidly changing wireless environment and the hardware limitation of the UE, we propose to deploy the AI/ML model in network side first to have the preliminary study at the SI phase.  Online training is not suggested at this stage due to the difficulty on obtaining the training label, although there have been plenty of study and discussion in REL-17 Enh-Pos for the utilization of PRU, it is still pre-mature to introduce it to AI/ML positioning now. It can be a further discussion point in the future after the SI phase. |
| NVIDIA | Support |
| Fraunhofer | Support |
| Nokia, NSB | We are fine with this proposal. |
| LG | Fine with the proposal as a start point discussion. |
|  |  |
| Moderator | To OPPO: the wording of this proposal does not preclude case by case study. Rather, the intention is to assure no prioritization on one way of training over the other for now. A sub-bullet on inference is added.  To Samsung: definition of online vs. offline training is to be discussed in agenda 9.2.1. My intention is to not preclude anything for now.  To Fujitsu: moderator’s understanding of this Rel-18 SI is not only identifying areas for potential Rel-19 normative work but also serves as the base for future releases on AI/ML work as well. It’s understandable not every company prefer to support/specify online training. However, I don’t share your understanding that study of it means introduction to AL/ML positioning. Rather, precluding it to be studied at the first meeting of this SI is pre-mature.  Wording update into Proposal 1-2a below. |

##### Proposal 1-2a

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

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

Companies are encouraged to provide comments.

|  |  |
| --- | --- |
| Company Name | Comments/Views |
| Spreadtrum | Generally we are fine as the starting point. |
| CATT | Fine with this proposal. |
| CAICT | Fine with this proposal |
| HW/HiSi | We suggest studying the specification impacts separately for each sub use case, since they might be different, especially when considering direct AI/ML positioning and AI assisted positioning.  For direct AI/ML positioning, we think training at network side would be a universal solution but for AI assisted positioning, we think training at either UE or network side can be studied.  Training at both UE and network side will complicate the discussion and should be deprioritized. |
| ZTE | Share some similar views that single side training/inference for positioning should be prioritized. |
| Ericsson | First, we think single sided ML should be prioritized. Thus suggest changing ‘and/or’ to ‘or’  Second: it should be clarified how the two bullets in the proposal are related. It is natural to have training and inference on the same side. Does the proposal imply that training and inference can be on different side? For example, network train the ML model for UE side, then UE performs inference. Then it should be explained how the network obtain training data from UE perspective. Also how does the gNB know each UE’s software/hardware capabilities such that the trained model is implementable for a given UE. There are also many practical issues, e.g., how to re-train or update the model, security concern of one vendor (e.g., UE) uses another vendor’s (e.g., network) model, legal responsibility if the model fails, etc. Thus, it is recommended to add a note:   * “Note: for a given AI/ML model, training and inference are performed on the same side.”   Another issue is re-training/updating of a model in life cycle management. ‘re-training’ can be added to the first bullet:   * Training at UE and/or network side   + Offline and/or online training   + Training includes re-training and model updating |
| NEC | We are fine with the update. |
| Moderator | To Huawei and Ericsson: the intention of this proposal is not to prioritize AI/ML approaches depends on where training/inference is for now.  To Ericsson: current wording of bullets is general and does not limit to one side training/inference. There’re proposals to consider AI model training at one side then sharing and inference at the other side, e.g. [10, OPPO]. For your 3rd comment, as I answered to Samsung’s question toward proposal 1-2, the definition of online/offline training (whether include re-training or updating) is to be discussed in agenda 9.2.1. |
| LG | Based on moderator’s comment, we are fine with the current proposal. |
| vivo | Support |
| Sony | Support |
| Samsung | We are fine to the proposal. |
| InterDigital | Support |
| OPPO | Just to make a clarification: in our tdoc, we analyzed various possible AL/ML mechanism, including model sharing. However, we don’t intend to treat model sharing with high priority.  This proposal has much overlapping with agenda 9.2.1. Many companies propose to focus on offline training. The output of 9.2.1 and 9.2.4.2 should be aligned and avoid collision. |
| Lenovo | Support |
| CMCC | The detailed spec impacts related to model training and inference can be discussed per sub use case. We suggest the following update:  Study aspects in terms of potential benefit(s) and requirement(s)/specification impact(s) of AI/ML model training and inference in sub use cases of AI/ML for positioning accuracy enhancement considering   * Training at UE and/or network side   + Offline and/or online training * Inference at UE and/or network side |
| Xiaomi | We are fine with the proposal |
| Nokia/NSB | We are fine with the proposal and agree that we should not limit solutions to any particular approach. |
| Moderator | To OPPO:  I don’t understand how this proposal is overlapped with agenda 9.2.1 when this proposal calls for study of positioning specific aspects “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”.  Based on my understanding of discussion in agenda 9.2.1, whether offline training of common framework is prioritized or not in agenda 9.2.1, offline training is not precluded to be studied. How is this proposal conflicting with the potential output of agenda 9.2.1?  To CMCC: please see discussion point 1-5. Companies have different understanding of “sub use case”. I don’t see any confusion or misinterpretation without adding you suggested “sub use case”. |
| Apple | Fine with proposal |
| Qualcomm | We prefer to focus on studying aspects related to offline training. Training and inference location and related aspects are better to be discussed while accounting for agreements in 9.2.1 general framework |
| Futurewei | This seems to be already allowed/supported by the wording in the SID. Not sure if this additional agreement is needed. |
| Intel | We are generally okay but have a similar view as Qualcomm above – it seems the online/offline discussion is occurring in parallel |

## 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.

|  |  |
| --- | --- |
| 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 |
| Samsung | Some changes in second bullets:   * 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~~   “reporting” is not correct, it should be measurements itself;  The purpose is not needed, as we think “improve accuracy” is for all cases here. |
| NEC | Support generally.  We suggest categorizing the sub use case identical with other use cases like beam management and CSI feedback enhancement for uniformity.  Anyway, although our way to categorize the sub use case based on ‘AI/ML may improve positioning accuracy’, we also agree with the category proposed by FL.  Besides, the first FFS in the first bullet seems unclear, we suggest change it to:   * 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 input to 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) |
| Futurewei | Ok |
| Fujitsu | We agree with the moderator’s categories as Direct/Assisted AI/ML, furthermore, each company can select one sub use case under each category for study, e.g., RF fingerprint for Direct and LOS/NLOS identification for Assisted.  We do not suggest using conventional positioning methods to categorize the sub use cases of AI4Pos, such as DL-TDOA/RTT/AoA and so on, it can all be classified into Direct positioning method which share the similar way of study and specification impact.  We also noticed that the terminologies used here are different from the ones used in 07 email discussion thread, maybe it is better to have the terminologies unified. |
| NVIDIA | Support in general. The wording can be improved. |
| Fraunhofer | Support FL proposal |
| Nokia, NSB | We require further clarification regarding this proposal. The relation between sub use cases and the categorization is not clear. For e.g., a sub use case could be “positioning accuracy enhancement in heavy NLOS” with possible solutions that could be categorized into direct AI/ML positioning or AI/ML assisted positioning. If the intent is to classify solutions for various sub use cases into these two categories, we support that intent since it makes sense. However, we would like to request the moderator to clarify this proposal further. Also, similar discussions already happened in AIML-07 email discussion, and we are not sure if we need to repeat the same discussion as part of both agenda items. Our modified proposal is as follows: Proposal 1-3 For further study of sub use cases and their potential specification impact, at least the following categorization of potential solutions for candidate sub use cases of AI/ML for positioning accuracy enhancement are considered.   * Direct AI/ML positioning: at least one 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: at least one 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)   Note: Companies are encouraged to clarify all details/aspects of the solutions for their proposed sub use cases of AI/ML for positioning accuracy enhancement |
| LG | Fine with the current categorization in principle. For the consistent categorization of the bullets, we suggest the following modification of the wording as:   * ~~Direct~~ AI/ML based positioning: the output of AI/ML model inference is UE location * 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 |
|  |  |
| Moderator | To ZTE: applicable scenario(s) here meant for discussion on scenario(s). For instance, several companies discussed AI/ML positioning for heavy NLOS scenario. Moderator’s understanding is we need to discuss what is heave NLOS and related AI/ML model generalization aspect(s).  To Samsung and NEC: thanks for the wording suggestion which I took.  To Fujitsu and Nokia: moderator’s understanding is that aspects of AI/ML approaches other than performance evaluation related for a sub use case are under agenda 9.2.4.2.  To Nokia and all: I also took the wording “AI/ML approaches for sub use cases” from the SID to align the understanding here as companies may have different interpretation on sub use case.  To Nokia: on the wording “at least one output”. I’m not sure that would work out to classify an AI/ML model whose output include both UE location and a measurement. Please clarify your intention so that I can capture into a future revision.  To LG: I think it’s debatable AI/ML assisted is also AI/ML based.  Wording update into Proposal 1-3a below. |
| Xiaomi | We are OK with the proposal |

##### Proposal 1-3a

For further study of sub use cases and potential specification impact, at least the following categorization of AI/ML approaches for candidate sub use case(s) 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 for sub use case(s) of AI/ML for positioning accuracy enhancement

Companies are encouraged to provide comments.

|  |  |
| --- | --- |
| Company Name | Comments/Views |
| Spreadtrum | We are fine in principle. |
| CATT | Support this classification. |
| CAICT | We think the proposal is clear and fine for us. |
| HW/HiSi | Support this classification |
| ZTE | Support |
| Ericsson | We are fine with the proposal.  To clarify: we understand that the AI/ML model circled below is excluded based on the above proposal, since it does not fit the description of either ‘direct’ or ‘AI-assisted’. |
| NEC | We are fine with the update. |
| Moderator | To Ericsson: the AI/ML model circled in your example can belong to direct AI/ML positioning if the output is UE location with an intermediate feature (of channel observation) as the model input. |
| LG | As moderator mentioned, we tend to agree that AI/ML assisted is also AI/ML based but we still think that the modification of related wording is needed. Regarding AI/ML assisted positioning, the intermediate measurement/output by AI/ML is utilized for existing positioning techniques which seems indirect approach for obtaining UE location compared to the first bullet to our understanding. In this sense, we suggest the following modification of the wording as:   * Direct AI/ML positioning: the output of AI/ML model inference is UE location * Indirect AI/ML ~~assisted~~ positioning: the output of AI/ML model inference is new measurement and/or enhancement of existing measurement   We are also open for the better wording on that. |
| vivo | Support |
| Sony | OK with the proposal |
| Samsung | We are fine to the proposal. LG’s change is also ok. |
| InterDigital | Support |
| OPPO | Support. We are also fine with LG’s modification |
| Lenovo | Generally supportive of proposal. Just for clarification, the proposal would apply to both UE-assisted and UE-based methods? If so, could we add a clarifying note, that the study of both direct AI/ML and assisted/Indirect AI/ML positioning is applicable to all positioning modes, e.g., UE-based, UE-assisted. |
| CMCC | Support |
| Xiaomi | Support |
| Nokia/NSB | We think the exclusion of intermediate feature being provided as an input to second AI/ML model to be quite limiting at this stage of the study. We do not support this proposal. We are also not sure why input and output of AI/ML, and generalization aspects are listed FFS in this proposal which is supposed to be about classification of sub use cases. |
| Moderator | To Lenovo: this proposal is about categorization of AI/ML approaches. Right now, it does not limit nor indicate support of UE-based and/or UE-assisted positioning. I prefer not to adding note given the study is not precluded here.  To Nokia: I don’t understand how you get the idea that “intermediate feature being provided as an input to second AI/ML model” is excluded. Ericsson stated their understanding that they think it’s excluded to consider a 2nd AI/ML model. Please see my above response to Ericsson, which I copied below as well “To Ericsson: the AI/ML model circled in your example can belong to direct AI/ML positioning if the output is UE location with an intermediate feature (of channel observation) as the model input.” So it’s clear that intermediate feature being provided as an input to second AI/ML model is NOT excluded. Please let me know if you think otherwise.  To Nokia: I’m a bit puzzled now. Nokia commented toward proposal 1-3 on the term of sub use case and said “If the intent is to classify solutions for various sub use cases into these two categories, we support that intent since it makes sense.” That’s the reason I revised original proposal 1-3 into proposal 1-3a with the wording “categorization of AI/ML approaches for candidate sub use case(s)”. Now for AI/ML approaches, we have those FFS bullets. |
| Apple | Fine with the proposal |
| Moderator | Further response to Nokia:  Current wording of this proposal says “at least the following categorization of AI/ML approaches … are considered”. I don’t think this preclude the usage of both direct AI/ML and AI/ML assisted positioning together for a sub use case. |
| Qualcomm | We are ok with the update. |
| Nokia/NSB | To moderator: Thank you for further detailed clarifications regarding our comment! Our thoughts on this topic are as follows:  **Background regarding our confusion regarding this categorization**: As part of the email discussion for AI 9.2.4.1 [AIML-07] the following categorization is proposed:  *“Broadly speaking, the sub-use cases use either the one-step approach (aka, ML-based) or the two-step approach (aka, ML-assisted).*   1. *For the one-step approach, the output of the ML model is directly the target UE’s position.* 2. *For the two-step approach, the output of the ML model is an intermediate quantity (e.g., LOS/NLOS, TOA) which can be used as an input for estimating the target UE’s position.*    * *In the two-step approach, the module for estimating the target UE’s position can be:*      1. *an existing Rel-16/Rel-17 positioning method,*      2. *or a ML model.”*   Our understanding of Direct AI/ML positioning based on the example provided seem to map to “one-step approach” discussed in 9.2.4.1 and AI/ML-assisted positioning (again based on the example provided) seem to match two-step approach sub-option (2)(a) discussed in 9.2.4.1.  In our opinion, since this type of categorization is being discussed in both agenda items, it would be better if we can agree on which agenda item this topic should be discussed. It would be more efficient to have this discussion in one place, so that we can avoid multiple definitions of what seems to be the same concept.  In our opinion it should be discussed here (i.e., in 9.2.4.2) since it relates to potential solutions for sub-use cases.  Based on your clarifications, we are fine with this proposal, especially since it is clear to us now that no options are precluded as part of this proposal. |
| NEC | We also agree with Nokia that ‘Direct AI/ML positioning based on the example provided seem to map to “one-step approach” discussed in 9.2.4.1 and AI/ML-assisted positioning (again based on the example provided) seem to match two-step approach sub-option (2)(a) discussed in 9.2.4.1’, and a bridge is needed between 9.2.4.1 and 9.2.4.2 to align the definition.  As for the illustration from Ericsson, from the response of Moderator that ‘if the output is UE location with an intermediate feature (of channel observation) as the model input’, we wonder if the boundary of direct AI/ML positioning and AI/ML-assisted positioning if the output of the last AI model if multiple AI models are connected in series? In detail, can we regard if the output of the last AI model is UE location, it can be categorized as direct AI/ML positioning, otherwise it will be categorized as AI/ML-assisted positioning? |
| Futurewei | Ok with proposal. |
| Intel | We have a similar question as Ericsson in the 2-step process, if it is included then we assume that the 2 AI models separated by “intermediate feature” can be trained together. May be good to be clear if the proposal includes such case. |

## 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.

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| --- | --- |
| 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. |
| Samsung | Performance gain is of course very important. But we wonder how to decide which sub-use case should be adopted based on the performance gain. Different companies has different platform (settings, preferred AI model, different hyper parameter settings), how to judge the performance gain? If one source reports 10 m improvements and will it be definitely more attractive than another reported 5m improvements?  For other KPI, we would like what are they potentially? |
| NEC | Agree the two listed aspects. Besides, we think AI/ML based positioning accuracy enhancement should also focus on the thorny issues that traditional technologies cannot solve, like heavy NLOS condition, synchronization error. |
| Futurewei | Ok |
| Fujitsu | We do not suggest that many details to be discussed at this stage, it is recommended to focus on the performance gain, complexity, and generalization of the AI model first.  For the specification impact part, we prefer to select the sub use cases with less specification impact, e.g., there are two sub use cases with similar performance then we will select the one with minor specification impact. |
| NVIDIA | We are ok with this proposal, though it’s not clear how useful this proposal is, considering the discussion of evaluation KPIs is largely unsettled. |
| Fraunhofer | Support. |
| Nokia, NSB | We are fine with this proposal, however similar to proposal 1-3, we think that the aspects should relate to the solutions for sub use cases. We agree with Samsung that from our perspective, it is unclear to us as to how we can evaluate the performance gains of a sub use case. Perhaps it is then worthwhile to clarify what we mean by a sub use case, are we talking about solutions when we use the term ‘sub use case’? |
| LG | Fine in principle. Based on the performance gain, it should also be considered with model complexity and, potentially, efficiency aspects which are discussed further of the definition on that. |
|  |  |
| Moderator | To answer some companies’ questions, let me quote from the SID, “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 is that any representative sub use case would be the one where the (performance) benefits of AI/ML approaches can be demonstrated. Correspondingly, the study on requirements (potential specification impact) to enable such AI/ML approaches would become the base to formulate a framework to apply AI/ML to the air-interface for these and other use cases.  The intention of this proposal is to make sure we look at all aspects not just one for the selection of representative sub use case(s). It’s not meant down select one AI/ML approach over the other.  To Nokia and all: I also took the wording “AI/ML approaches for sub use cases” from the SID to align the understanding here as companies may have different interpretation on sub use case.  To OPPO: my understanding is that complexity of AI/ML approaches and potential specification impact give insight on impact on UE/NW implementation. If you think otherwise, that’s still allowed given the wording “at least” in the main sentence.  Wording update into Proposal 1-4a below. |

Proposal 1-4a

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

* Evaluation results of performance and other KPIs
  + Note: KPIs are to be discussed and expected to be agreed in agenda 9.2.4.1
* Potential specification impact

Companies are encouraged to provide comments.

|  |  |
| --- | --- |
| Company Name | Comments/Views |
| Spreadtrum | Generally we are fine. |
| CATT | We are fine with this proposal.  In addition, in our understanding, the generalization performance is already included in ‘performance’ of the first bullet. |
| CAICT | Fine with the proposal. |
| HW/HiSi | Agree |
| ZTE | Support |
| Ericsson | We are fine with the intention.  For the first bullet, it is not clear what performance refers to. Since the KPI discussion in AI9.2.4.1 includes positioning accuracy percentiles, it is recommended to change to:  “Evaluation results of ~~performance and other~~ KPIs”  One related question. In our understanding, the above implies that  (1) RAN1 simulate N1 candidate sub-use cases, then  (2) RAN1 select N2 representative sub-use cases according to above proposal, N1 > N2.  Our understanding is Step (1) in AI 9.2.4.1, Step (2) in AI 9.2.4.2. It would be good to align this among companies. For example, if our understanding is correct, then AI 9.2.4.1 should select N1 candidate sub-use cases for simulation.  If our understanding is incorrect, then companies should discuss also the N1 candidate sub-use cases in AI 9.2.4.2.  Due to the large number of possible sub-use cases, we don’t think it’s efficient to skip (1) entirely. |
| NEC | We are not very clear about the intention of this proposal. If the order of this proposal is to guide the criterion of sub use case, it seems difficult to: (1) evaluate the performance and other KPIs case by case, (2) quantitate the specification impact (at least from this proposal).  The proposal 1-3a has categorized to two kinds of AI/ML approaches, i.e., direct AI/ML positioning and AI/ML assisted positioning. We think this proposal is redundant since the use case can be categorized as one-step approach(the output of AI/ML model is UE location) and two-step approach(the output of AI/ML is intermediate results) rather than other non-binary factors. |
| Moderator | To Ericsson: the first bullet means results of “performance KPIs and other KPIs”.  To Ericsson and NEC: I believe companies have different interpretation of sub use case. Which is why I tried to use the wording from the SID (copied below) to align the understanding here.  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   For positioning use case, most companies are proposing study of AI/ML for positioning accuracy enhancement in heavy NLOS scenario (my understanding of a sub use case according to the SID). Companies have different AI/ML approaches but they all serve the same goal. In addition, there’re proposals on AI/ML positioning for multipath, AI/ML for enhancement of PRS efficiency and AI/ML positioning for synchronization error (i.e. different sub use cases) etc..  Hope this clarifies.  To NEC: the intention of this proposal is to make sure we look at all aspects not just one for the selection of representative sub use case(s). It’s not meant down select one AI/ML approach over the other. |
| LG | Fine with the proposal. |
| vivo | Support |
| Sony | Support and agree with Ericsson proposal to modify the first bullet. |
| Samsung | We are fine to the proposal. |
| InterDigital | Support |
| OPPO | Support |
| Lenovo | Support of FL’s proposal, also like to highlight that other identified KPIs (e.g., complexity) could also be considered in conjunction to performance. It may be counter-productive to only prioritize high performing representative use case when in reality it might be to complex to deploy from UE/network perspective. |
| CMCC | To align with the discussion in AI 9.2.1, we suggest change “other KPIs” to “common KPIs”. |
| Xiaomi | Support |
| Nokia/NSB | We are fine with this proposal and the removal of “~~performance and other~~”, since it makes the proposal clear. We agree that we need to simulate key sub-use cases select a subset for further study. |
|  |  |
| Moderator | Wording update into proposal 1-4b below. |

##### Proposal 1-4b

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

* Evaluation results of KPIs
  + Note: KPIs are to be discussed and expected to be agreed in agenda 9.2.4.1
* Potential specification impact

Companies are encouraged to provide comments.

|  |  |
| --- | --- |
| Company Name | Comments/Views |
| Qualcomm | We are fine with the updated proposal. |
| Nokia/NSB | We are fine with this updated proposal. |
| ZTE | Support |
| NEC | Fine with the updated proposal. |
| OPPO | We are fine with the proposal |
| InterDigital | Support |
| Ericsson | We are fine with Proposal 1-4b, assuming there are more than one sub-use cases to select from. Thus, this proposal is pending section 2.6 discussion. |
| Apple | Fine with proposal |

## Clarification on “sub use case”

It has been brought up to moderator’s attention that companies have different interpretation/understanding of the term “sub use case”. Consequently, companies have different understanding when they refer to “AI/ML approach”. Note that both terms are used in the SID.

|  |
| --- |
| 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. |

In the context of AI/ML for positioning accuracy enhancement, there are two ways to interpret “sub use case” based on companies’ contributions and comments provided during the discussion.

1. Some companies refer to “sub use case” by scenario. For example, “AI/ML based positioning in heavy NLOS scenario” which several companies are proposing is a “sub use case” of AI/ML for positioning accuracy enhancement. In this case, “AI/ML approaches” is interpreted as functionalities provided by AI/ML model (e.g., directly estimate UE position, ML-assisted estimation etc.) for this “sub use case”.

2. Some companies refer to different “sub use cases” as different {input, output} of an AI/ML model. For instance, LOS/NLOS identification as a “sub use case”; directly estimate UE position with fingerprinting method as another “sub use case”. In this case, “AI/ML approaches” for a “sub use case” is interpreted as where AI/ML model training/inference occurs, e.g., UE-side, network-side, etc.

Note that some companies actually have mixed usage of both interpretations when referring to “sub use case” in their contributions. Moderator has to admit that mixed usage of “sub use case” interpretations also occurred when summarizing different companies’ views in previous versions of this summary.

Moderator’s current understanding of “sub use case” is more aligned with the first way of interpretation mainly based on the description of the SID. The SID says “positioning accuracy enhancements for different scenarios”. So for the “use case” of positioning, “sub use cases” are referring to AI/ML positioning for different scenarios where “AI/ML based positioning in heavy NLOS scenario” is a “sub use case”. Here, different AI/ML approaches proposed by companies all attempt to improve the positioning accuracy in this heavy NLOS scenario. Note that for CSI feedback enhancement and beam management use cases, the SID lists examples for each use case in terms of functionality. While the SID only lists one example for positioning use case in terms of scenario.

Given there’s a task in the SID “finalize representative sub use cases” for this agenda 9.2.4.2, it would be better if we can align the understanding of “sub use case” for positioning among companies for our future discussion. The following discussion point is setup to collect companies’ input.

##### Discussion point 1-5

In the context of AI/ML for positioning accuracy enhancement discussion, what is your understanding of “sub use case”?

* Option 1: by scenario
* Option 2: by {input, output} of an AI/ML model

Companies are encouraged to provide their answer/comments to the above question.

|  |  |
| --- | --- |
| Company Name | Comments/Views |
| Lenovo | Our understanding of sub-use case is by scenario. Examples include using AI/ML to improve positioning KPIs under heavy NLOS scenarios, using AI/ML to improve the fingerprinting positioning KPIs, using AI/ML to improve the performance of LOS/NLOS classification performance, etc. We view such examples as possible scenarios in which to apply AI/ML under the umbrella of the positioning use case. Once we have established the sub use cases then we can further refine each of the sub use case based on Proposal 1-3a, which discusses the AI/ML categorization approach including details such as input/outputs (similar to Option 2) of the Proposal. |
| CMCC | We prefer option 2. For option 1, how to define a scenario is not clear. For example, whether NLOS and LOS are two scenarios, or whether heavy NLOS and non-heavy NLOS are two scenarios? |
| Nokia/NSB | Our understanding is similar to Lenovo. The use case we are considering in this study is positioning accuracy enhancement, hence naturally sub-use case should be a subset of the use case we are studying and it has no relation model input/output. In our view, positioning accuracy enhancement under heavy NLOS and positioning measurement reporting enhancements are potential sub use cases, which broadly target positioning accuracy enhancement with the help of AI/ML. |
| Apple | From the SID definition, it should be option 1. However, we do think that we need to have another definition for Option 2 e.g. “AI/ML approaches” as used in Proposal 2-1b |
| Moderator | To all:  The purpose of this discussion point is try to clarify/align our interpretation of “sub use case”. We have a task from the SID to “finalize representative sub use cases” by RAN1#111. If we don’t have a common understanding of “sub use case”, it’s not possible for us to select and finalize representative sub use case(s).  To Apple: given we don’t have an immediate task from the SID to down select “AI/ML approaches”, I think we can study aspects of different AI/ML approaches based on companies’ input without a common definition. |
| Qualcomm | Positioning use case can have many sub use cases, including position estimation, tracking, prediction, etc. From our reading, companies agree on position estimation as a sub use case. Any categorization of scenarios (Option 1 in Moderator’s question) and/or ML approach (i.e., Option 2 in Moderator’s question) is better not to be confused as sub use cases. Different scenarios, e.g., InF-DH, InF-SL, InF-DL, Umi, etc, can be used to evaluate the sub use case of positioning estimation. On a given scenario, different ML approaches, e.g., RFFP, LOS/NLOS identification, etc., can also be evaluated to achieve the same objective of same sub use case, i.e., enhancing positioning estimation accuracy. |
| ZTE | Our understanding is option 1. Option 2 is a second detail of option 1. For a given sub use case, there could different kinds of AI/ML input/output that needs further discussion.  In addition, to avoid confusion, we can simply use direct AI/ML positioning and AI/ML assisted positioning in Proposal 1-3a as two sub use cases. Then, we can focus on what is the input/output for different sub use cases. |
| NEC | Our understanding of ‘sub use case’ is Opiton1.  We share the view with Nokia. Besides, the introduction of AI/ML in RAN1 is to solve the thorny issues that traditional technologies cannot solve, like heavy NLOS condition, synchronization error, which I think should be defined by ‘scenario’. The AI model is just a tool for solving the issues in those ‘scenarios’, and we should not spend more energy to discussing which is the input/output of the AI model.  @CMCC: We think you mentioned ‘NLOS and LOS’ is a ‘scenario’ for the selection of sub use case which can be categorized to the ‘scenario’ that LOS is uncertainty rather than the physical scenario since traditional technologies(like DTDOA/Multi-RTT) may be unreliable, and AI model like LOS/NLOS identification is the AI/ML approaches to solve the issue. Sorry for the unknowing if I miss something. |
| Ericsson | We think both Option 1 and Option 2 are confusing/misleading.  For Option 1, ‘scenario’ can have many interpretations.   * One possible interpretation is, ‘scenario’ (sub use case) refers to ‘deployment scenario’, e.g., indoor factory, urban macro, heavy NLOS, etc. In our view, this is not appropriate to refer to sub use case, since a ML model can (ideally) work for multiple deployment scenarios. This kind of ‘scenario’ only affects the data set construction. * Another possible interpretation is, ‘scenario’ (sub use case) refers to “AI/ML based positioning in heavy NLOS scenario” in SID. In this case, there is a single sub-use case for positioning in SID, and there is no need to select a representative sub-use case, since there is only one to start with. All proposed AI/ML models and evaluations so far are for a single sub-use case. We don’t share this understanding of ‘scenario’ (sub use case). * Another possible interpretation is, ‘scenario’ (sub use case) refers to “with network sync error”, “without network sync error”, ‘with clock drift”, “without clock drift”, etc. In our understanding, this only describes if the input of the AI/ML model suffers from impairments or not. The same ML model can be trained regardless of the quality of the input. We don’t share this understanding of ‘scenario’ (sub use case). * For Option 2, “by {input, output} of an AI/ML model” is in the right direction but too simplistic and narrow in our view. For example, for the same functionality of LOS/NLOS classification, the input can be one or more of {CIR, PDP, L1-RSRP, …}, the output can be one or both of {hard LOS/NLOS classification, and likelihood of the path being LOS}. But all variations of {input, output} of the AI/ML for LOS/NLOS classification belong to the same sub-use case.   In our understanding, the sub-use case is understood as the functionality that the AI/ML model is intended to fulfil. Exemplary sub-use cases are:   * LOS/NLOS classification; * Time of arrival estimation; * Fingerprinting to directly estimate UE’s position.   For each sub-use cases, the possible {input, output} can be further discussed. |
| Futurewei | What are the benefits to the evaluation effort to have this agreement? |
| HW/HiSi | The SID says that positioning accuracy enhancements for different scenario shall be evaluated:  From the SI:   * “Positioning accuracy enhancements for different scenarios including, e.g., those with heavy NLOS conditions [RAN1]   One scenario can be heavy NLOS conditions where traditional methods do not work. Another scenario could be to find AI/ML based solutions for moderate NLOS conditions, where legacy methods may still work but could be enhanced significantly.  Therefore, our understanding is more aligned with Option 1. Option 2, on the other hand implies that a specific input and output have to be defined. But this we regard as a solution/implementation in a given scenario. |
| vivo | Our current understanding is also aligned with Option 1.  We disagree with the direction of Option 2 where {input, output} of an AI/ML model is used to represent a sub use case. Different input and output of AI/ML model(s) can be used to improve positioning accuracy in a same scenario. For the same reasoning, we also disagree with the understanding where sub use case represents functionality that the AI/ML model is intended to fulfil. Again, different functionality of AI/ML model(s) can be used for the same purpose. |
| Ericsson | In our understanding, the goal of this discussion is to clarify what are the list of candidate sub- use cases. Based on this list, then the following steps can be anticipated:   1. the group performs evaluation on the list of candidate sub- use cases; 2. then KPIs and spec impact are compared amongst the list of candidate sub- use cases (see Proposal 1-4b); 3. based on these considerations, the group perform the step of “finalize representative sub use cases”.   Thus, it is not possible for companies to perform evaluation, without a clear understanding what are the list of candidate sub- use cases.  We suggest that the possible interpretations are elaborated, with the list of exemplary sub- use cases provided for each, so that the group can decide which interpretation makes the most sense. For example, it is really not clear what ‘scenario’ refers to. When companies say ‘option 1’, they actually refer to different meanings.  From what we can see, the following is a possible list of interpretations for companies to choose from:  **Interpretation 1:** There are **more than 1** candidate sub use cases. Sub use case refer to functionality that the AI/ML model is intended to fulfil for the purpose of positioning accuracy enhancements. Exemplary sub- use cases are:   * + - * LOS/NLOS classification;       * Fingerprinting to directly estimate UE’s position.   **Interpretation 2:** There are **more than 1** candidate sub use cases. Sub use case refer to deployment scenario. Exemplary sub- use cases are:   * + - * indoor factory,       * urban macro,       * urban micro   **Interpretation 3:** There are **more than 1** candidate sub use cases. Sub use case refer to any environmental issues or UE/gNB implementation imperfections which makes positioning difficult for existing methods. Exemplary sub- use cases are:   * + - * heavy NLOS       * TRP synchronization error;       * UE/gNB RX and TX timing error   **Interpretation 4:** There is **only 1 candidate sub use cases**. Sub use case refer to “AI/ML based positioning in heavy NLOS scenario”. No need to perform the step of “finalize representative sub use cases”. If follow this interpretation, then Proposal 1-4b is not needed. |

# 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 ignaling, 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 ignaling 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 ignaling 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 ignaling 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 ignaling 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 ignaling 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.

|  |  |
| --- | --- |
| 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. |
| Samsung | Suggesting some changes in the lists   * 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 for model configuration   + assistance signalling, ~~and~~ procedure and conditions for model activation/deactivation * AI/ML model monitoring and update   + assistance signalling and procedure for model performance monitoring   + assistance signalling, ~~and~~ procedure and conditions for model update/tuning   We would like to add following aspects for study:   * AI/ML model recovery/terminates   + Conditions/events for triggering the model recovery/termination |
| NEC | Agree with the listed aspects. We also suggest listing AI/ML model selection as a bullet if multiple AI models are configured in UE sides.   * AI/ML model selection   + signalling and procedure for model selection |
| Fujitsu | As we discussed above, the online training related topic is not in our prioritized discussion list. The prioritized spec impact points for the discussion will be:   * AI/ML model monitoring and update * AI/ML model indication/configuration   The input/output spec impact such as measurement reporting, LOS/NLOS indication can also be studied but it will be better to be aligned with R17 Enh-Pos. |
| NVIDIA | Maintaining such a list is beneficial to guide the work going forward. Additional/revised aspects can be considered as the study item progresses.  It should be noted that many of the listed aspects are also under discussion in 9.2.1. Some coordination would be beneficial for alignment. |
| Fraunhofer | Ok |
| Nokia, NSB | We are fine with this proposal and agree that further details could be added to this proposal as the study progresses. |
| LG | Fine with the listed aspects. Additionally, the detailed spec impact can be dependent on per sub-use case and hence, we need to focus on investigating the representative sub use-cases first. |
|  |  |
| Moderator | To ZTE, InterDigital: sub-bullet added/revised.  To ZTE, InterDigital: wording of note is revised for clarification  To OPPO: see my response to proposal 1-4, we need to look at potential specification impact for the selection of representative sub use case(s). Not sure what you meant by “more progress of sub use cases”. But I hope we don’t go in a loop of chicken-and-egg problem.  To Samsung: not sure what’s the difference between recovery/terminates and activation/deactivation. I added under model indication.  To NEC: sub-bullet added under model indication  To InterDigital, Fujitsu and all: the intention of this proposal is to give a guidance for further study and does not indicate any prioritization or narrow the scope.  Wording update into Proposal 2-1a below. |

Proposal 2-1a

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 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)
* Other aspects are not precluded
* Note: not all aspects may apply to an AI/ML approach in a sub use case

Companies are encouraged to provide comments.

|  |  |
| --- | --- |
| Company Name | Comments/Views |
| Spreadtrum | Generally we are fine to have this as the starting point. |
| CATT | Fine with this list as a starting point. The specification impacts can be further studied after the sub use cases and the corresponding collaboration levels are clear. |
| CAICT | Support moderator’s proposal and use the proposed framework for further study. |
| HW/HiSi | We are in general fine to list high-level potential specification impact. For details, we prefer to discuss them after the sub use cases are finalized and performance gain are evaluated.  We think this proposal should be treated as a guidance rather than strictly applying and it can be revised during the study, e.g., adding some thing, rewording some sentences and removing some aspects listed if them are found to be applied to none of the sub use case.  We therefore suggest to modify the proposal as follows:  Companies are encouraged to study and provide inputs on potential specification impact at least for the following aspects.   * AI/ML model training, e.g.   + 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, e.g.   + assistance signalling and procedure (e.g., for model configuration, model activation/deactivation, model recovery/termination, model selection) * AI/ML model monitoring and update, e.g.   + assistance signalling and procedure (e.g., for model performance monitoring, model update/tuning) * AI/ML model inference input, e.g.   + 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, e.g.   + report/feedback of model inference output   + post-processing of model inference output * UE capability for AI/ML model(s) * Other aspects are not precluded * Note: not all aspects may apply to an AI/ML approach in a sub use case |
| ZTE | Support in principle. We prefer to have another note:  Note: The definitions of above terminologies should be discussed in agenda item 9.2.1. |
| Ericsson | We are fine to have the proposal as a starting point.  On the other hand, many of the bullets are highly correlated to general aspect discussion in 9.2.1. In our view, the discussion here should focus on issues due to the special need of positioning. |
| NEC | OK |
| Moderator | To Huawei: the intention of this proposal is clearly indicated as encouragement for companies to study and provide input. I don’t see how this could be interpreted as agreed/identified specification impact. With “Other aspects are not precluded” and “Note: not all aspects may apply to an AI/ML approach in a sub use case”, I don’t think we need to add e.g. for every bullet.  To ZTE and Ericsson: if it’s not obvious to you, wording revised and note added into proposal 2-1b below. |

##### Proposal 2-1b

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)
* 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

Companies are encouraged to provide comments.

|  |  |
| --- | --- |
| Company Name | Comments/Views |
| LG | Fine with the current version |
| vivo | Support |
| Samsung | We are fine to the proposal. |
| Lenovo | Supportive of the revised proposal. The difference between model deactivation and termination under AI/ML model indication/configuration is not so clear, since it could mean the “switching off” of a particular AI/ML model. Suggest to use either deactivation or termination, if the end goal is the same. |
| CMCC | For the bullet “UE capability for AI/ML model(s)”, we suggest list the examples as what we do for other bullets.   * UE capability for AI/ML model(s), including model training, model inference, and model monitoring. |
| Nokia/NSB | We are fine with this updated proposal. |
| Apple | Fine with the proposal |
| Moderator | To Lenovo: given model deactivation and termination are just examples here, I think it’s okay to leave as it is and we can decide after more study/input.  To CMCC: thanks for the suggestion. I’ll let other companies comment to see if they agree with you before I incorporate it into a future revision. |
| Qualcomm | We are ok with the general theme of the proposal. Specifying model input type and definition at the UE side is not required**.** FFS is the applicability and details of proposed items to different ML approaches. |
| ZTE | Fine with current proposal. |
| NEC | Fine with the updated proposal. |
| OPPO | We are fine with roposal |
| InterDigital | Ok with the proposal |

## Other issue(s)

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

|  |  |
| --- | --- |
| Company Name | Comments/Views |
|  |  |
|  |  |
|  |  |

# Conclusion

TBD

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