3GPP TSG-RAN WG1 Meeting #109-e Tdoc R1-220xxxxx

e-Meeting, May 9th – 20th, 2022

Agenda Item: 9.2.4.1

Source: Moderator (Ericsson)

Title: Summary #1 of [109-e-R18-AI/ML-07] Email discussion on evaluation of AI/ML for positioning accuracy enhancement

Document for: Discussion, Decision

# Introduction

This document summarizes the discussions during RAN1#109-e for the following email thread.

[109-e-R18-AI/ML-07] Email discussion on evaluation of AI/ML for positioning accuracy enhancement by May 20 – Yufei (Ericsson)

* Check points: May 18

This discussion corresponds to the objectives related to the positioning use case described in RP-213599 (SID) below.

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| RP-213599 (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.  AI/ML model, terminology and description to identify common and specific characteristics for framework investigations:   * Characterize the defining stages of AI/ML related algorithms and associated complexity:   + Model generation, e.g., model training (including input/output, pre-/post-process, online/offline as applicable), model validation, model testing, as applicable   + Inference operation, e.g., input/output, pre-/post-process, as applicable * Identify various levels of collaboration between UE and gNB pertinent to the selected use cases, e.g.,   + No collaboration: implementation-based only AI/ML algorithms without information exchange [for comparison purposes]   + Various levels of UE/gNB collaboration targeting at separate or joint ML operation. * Characterize lifecycle management of AI/ML model: e.g., model training, model deployment , model inference, model monitoring, model updating * Dataset(s) for training, validation, testing, and inference * Identify common notation and terminology for AI/ML related functions, procedures and interfaces * Note: Consider the work done for *FS\_NR\_ENDC\_data\_collect* when appropriate   For the use cases under consideration:   1. Evaluate performance benefits of AI/ML based algorithms for the agreed use cases in the final representative set:    * Methodology based on statistical models (from TR 38.901 and TR 38.857 [positioning]), for link and system level simulations.      + Extensions of 3GPP evaluation methodology for better suitability to AI/ML based techniques should be considered as needed.      + Whether field data are optionally needed to further assess the performance and robustness in real-world environments should be discussed as part of the study.      + Need for common assumptions in dataset construction for training, validation and test for the selected use cases.      + Consider adequate model training strategy, collaboration levels and associated implications      + Consider agreed-upon base AI model(s) for calibration      + AI model description and training methodology used for evaluation should be reported for information and cross-checking purposes    * KPIs: Determine the common KPIs and corresponding requirements for the AI/ML operations. Determine the use-case specific KPIs and benchmarks of the selected use-cases.      + Performance, inference latency and computational complexity of AI/ML based algorithms should be compared to that of a state-of-the-art baseline      + Overhead, power consumption (including computational), memory storage, and hardware requirements (including for given processing delays) associated with enabling respective AI/ML scheme, as well as generalization capability should be considered.   …  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. |

# Deployment Scenarios and Simulation Assumptions

## Deployment scenarios

For evaluation of AI/ML enabled positioning, one important question is, what deployment scenarios should be used, and what channel model should be applied for the selected scenario.

### Companies’ view from contribution

For the topic of which deployment scenario(s) to use in the evaluation of AI/ML based positioning, companies’ views are listed below, based on the submitted contributions.

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| * Huawei (R1-2203144)   **Proposal 5**: For AI/ML-based positioning evaluation, adopt IIoT scenario as baseline.  • A small number of gNB antennas should be evaluated. |
| * ZTE (R1-2203252)   **Proposal 1**: AI/ML for NR positioning should target on improving positioning accuracy under heavy NLOS conditions.  **Proposal 4**：Reuse common scenario parameters defined in Table 6-1 of TR 38.857, which defines the carrier frequency, bandwidth, sub-carrier spacing, UE antenna configuration, network synchronization error, and UE/gNB Rx/Tx timing errors.  **Proposal 5**: Reuse parameters common to InF scenarios defined in Table 6.1-1 of TR 38.857 with the following modifications (also highlighted in Appendix B),   * InF-DH channel should be the baseline for evaluation; * UE horizontal drop is not required to be in a convex hull; * No need to have dynamic UE/gNB antenna heights; * Baseline clutter parameters {density , height , size } for InF-DH channel are {60%, 6m, 2m}. |
| * Ericsson (R1-2203285)   **Proposal 1** Prioritize the use cases of indoor smart factory for the study of AI/ML based positioning enhancements.  **Proposal 2** The sub use cases include indoor factory floor (a) with sparse clutter and (b) with dense clutter.  **Proposal 3** Deprioritize general outdoor commercial use cases for the study of AI/ML based positioning enhancements. |
| * CATT (R1-2203455)   **Proposal 2**: For AI/ML-based positioning evaluation in Rel-18, the scenarios of InF-DH and InF-DL should be considered. |
| * Vivo (R1-2203554):   **Proposal 1: S**elect the InF-DH scenario with clutter parameter {density 60%, height 6m, size 2m} as a typical scenario for positioning accuracy enhancement evaluation. |
| * Xiaomi (R1-2203812)   **Proposal 1**: The 1st priority for the study of AI/ML based positioning accuracy enhancement is the inF-DH scenario   * Parameters listed in Table 6.1-1 and Table 6.1-1 of 38.857 could be the starting point of evaluation |
| * Samsung (R1-2203901)   **Proposal 1**: At least InF-DH and/or InF-DL scenarios shall be considered in AI/ML for positioning evaluation.  **Proposal 2**: Simulation assumption in Rel16/17 Positioning enhancement can be a starting point for AI for positioning evaluation.  **Proposal 3**: The high clutter density {60%, 6m, 2m} for clutter parameters in InF scenarios shall be specified as another baseline for AI/ML evaluation. |
| * OPPO (R1-2204019)   **Proposal 1**: For the evaluation of AI/ML-based positioning accuracy improvement, support the InF-DH scenario with the high clutter density set as 60%. |
| * FUTUREWEI (R1-2204104)   **Proposal 1**: For evaluation methodology, reuse the following scenarios specified in [3]:   * IIOT use case:   + Scenario 1. InF-SH for FR1 and FR2   + Scenario 2. InF-DH for FR1 and FR2 * General commercial use cases:   + Scenario 2. UMi street canyon for FR1 and FR2 (ISD 200m)   + Scenario 3. UMa (ISD 500m) for FR1 only (Macro cell only deployment scenario)   **Proposal 2**: For scenario parameters, reuse the following:   * Common parameters applicable to all scenarios: reuse the common parameters for Rel-17, specified in Table 6-1 of TR 38.857 [3]. * Common parameters for InF scenarios: reuse the common parameters for Rel-17, specified in Table 6.1-1 of TR 38.587 [3]. * Parameters for Urban micro (UMi) scenario: reuse parameters specified in Table 6.1.1-4 of TR 38.855 [4]. * Parameters for Urban macro (UMa) scenario: reuse parameters specified in Table 6.1.1-6 of TR 38.855 [4]. |
| * LG (R1-2204153)   **Proposal #1**. Consider the followings channel models and candidate parameter values for heavy NLOS conditions for positioning accuracy enhancement based on AI/ML as   * Channel model: InF-DH (mandatory) / InF-DL (optional) * Candidate parameter values: clutter size, clutter density, height of BS etc. |
| * InterDigital (R1-2204159)   **Proposal 1**: Use IIoT scenarios (e.g., InF-DL or InF-DH) from TR 38.901 as one of the evaluation scenarios for AIML based positioning  **Proposal 2**: Evaluate performance of the UEs located in the corner of the factory floor in IIoT scenarios |
| * CAICT (R1-2204184)   **Proposal 1**: IIOT use cases defined in 38.857 could be used as high priority for evaluation. |
| * Apple (R1-2204242)   **Proposal 2**: To demonstrate the efficacy of the method a comparison of AI-based positioning methods and traditional positioning methods should be evaluated in a heavy NLOS scenario and a light NLOS scenario.   * Use cases with heavy NLOS defined in 38.857 (Study on NR Positioning Enhancements (Release 17)), e.g. InF-DH, should be selected for evaluation. * A low NLOS use case (e..g UMa) may also be evaluated for comparison * The clutter parameters for the InF-DH scenario should harmonized. * Additional non-ideal assumptions such as UE/TRP Rx/Tx timing errors and synchronization errors may also be considered as optional. * Spatial consistency is recommended. * The absolute-time-of arrival model defined in TR 38.901 should be considered. |
| * CMCC (R1-2204299)   **Observation 1**: Compared with legacy positioning schemes, AI/ML based positioning schemes could improve the positioning accuracy for heavy NLOS scenario. |
| * Lenovo (R1-2204421)   **Proposal 1**: RAN1 consider to AI/ML evaluation scenarios with high NLOS/multipath, e.g., Indoor factory scenarios with dense clutter. |
| * Fraunhofer (R1-2204837)   **Proposal 2**: Evaluate the performance of ML based positioning technologies for at least two areas: - Areas was covered by the training data - Area is in between areas covered by the training. |
| * NVIDIA (R1-2204844)   **Proposal 1**: Focus on scenarios with heavy NLOS signal propagation conditions between base station and UE to study AI/ML based algorithms for positioning accuracy enhancements.  **Proposal 2**: Indoor factory (InF) scenarios should be evaluated as part of the study on AI/ML based algorithms for positioning accuracy enhancements.  **Proposal 3**: Use the simulation assumptions in TR 38.857 as a starting point for the evaluation of AI/ML based algorithms for positioning accuracy enhancement. |
| * Qualcomm (R1-2205028)   **Proposal 1**: The evaluation should focus on demonstrating positioning accuracy enhancements using AI/ML methods in challenging multipath and NLOS conditions in both indoor and outdoor conditions.  **Proposal 2**: For evaluation scenarios, consider InF-DH deployment with extreme clutter conditions for indoor scenarios and UMi/UMa with small LOS probability for outdoor scenarios). Companies to agree on updated clutter and LOS settings for proposed scenarios.  **Proposal 3**: The channel model in TR 38.901 is adequate for conducting initial evaluation on AI/ML positioning enhancement. It is recommended to have spatial consistency and/or consistent temporal evolution enabled, as in Section 7.6.3.1 and 7.6.3.2 for generating the channels.  **Proposal 4**: Companies to agree on channel characteristics to be used for evaluating ML positioning, including LOS probability, decorrelation distance (if any), etc., only if the current values specified in TR 38.857 or the agreed parameters on in Rel-17 found to be insufficient.  **Proposal 5**: RAN1 to recognize and document the necessity for studying improved channel models for future studies.  **Proposal 6**: Companies are also encouraged to submit evaluations with ray tracing or with field data to understand the performance of AI/ML positioning methods in real world scenarios due to the known drawbacks of using statistical channels. |
| * Fujitsu (R1-2205080)   **Proposal 1**: In order to generate AI/ML-catered datasets with sufficient target channel properties for training, additional simulation parameter sets should be developed by adjusting and expanding the existing cases defined in TR38.857.  **Proposal 2**: For the evaluation on AI/ML for positioning accuracy enhancement, field data should be excluded during the study item phase. |

### 1st round discussion

As a reference, various channel models have been developed in TR38.901 for the IIoT indoor factory use case, which reflect the various layout of the factory floor. The following are the sub-scenarios in TR38.901:

* InF-SL: Indoor Factory with Sparse clutter and Low base station height (both Tx and Rx are below the average height of the clutter)
* InF-DL: Indoor Factory with Dense clutter and Low base station height (both Tx and Rx are below the average height of the clutter)
* InF-SH: Indoor Factory with Sparse clutter and High base station height (Tx or Rx elevated above the clutter)
* InF-DH: Indoor Factory with Dense clutter and High base station height (Tx or Rx elevated above the clutter)
* InF-HH: Indoor Factory with High Tx and High Rx (both elevated above the clutter)

Based on companies’ contributions, IIoT Indoor Factory (InF) scenarios have wide support, even though companies have different take on exact which sub-scenarios under InF to use.

Support (17): Huawei, HiSilicon (IIoT), ZTE(InF-DH), Ericsson (InF-SH, InF-DH), CATT (InF-DH, InF-DL), Vivo (InF-DH), Xiaomi (InF-DH), Samsung (InF-DH, InF-DL), OPPO (InF-DH), FUTUREWEI (InF-SH, InF-DH), LG (InF-DH (mandatory) / InF-DL (optional)), InterDigital (InF-DH, InF-DL), CAICT (IIoT in 38.857), Apple (e.g., InF-DH), Lenovo (InF with dense clutter), NVIDIA (InF), Qualcomm (InF-DH)

Accordingly, it is recommended to adopt InF scenario for evaluation of AI/ML based positioning. Details are to be further discussed.

Please indicate if you support or do not support the proposal, and provide further comments if any.

**Proposal 2.1.2-1**

The IIoT indoor factory (InF) scenario is a prioritized scenario for evaluation of AI/ML based positioning.

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|  | **Company** |
| Support | vivo |
| Not support |  |

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| **Company** | **Comments** |
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Among sub-scnearios of InF, 3 sub-scenarios were explicitly proposed by companies. In Rel-17 study item (see Appendix A, simulation parameters in TR38.838), InF-SH and InF-DH were used. For Rel-18, some companies propose to reuse {InF-SH and InF-DH}, while other companies propose to consider dense cluster scenario only, i.e., InF-DH, InF-DL. Thus, InF-DH has the most support, while it should be further discussed whether to include InF-SH and/or InF-DL.

* InF-DH (12+?): ZTE, Ericsson, CATT, Vivo, Xiaomi, Samsung, OPPO, FUTUREWEI, LG, InterDigital, Apple, Lenovo (?), Qualcomm
* InF-DL (4+?): CATT, Samsung, LG, InterDigital, Lenovo (?)
* InF-SH (2): Ericsson, FUTUREWEI

Additionally, most companies propose to use the clutter parameters {density, height, size}={60%, 6m, 2m} for InF-DH channel. This is an optional setting in TR38.838, and the most challenging one listed therein (the other two settings are: (Baseline): {40%, 2m, 2m}; (Optional): {40%, 3m, 5m}). The rationale is, this clutter setting causes severe NLOS problem, thus it is a good scenario for demonstrating the performance advantage of AI/ML based positioning as compared to the existing positioning methods.

It is proposed to adopt the proposal below according to majority view, while other sub-scenarios and parameters can be further discussed.

Please indicate if you support or do not support the proposal, and provide further comments if any.

**Proposal 2.1.2-2**

For evaluation of AI/ML based positioning, the InF deployment scenario includes at least the InF-DH sub-scenario for FR1 and FR2.

* Baseline clutter parameters {density , height , size} for InF-DH channel is {60%, 6m, 2m}.

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|  | **Company** |
| Support | vivo |
| Not support |  |

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| **Company** | **Comments** |
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**Question 2.1.2-3**

For evaluation of AI/ML based positioning, should RAN1 select other InF sub-scenarios beyond InF-DH? If so, how many other sub-scenarios, and which one(s)?

* Alt 1: 0 (i.e., InF-DH only is sufficient, FFS more clutter parameters than the baseline)
* Alt 2: 1 more InF sub-scenario (e.g., InF-SH, InF-DL) other than InF-DH;
* Alt 3: >=2 more InF sub-scenarios (e.g., InF-SH, InF-DL) other than InF-DH;

Note: individual company can submit evaluation results for any scenario even if the scenario is not prioritized in RAN1.

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| **Alternatives** | **Company**  (For Alt 2 and 3, identify the InF sub-scenario(s) other than InF-DH) |
| Alt 1 |  |
| Alt 2 |  |
| Alt 3 | vivo |

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| **Company** | **Comments** |
| vivo | As presented in our contribution, we proposed to evaluate under all InF scenarios for an AI/ML model. The motivation is to verify/validate the AL/ML model generalization performance, which is discussed in section 3.5 of this summary.  If we only evaluate one scenario which is the same as the one used to generate training dataset, it’s not possible to see the AI/ML model generalization performance for different scenarios. |
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Based on companies’ contributions, some companies (e.g., FUTUREWEI, Qualcomm, Apple) propose to include also UMi/UMa scenarios, while others (e.g., Ericsson) propose to deprioritze. Regarding simulation parameters for UMi/UMa, Rel-16 scenarios and channel models in TR 38.855 are expected to be reused, similar to the treatment of “General commercial use cases” in 38.857. For reference, the simulation parameters in 38.855 for UMi and UMa are copied in Appendix B.

Please provide your view if UMi and/or UMa need to be adopted for evaluation of AI/ML based positioning. Please provide further comments, if any.

**Question 2.1.2-4**

For evaluation of AI/ML based positioning, should RAN1 should include UMi (Urban Micro) and UMa (Urban Macro) as a prioritized scenario?

* Alt 1: no, neither UMi nor UMa
* Alt 2: yes, UMi
* Alt 3: yes, UMa
* Alt 4: yes, both UMi and UMa

Note: individual company can submit evaluation results for any scenario even if the scenario is not prioritized in RAN1.

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| **Alternatives** | **Company** |
| Alt 1 | vivo |
| Alt 2 |  |
| Alt 3 |  |
| Alt 4 |  |

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| **Company** | **Comments** |
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## Simulation Assumptions

### Companies’ view from contribution

Regarding simulation assumptions to use in the evaluation of AI/ML based positioning, companies’ views are listed below, based on the submitted contributions.

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| * ZTE (R1-2203252)   **Proposal 4**：Reuse common scenario parameters defined in Table 6-1 of TR 38.857, which defines the carrier frequency, bandwidth, sub-carrier spacing, UE antenna configuration, network synchronization error, and UE/gNB Rx/Tx timing errors.  **Proposal 5**: Reuse parameters common to InF scenarios defined in Table 6.1-1 of TR 38.857 with the following modifications (also highlighted in Appendix B),   * InF-DH channel should be the baseline for evaluation; * UE horizontal drop is not required to be in a convex hull; * No need to have dynamic UE/gNB antenna heights; * Baseline clutter parameters {density , height , size } for InF-DH channel are {60%, 6m, 2m}. |
| * Ericsson (R1-2203285)   **Proposal 6** Reuse the simulation parameters in Table 6.1-1 of TR38.857 for performance evaluation. |
| * CATT (R1-2203455)   **Proposal 4**: For AI/ML-based positioning, 3GPP statistic models in TR 38.857 are used to construct the dataset in the first stage, and field data is considered in the next stage. |
| * Vivo (R1-2203554):   **Proposal 3**: For the purpose of link level and system level evaluation, statistical models (from TR 38.901 and TR 38.857) are utilized to generate dataset for AI/ML based positioning for model training/validation and testing.   * + Field data measured in actual deployment for AI/ML model performance testing should be allowed and encouraged |
| * Xiaomi (R1-2203812)   **Proposal 1**: The 1st priority for the study of AI/ML based positioning accuracy enhancement is the inF-DH scenario   * Parameters listed in Table 6.1-1 and Table 6.1-1 of 38.857 could be the starting point of evaluation |
| * Samsung (R1-2203901)   **Proposal 2**: Simulation assumption in Rel16/17 Positioning enhancement can be a starting point for AI for positioning evaluation. |
| * OPPO (R1-2204019)   **Proposal 1**: For the evaluation of AI/ML-based positioning accuracy improvement, support the InF-DH scenario with the high clutter density set as 60%. |
| * FUTUREWEI (R1-2204104)   **Proposal 2**: For scenario parameters, reuse the following:   * Common parameters applicable to all scenarios: reuse the common parameters for Rel-17, specified in Table 6-1 of TR 38.857 [3]. * Common parameters for InF scenarios: reuse the common parameters for Rel-17, specified in Table 6.1-1 of TR 38.587 [3]. * Parameters for Urban micro (UMi) scenario: reuse parameters specified in Table 6.1.1-4 of TR 38.855 [4]. * Parameters for Urban macro (UMa) scenario: reuse parameters specified in Table 6.1.1-6 of TR 38.855 [4]. |
| * CAICT (R1-2204184)   **Proposal 1**: IIOT use cases defined in 38.857 could be used as high priority for evaluation.  **Proposal 2**: Synchronization error should be considered in evaluation assumptions. |
| * Apple (R1-2204242)   **Proposal 2**: To demonstrate the efficacy of the method a comparison of AI-based positioning methods and traditional positioning methods should be evaluated in a heavy NLOS scenario and a light NLOS scenario.   * Use cases with heavy NLOS defined in 38.857 (Study on NR Positioning Enhancements (Release 17)), e.g. InF-DH, should be selected for evaluation. * A low NLOS use case (e..g UMa) may also be evaluated for comparison * The clutter parameters for the InF-DH scenario should harmonized. * Additional non-ideal assumptions such as UE/TRP Rx/Tx timing errors and synchronization errors may also be considered as optional. * Spatial consistency is recommended. * The absolute-time-of arrival model defined in TR 38.901 should be considered. |
| * NVIDIA (R1-2204844)   **Proposal 3**: Use the simulation assumptions in TR 38.857 as a starting point for the evaluation of AI/ML based algorithms for positioning accuracy enhancement. |
| * Qualcomm (R1-2205028)   **Proposal 3**: The channel model in TR 38.901 is adequate for conducting initial evaluation on AI/ML positioning enhancement. It is recommended to have spatial consistency and/or consistent temporal evolution enabled, as in Section 7.6.3.1 and 7.6.3.2 for generating the channels.  **Proposal 4**: Companies to agree on channel characteristics to be used for evaluating ML positioning, including LOS probability, decorrelation distance (if any), etc., only if the current values specified in TR 38.857 or the agreed parameters on in Rel-17 found to be insufficient.  **Proposal 5**: RAN1 to recognize and document the necessity for studying improved channel models for future studies.  **Proposal 6**: Companies are also encouraged to submit evaluations with ray tracing or with field data to understand the performance of AI/ML positioning methods in real world scenarios due to the known drawbacks of using statistical channels. |
| * Fujitsu (R1-2205080)   **Proposal 1**: In order to generate AI/ML-catered datasets with sufficient target channel properties for training, additional simulation parameter sets should be developed by adjusting and expanding the existing cases defined in TR38.857.  **Proposal 2**: For the evaluation on AI/ML for positioning accuracy enhancement, field data should be excluded during the study item phase.  **Proposal 5**: A common set of simulation parameters per scenario should be used. |

### 1st round discussion

Based on companies’ view in contributions, the following have wide support, i.e., common scenario parameters used in Rel-17 study item can be reused. These parameters are applicable to all scenarios, and covers both FR1 and FR2. Note that Table 6-1 of TR 38.857 are copied in Appendix A for reference.

**Proposal 2.2.2-1**

For evaluation of AI/ML based positioning, reuse the common scenario parameters defined in Table 6-1 of TR 38.857.

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|  | **Company** |
| Support | vivo |
| Not support |  |

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| **Company** | **Comments** |
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Regarding InF scenario, companies expressed preference to reuse the existing simulation assumption in Table 6.1-1 of TR 38.857, except that channel model (e.g., InF-DH, InF-DH, InF-SH) and clutter parameters (e.g., {60%, 6m, 2m}) need to be addressed separately (see section 2.1).

Furthermore, ZTE (R1-2203252) proposed to modify the following in Table 6.1-1 of TR 38.857:

* UE horizontal drop is not required to be in a convex hull;
* No need to have dynamic UE/gNB antenna heights;

That is, ZTE propose:

* For UE horizontal drop, use the optional distribution instead of the baseline:
  + “- (baseline) at least the convex hull of the horizontal BS deployment.
  + - (optional) It can also be the whole hall area if the CDF values for positioning accuracy is obtained from whole hall area.”
* For UE/gNB antenna heights, use the baseline (fixed height) instead of the optional:

| UE antenna height | Baseline: 1.5m  (Optional): uniformly distributed within [0.5, X2]m, where X2 = 2m for scenario 1(InF-SH) and X2= for scenario 2 (InF-DH) |
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| gNB antenna height | Baseline: 8m  (Optional): two fixed heights, either {4, 8} m, or {max(4,), 8}. |

ZTE (R1-2203252) provided the following reasoning:

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| * UE horizontal drop is not required to be in a convex hull * *The reason for UE to be dropped inside a convex hull is to increase UE availability for traditional positioning methods.* * No need to have dynamic UE/gNB antenna heights * *Dynamic UE/gNB antenna heights are to evaluate the performance of 3-dimentional UE locations. We prefer to focus on 2-dimentional UE locations during the initial evaluation for AI/ML based positioning.* |

Thus, the following is proposed so that most simulation parameters can be agreed. The points raised by ZTE are to be further discussed.

**Proposal 2.2.2-2**

Reuse parameters common to InF scenarios defined in Table 6.1-1 of TR 38.857, except the following:

* Channel model;
* Clutter parameters;
* UE horizontal drop;
* UE/gNB antenna heights;

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|  | **Company** |
| Support |  |
| Not support |  |

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| **Company** | **Comments** |
| vivo | In principle, we support to reuse previous defined parameters in Table 6.1-1 of TR 38.857  However,  1. Table 6.1-1 of TR 38.857 only defined layout/parameters for InF-DH and InF-SH. We need to add layout/parameters for other InF ssenarios as well.  2. It’d be clear if the update to Table 6.1-1 of TR 38.857 is also listed into the proposal. It’s no clear what’re the udpate to the 4 sub-bullets of this proposal. |
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## Simulation Methodology

### Companies’ view from contribution

Some issues related to simulation methodology are discussed in companies’ contributions. Representative views are copied below.

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| * ZTE (R1-2203252)   **Proposal 4**：Reuse common scenario parameters defined in Table 6-1 of TR 38.857, which defines the carrier frequency, bandwidth, sub-carrier spacing, UE antenna configuration, network synchronization error, and UE/gNB Rx/Tx timing errors.  **Proposal 6**: In order to generate datasets for AI/ML based positioning, the following procedures for spatial consistency should be modeled,   * Section 7.5 of TR 38.901 defines the correlation distance for DS, ASD, ASA, SF, ZSA, ZSD; * Clause 7.6.3.1 of TR 38.901 introduces procedures to model the spatial consistency for cluster-specific and ray-specific random variables, LOS/NLOS state, and Indoor/Outdoor state; * Section 7.9.6 of TR 38.901 gives values to model the spatial consistency of absolute time of arrival. |
| * CAICT (R1-2204184)   **Proposal 2**: Synchronization error should be considered in evaluation assumptions. |
| * Apple (R1-2204242)   **Proposal 2**: To demonstrate the efficacy of the method a comparison of AI-based positioning methods and traditional positioning methods should be evaluated in a heavy NLOS scenario and a light NLOS scenario.   * Use cases with heavy NLOS defined in 38.857 (Study on NR Positioning Enhancements (Release 17)), e.g. InF-DH, should be selected for evaluation. * A low NLOS use case (e..g UMa) may also be evaluated for comparison * The clutter parameters for the InF-DH scenario should harmonized. * Additional non-ideal assumptions such as UE/TRP Rx/Tx timing errors and synchronization errors may also be considered as optional. * Spatial consistency is recommended. * The absolute-time-of arrival model defined in TR 38.901 should be considered. |
| * Vivo (R1-2203554):   **Observation 2:** Performance under different spatial consistency assumption can be vastly different, and positioning performance with spatial consistency (0.99m@90%) is noticeably better than that of without spatial consistency (5.89m@90%).  **Proposal 5:** Spatial consistency assumption should be adopted for performance evaluation. |
| * Qualcomm (R1-2205028)   **Proposal 3**: The channel model in TR 38.901 is adequate for conducting initial evaluation on AI/ML positioning enhancement. It is recommended to have spatial consistency and/or consistent temporal evolution enabled, as in Section 7.6.3.1 and 7.6.3.2 for generating the channels.  **Proposal 10**: Evaluation should also consider evaluating the robustness to UE and network impairments (e.g., UE clock drift, group delays, TRP synchronization, etc.). Companies to agree on these settings. Companies can adopt previous settings used in RAN1 Rel-17, TR 38.857 . |

### 1st round discussion

Several companies emphasized the importance of spatial consistency when performing the evaluation, especially for the fingerprinting based method. These companies include: vivo, Qualcomm, ZTE, Huawei, Apple. Indeed spatial consistency is important in simulation setup. The implementation of spatial consistency has been addressed in previous RAN1 discussion, and companies can implement according to Clause 7.6.3 of TR 38.901.

**Proposal 2.3.2-1**

Spatial consistency is enabled in the channel model for evaluation of AI/ML enabled positioning.

* + The implementation of spatial consistency is according to Clause 7.6.3 of TR 38.901.

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| --- | --- |
|  | **Company** |
| Support | vivo |
| Not support |  |

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| **Company** | **Comments** |
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Several companies pointed out that the evaluation should consider potential UE and network impairments, including: UE and network synchronization, UE clock drift, inter-TRP synchronization, group delays, etc.

Network synchronization is a parameter in Table 6-1 of TR 38.857, see below. In Rel-17 study item, both perfect synchronization and 50ns synchronization error were investigated. Similarly, UE/gNB RX and TX timing error are also modelled in Table 6-1 of TR 38.857, with the error range up to participating companies.

To investigate realistic positioning accuracy, UE and network impairments have to be included in the simulation study. Such investigation should be included in Rel-18, similar to Rel-17 study item.

TR38.857, Table 6-1 Common scenario parameters applicable for all scenarios:

|  |  |
| --- | --- |
| Network synchronization | The network synchronization error, per UE dropping, is defined as a truncated Gaussian distribution of (T1 ns) rms values between an eNB and a timing reference source which is assumed to have perfect timing, subject to a largest timing difference of T2 ns, where T2 = 2\*T1  – That is, the range of timing errors is [-T2, T2]  – T1: 0ns (perfectly synchronized), 50ns (Optional) |
| UE/gNB RX and TX timing error | (Optional) The UE/gNB RX and TX timing error, in FR1/FR2, can be modeled as a truncated Gaussian distribution with zero mean and standard deviation of T1 ns, with truncation of the distribution to the [-T2, T2] range, and with T2=2\*T1:  - T1: X ns for gNB and Y ns for UE  - X and Y are up to sources  - Note: RX and TX timing errors are generated per panel independently  Apply the timing errors as follows:  - For each UE drop,  - For each panel (in case of multiple panels)  - Draw a random sample for the Tx error according to [-2\*Y,2\*Y] and another random sample for the Rx error according to the same [-2\*Y,2\*Y] distribution.  - For each gNB  - For each panel (in case of multiple panels)  - Draw a random sample for the Tx error according to [-2\*X,2\*X] and another random sample for the Rx error according to the same [-2\*X,2\*X] distribution.  - Any additional Time varying aspects of the timing errors, if simulated, can be left up to each company to report.  - For UE evaluation assumptions in FR2, it is assumed that the UE can receive or transmit at most from one panel at a time with a panel activation delay of 0ms. |

**Proposal 2.3.2-2**

The evaluation investigates the network synchronization and the UE/gNB RX and TX timing error by reusing TR 38.857 assumptions.

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|  | **Company** |
| Support | vivo |
| Not support |  |

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| --- | --- |
| **Company** | **Comments** |
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|  |  |

# Performance Targets and Key Performance Indicators (KPI)

## Companies’ view from contribution

For performance targets and Key Performance Indicators (KPI), some companies’ input are copied below.

|  |
| --- |
| * Huawei (R1-2203144)   **Proposal 3**: For AI/ML-based positioning evaluation, adopt the positioning accuracy and model complexity as the KPIs.  **Proposal 6**: For AI/ML-based LOS/NLOS Identification evaluation, the baseline solution should be aligned with an existing traditional algorithm.  **Proposal 9**: For the evaluation of AI/ML-based fingerprint positioning, study the generalization of the AI/ML model for varying environments. |
| * ZTE (R1-2203252)   **Proposal 2**: Regarding target requirements for AI/ML based positioning, we should have comprehensive considerations on performance, inference latency, computational complexity, overhead, power consumption, memory storage, and hardware requirements.  **Proposal 3**: For evaluating performance of AI/ML based NR positioning technologies, the percentiles of positioning errors at 50%, 67%, 80%, 90% and 95% should be analyzed. |
| * Ericsson (R1-2203285)   **Proposal 4** The target performance requirements include sub-meter level horizontal accuracy and >=99% availability.  **Proposal 5** Positioning accuracy enhancements can be reflected in metrics other than sharper horizontal-vertical accuracy, e.g., improved radio resource efficiency, reduced higher layer signalling overhead, improved robustness.  **Proposal 7** The baseline performance to compare and demonstrate the potential AI/ML gain are the existing NR positioning methods including Rel-17 enhancements.  **Proposal 15** For evaluation results, participating companies are encouraged to report at least: (a) horizontal accuracy; (b) resource utilization; (c) complexity of the ML model; (d) model generalization. |
| * CATT (R1-2203455)   **Proposal 3**: For AI/ML-based positioning evaluation, the baseline for comparing AI/ML model performance is positioning methods specified in Rel-16/Rel-17.  **Proposal 6**: For AI/ML-based positioning, in addition to AI-specific KPIs, the following KPIs are considered:   * The accuracy of intermediate measurement results (e.g. error of ToA/AoA/AoD) if AI/ML-based intermediate measurement estimation is applied. * The correct rate of LOS/NLOS identification if AI/ML-based LOS/NLOS identification is applied. * The final positioning accuracy (e.g. positioning error at 90% CDF). |
| * Vivo (R1-2203554):   **Proposal 4**: The positioning accuracy performance of AI/ML based positioning should be evaluated under all scenarios.  **Proposal 6**: Performance related KPIs, such as @50%, @90% positioning accuracy defined in TR 38.857, can be used directly to evaluate the performance gain of AI/ML based positioning.  **Proposal 7**: Consider the following different levels of generalization performance for performance evaluation.  - Generalization performance form one cell to another  - Generalization performance from one one drop to another  - Generalization performance from one scenario to another  **Proposal 8**: Computational complexity, parameter quantity and training data requirement are three crucial cost-related KPIs for AI/ML based positioning, and should be considered with high priority at the beginning of this study . |
| * Xiaomi (R1-2203812)   **Proposal 3**: The performance metric for evaluation is the positioning error for specific percentiles of UEs |
| * Samsung (R1-2203901)   **Proposal 4**: The evaluation metrics of AI model should be considered for studying AI for positioning.  **Proposal 7**: The KPIs in Rel-17 shall be the starting point for Rel-18 AI/ML positioning. |
| * OPPO (R1-2204019)   **Proposal 2**: Regarding the positioning accuracy, reuse the following metrics for the evaluation:   * CDF of the positioning accuracy * Achieved accuracy at 90%   **Proposal 3**: Regarding the complexity of AI/ML-based method, use FLOPs as the metric at the initial stage |
| * FUTUREWEI (R1-2204104)   Proposal 3: Reuse the Rel-17 performance evaluation metrics and performance targets specified in TR 38.587 [3] on NR positioning enhancements for Rel-18 AI/ML-based positioning accuracy enhancements use case.  Other KPIs from AI/ML modeling perspective:  Observation 1: For LOS / NLOS classification sub use case, using accuracy alone is not sufficient to evaluate the performance of the classification algorithm.  Observation 2: When designing or using AI/ML-based approach, it is important to take into account its associated complexity while measuring complexity for NN-based AI/ML models and non-NN based AI/ML models may be different.  Observation 3: Complexity for NN-based AI/ML models can be measured using model (or space) complexity and computational complexity, which reflect the memory usage and computation power needed respectively.  Observation 4: Complexity for non-NN based AI/ML models can be represented using the Big O notation for space complexity and computational (or time) complexity, which reflect the amount of space and number of operations taken by the AI/ML algorithm respectively.  Proposal 4: Adopt additional KPIs in assessing AI/ML-based LOS / NLOS classification performance. Examples of such metric to be considered are the ‘Precision’ and ‘Recall’ metrics as described.  Proposal 5: Adopt model / space complexity as one of the KPIs to evaluate the complexity of AI/ML-based approach for positioning accuracy enhancements use case.  For NN-based models, model or space complexity measurements include number of parameters in the model and memory usage. For non-NN-based models, space complexity reflects the amount of space taken by the AI/ML model to complete the task as a function of the size of the input, and/or configurations/settings of the AI/ML model.  Proposal 6: Adopt computational complexity as one of the KPIs to evaluate the complexity of AI/ML-based approach for positioning accuracy enhancements use case.  For NN-based models, computational complexity can be estimated using number of floating-point operations (FLOPs) or number of multiplies and accumulates (MACs). For non-NN-based models, computational complexity reflects the number of operations taken by the AI/ML model as a function of the size of the input, and/or configurations/settings of the AI/ML model. |
| * InterDigital (R1-2204159)   **Proposal 3**: Evaluate latency required for AIML based positioning which includes time required to train AIML models and rate at which the AIML models can generate predicted UE locations |
| * CAICT (R1-2204184)   **Proposal 4**: Position accuracy is used as the main KPI for AI/ML based algorithms.  **Proposal 5**: Generalization ability of an AI/ML model should be considered. |
| * Apple (R1-2204242)   **Proposal 5**: In evaluating the performance of AI-based NR positioning, as in the Rel-17 study on positioning, the metric should be based on the CDF of the 2-D positioning error (horizontal accuracy) with the following percentiles of positioning error are analyzed: 50%, 67%, 80%, 90%.  **Proposal 6**: The baseline for comparison are the Rel-16/Rel-17 positioning mechanisms. |
| * CMCC (R1-2204299)   **Observation 1**: Compared with legacy positioning schemes, AI/ML based positioning schemes could improve the positioning accuracy for heavy NLOS scenario.  **Observation 2**: For AI/ML based positioning schemes, how to improve the generalization capability should be supported. |
| * Nokia (R1-2204575)   **Proposal 4**: RAN1 to study positioning measurement and feedback enhancements considering overhead reduction and error between original and decompressed measurements as relevant KPIs.  **Proposal 5**: Include above evaluation results in the TR to highlight the benefits of ML in improving positioning estimation accuracy compared to conventional methods.  **Proposal 6**: Include above evaluation results in the TR to highlight the benefits of ML in reducing positioning measurement reporting overhead in comparison with conventional methods. |
| * Lenovo (R1-2204421)   **Proposal 6**: Potential KPIs for the AI/ML positioning evaluation may at least include accuracy (horizontal and vertical), positioning latency, training overhead, model robustness, scalability, adaptability and complexity/power consumption. FFS the detailed metrics for model robustness, scalability, adaptability and complexity/power consumption. |
| * NVIDIA (R1-2204844)   **Proposal 8**: Key KPIs for the study of AI/ML based algorithms for positioning accuracy enhancements include horizontal accuracy and vertical accuracy. |
| * Qualcomm (R1-2205028)   **Proposal 9**: Evaluation should also consider evaluating robustness and sensitivity of AI/ML positioning to wireless environment dynamics.  **Proposal 10**: Evaluation should also consider evaluating the robustness to UE and network impairments (e.g., UE clock drift, group delays, TRP synchronization, etc.). Companies to agree on these settings. Companies can adopt previous settings used in RAN1 Rel-17, TR 38.857 .  **Proposal 11**: Baseline scheme should be the start-of-art classical scheme used in RAN1 Rel 17 . Companies are encouraged to provide assumptions on their baseline scheme. Positioning KPIs adopted in previous releases should be adopted in the AI/ML positioning study.  **Proposal 12**: The KPI can be the positioning accuracy for all AI positioning approaches and this applies to all sub use cases.  **Proposal 13**: Other training and inference KPIs that relate to AI positioning include:   * CDF of minimum distance between training samples **** this KPI helps understanding data collection requirements for achieving certain accuracy level. * UE area density for training set **** this KPI helps understanding data collection requirements for achieving certain accuracy level. * CDF of minimum distance between training and inference samples **** this KPI can help assessing how difficult was the generalization task when compared to training. |
| * Fujitsu (R1-2205080)   **Proposal 3**: The positioning accuracy defined in TR38.857 should be used as the KPI for the performance evaluation regardless of the output of the AI/ML models.  **Proposal 4**: The complexity, the storage requirement and the extra overhead introduced by the AI/ML model should be collected, and the trade-off between these factors and the performance should be evaluated. |
| * Rakuten (R1-2205066)   **Proposal 1:** Discuss enhancement of positioning accuracy for NLOS environment with minimum increase of latency by applying AI/ML.  In both cases, the most important KPI could be positioning accuracy improvement compared with the case without AI/ML application when the same simulation environment setting is configured. |

## Baseline Performance

### 1st round discussion

Several companies (e.g., Huawei, ZTE, Ericsson, CATT, Apple, Qualcomm) proposed to use the performance of existing positioning methods as the baseline performance. Since there are numerous positioning methods available (e.g., DL-TDOA, DL-AoD, Multi-RTT, NR E-CID, UL-TDOA, UL-AoA), each participating company should report which one is used as benchmark in their evaluation.

Accordingly, the following is proposed.

**Proposal 3.2.1-1**

For AI/ML-based positioning evaluation, the baseline performance to compare against is that of existing Rel-16/Rel-17 positioning methods.

* + Each participating company report the specific existing positioning method (e.g., DL-TDOA, Multi-RTT) used as comparison.

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|  | **Company** |
| Support |  |
| Not support |  |

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| --- | --- |
| **Company** | **Comments** |
| vivo | We have a preference to select one common baseline positioning method so that a concrete observation/conclusion may be drawn based on all companies‘ evalutions in the end of this SI. |
|  |  |
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## Positioning Accuracy

### 1st round discussion

Regarding positioning accuracy to evaluate, all companies consider horizontal accuracy. Regarding vertical accuracy, Ericsson (R1-2203285) think vertical accuracy is not needed since the vertical accuracy target (e.g., <3m) is loose compared to that of horizonal accuracy target (e.g., <1m). ZTE (R1-2203252) recommends to focus on horizontal accuracy for initial evaluation, and consequently dynamic UE/gNB antenna heights are not needed. While TR38.857 evaluated both horizontal and vertical accuracy, the evaluation in in this study item can focus on horizontal accuracy, while the vertical accuracy is optional to report.

Regarding CDF percentiles, TR38.857 uses {50%, 67%, 80%, 90%}. Two companies proposed to include higher values, i.e., Ericsson (>=99%), ZTE (95%). After the main KPI is resolved, the CDF percentiles will be further discussed.

As a first step of the discussion, the following is proposed.

**Proposal 3.3.1-1**

For all scenarios and use cases, the main KPI is the CDF of horizonal accuracy.

* Companies can optionally report vertical accuracy.

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|  | **Company** |
| Support |  |
| Not support |  |

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| --- | --- |
| **Company** | **Comments** |
| vivo | Is the intention to report CDF curve or just a set of selected CDF persentiles? We prefer to the latter and prefer a rewording of this proposal to make it clear. |
|  |  |
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Regarding the target position accuracy, Ericsson (R1-2203285) suggested to use the Service Level 5 and 6 cases in Table 5.7.1-1 of TS 22.104 V18.3.0 (2022-03).

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| --- | --- | --- | --- | --- | --- | --- | --- |
| Scenario | Horizontal accuracy | Vertical accuracy | Availability | E2E latency for position estimation of UE | Physical layer latency for position estimation | UE speed | Exemplary use case |
| (A) | < 50 cm | < 3 m | 99 % | 1 s | < 500 ms | < 30 km/h | Flexible, modular assembly area in smart factories (for autonomous vehicles, only for monitoring purposes) |
| (B) | < 30 cm | < 3 m | 99.9 % | 10 ms | < 5 ms | < 30 km/h | Inbound logistics for manufacturing |

In Rel-17 study item, the target positioning requirements for the IIoT use case are the following (see 38.857):

|  |
| --- |
| In Rel-17 target positioning requirements for IIoT use cases are defined as follows:  - Horizontal position accuracy (< 0.2 m) for 90% of UEs  - Vertical position accuracy (< 1 m) for 90% of UEs |

**Question 3.3.1-2**

For the IIoT use case, the target positioning requirements for horizonal accuracy and vertical accuracy is selected from one of the following alternatives:

1. Service Level 5 in Table 5.7.1-1 of TS 22.104 V18.3.0
   * Horizontal position accuracy (< 0.5 m) for 99% of UEs
   * Vertical position accuracy (< 3 m) for 99% of UEs
2. Service Level 6 in Table 5.7.1-1 of TS 22.104 V18.3.0
   * Horizontal position accuracy (< 0.3 m) for 99.9% of UEs
   * Vertical position accuracy (< 3 m) for 99.9% of UEs
3. IIoT target requirements in TR 38.857
   * Horizontal position accuracy (< 0.2 m) for 90% of UEs
   * Vertical position accuracy (< 1 m) for 90% of UEs

Please identify one alternative from the above as your preference.

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| --- | --- |
|  | **Company** |
| Alternative 1 |  |
| Alternative 2 |  |
| Alternative 3 |  |

Please provide your comments, if any.

|  |  |
| --- | --- |
| **Company** | **Comments** |
| vivo | We’d like to get clarification on the intention of this proposal.  The SID says we need to evlaute performance of AI/ML for positioning accuracy enhancement. It’s not clear to us we need to define a target perfromance. |
|  |  |
|  |  |

## AI/ML Complexity

### 1st round discussion

Several companies (e.g., Huawei, ZTE, Ericsson, vivo, Samsung, OPPO, Fujitsu) point out that complexity should be evaluated as a KPI, where complexity include model complexity and computational complexity. Based on companies’ input, the following is proposed.

**Proposal 3.4.1-1**

For evaluation of AI/ML based positioning, the KPI include the model complexity and computational complexity.

* For model complexity, the metric include: (1) the number of parameters in the model and (2) memory storage.
* For computational complexity, the metric is floating-point operations (FLOPs).

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|  | **Company** |
| Support |  |
| Not support |  |

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| **Company** | **Comments** |
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## Generalization of AI/ML Models

### 1st round discussion

Several companies (Huawei, Ericsson, CAICT, CMCC, Lenovo, Qualcomm, Fujitsu) pointed out the generalization capability of the AI/ML model is an important metric. That is, a metric is needed to represent the robustness and sensitivity of AI/ML positioning to wireless environment dynamics, performance variation from one cell to another cell, performance variation from one scenario to another scenario.

While model generalization is widely supported as a metric, different companies have used different methods to demonstrate it. Based on the input thus far, it is not easy to align to a same method. Companies are invited to comment if/how to align to a same methodology for evaluation of model generalization capability, or each company should be allowed to evaluate and report in their preferred way (i.e., without aligning to a same methodology).

**Proposal 3.5.1-1**

For evaluation of AI/ML based positioning, the KPI include the model generalization capability.

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|  | **Company** |
| Support | vivo |
| Not support |  |

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| --- | --- |
| **Company** | **Comments** |
| vivo | We explictly made proposals to invetigate AI/ML model generalization performance in our contribution. It seems our view is not captured in the summary here. |
|  |  |

**Question 3.5.1-2**

For the KPI of model generalization capability,

1. RAN1 align to a same methodology; FFS: how to define the methodology.
2. No aligned methodology is needed. Each company report their own robustness evaluation.

Please indicate your recommendation below.

|  |  |
| --- | --- |
|  | **Company** |
| Approach A | vivo |
| Approach B |  |

If Approach (A), please describe the aligned methodology you recommend RAN1 to adopt.

|  |  |
| --- | --- |
| **Company** | **Comments** |
| vivo | As we stated in our contribution, AI/ML model generalization performance evaluated form one cell to another, from one drop to another and from one scenario to another can be considered. |
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## Other Performance Metrics

### 1st round discussion

Beyond the widely supported KPIs listed above, there are other KPIs that have been pointed out by companies. Based on companies’ input, these KPIs can be optionally reported by supporters.

**Proposal 3.6.1-1**

For evaluation of AI/ML based positioning, the following are optional KPI to report by participating companies:

* Latency for estimating the position of the UE
* Radio resource efficiency
* higher layer signaling overhead

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|  | **Company** |
| Support |  |
| Not support |  |

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| **Company** | **Comments** |
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# Sub-use cases for Positioning

Here the sub- use cases refer to the functionalities fulfilled by an AI/ML model for the purpose of determining a target UE’s position.

## Companies’ view from contribution

A variety of sub-use cases have been described and evaluated in companies’ contributions. Representative texts are copied below.

|  |  |  |
| --- | --- | --- |
| * Huawei (R1-2203144)   Figure 1 shows the TDoA positioning process based on AI/ML-based LOS/NLOS identification. The AI-based LOS/NLOS identification is utilized to remove the NLOS paths from the calculation. It uses the channel’s Power Delay Profile (PDP) as input and calculates a LOS probability. As shown in Table 1, a neural network with a convolutional architecture is capable to learn this relationship well and can achieve a much better prediction accuracy than traditional methods, especially when the number of antennas is small.   |  | | --- | |  |   Figure 1 Positioning process based on LOS/NLOS identification.  Figure 3 shows the AI/ML-based fingerprint positioning process. It exploits that each UE position has a unique channel characteristic (i.e. the fingerprint). The AI/ML model can learn this relationship for a given environment and then use it to determine the UE coordinate based on the measured channel characteristics.   |  | | --- | |  |   Figure 3 AI/ML-based fingerprint positioning process |
| * ZTE (R1-2203252)   Here we conduct a preliminary evaluation based on the settings stated above. We use truncated channel in time domain (i.e., path RSRP(s) and timing(s) ) from total 18 TRPs as input of the AI/ML model. The output of the AI/ML model is 2-dimentional UE position.    Figure 4-2 An example of AI/ML model for positioning |
| * Ericsson (R1-2203285)   **Proposal 10** The study considers both UE-based and network-based position estimation.  **Proposal 16** RAN1 study focuses on the evaluation of positioning enhancement where AI/ML models support these functionalities: LOS/NLOS identification, timing estimate of detected paths. |
| * CATT (R1-2203455)   **Proposal 1**: For positioning, the evaluation methodology is as follows:   * For AI/ML-based intermediate measurement estimation, consider evaluating the result of ToA/AoA/AoD estimation as intermediate evaluation, and evaluating the positioning accuracy as final evaluation. * For AI/ML-based LOS/NLOS identification, consider evaluating the LOS/NLOS identification as intermediate evaluation, and evaluating the positioning accuracy as final evaluation. * For end-to-end positioning based on AI/ML, consider evaluating the positioning accuracy as final evaluation. |
| * vivo (R1-2203554):   …  For AI/ML based positioning, UE position can be estimated according to multiple TRPs’ Channel Impulse Response (CIR) vectors, as shown in Figure 4. Note that, AI model can be deployed at the UE side or network side.     1. UE position estimation with multiple TRPs’ CIRs   …  As shown in Figure 8, instead of constructing an AI model with 18 TRPs’ CIRs as input and the target UE’s location as output, we consider a more general framework with one TRP’s CIR as the input and an intermediate feature (such as TOA of that TRP at the target UE) as the output for each TRP, respectively. Based on the intermediate feature extracted from CIR of each TRP, location of the target UE can be further derived by utilizing other positioning algorithms, including AI-based or non-AI based algorithms. In order to distinguish from aforementioned positioning method based on multi-TPRs’ CIRs, we call it *two-step positioning method*, i.e., CIR-intermediate feature-positioning.  …     1. The framework of two-step positioning method   …  **Proposal 10:** Study further on the benefits of two-step positioning for AI/ML based positioning in terms of positioning accuracy and AI model generalization.  **Observation 8:** The selection of AI model may be strongly related to specific tasks, and a suitable model can facilitate better evaluation of performance gain for AI/ML based positioning |
| * Xiaomi (R1-2203812)     Figure 1 Principle of AI-based evaluation |
| * OPPO (R1-2204019)   In summary, the following schemes are used in our initial evaluation:   * **Non-AI-based DL-TDOA**: CHAN algorithm is used to estimate the location based on measurement results of DL RSTD * **AI + DL-TDOA**: A trained NN is used to estimate the location based on measurement results of DL RSTD * **AI + DL-TDOA + RSRP**: A trained NN is used to estimate the location based on measurement results of DL RSTD and associated RSRP * **AI + TOA**: A trained NN is used to estimate the location based on measurement results of TOA * **AI + TOA + RSRP**: A trained NN is used to estimate the location based on measurement results of TOA and associated RSRP * **AI + Normalized CIR**: A trained NN is used to estimate the location based on measurement results of normalized CIR * **AI + Normalized CIR + RSRP**: A trained NN is used to estimate the location based on measurement results of normalized CIR and associated RSRP |
| * FUTUREWEI (R1-2204104)   As discussed in [2], we propose considering both “AI/ML-based LOS / NLOS classification” and “AI/ML-based UE position estimation” as representative sub use cases for positioning accuracy enhancement. |
| * InterDigital (R1-2204159)   In Section 3, simulation results for 2 use cases have been presented namely, 1) NLOS Identification and 2) fingerprinting-based positioning. |
| * Apple (R1-2204242)   We evaluate an AI-only positioning technique in which a normalized CIR (normalized by the path loss of the closest gNB) and the L1-RSRP serve as inputs into a multi-input neural network that directly estimates the UE’s position.  Diagram  Description automatically generated  Figure 1: High Level AI model |
| * CMCC (R1-2204300)   **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 |   **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. |
| * Nokia (R1-2204575)   **Proposal 1:** For LOS/NLOS classification tasks using supervised learning, the data labeling methodology should be further studied, especially in terms of whether there could be a common understanding that could be achieved within RAN1.  **Proposal 3:** For regression tasks, such as ranging estimation, use absolute estimation error, e.g., absolute horizontal positioning error, to evaluate the performance of the ML model.  **Observation 3**: ML-based methods can provide significant performance gains for positioning measurement reporting in comparison to classical approaches. |
| * Fraunhofer (R1-2204837)  1. *Use case 1: ML measurement accuracy and reliability enhancements:*  The ToA/AoA measurement accuracy depends highly on the channel condition. ML based technologies can either enhance the accuracy or can provide channel classification information for reliability estimation, for example. 2. *Use case 2: ML based positioning algorithms:* Positioning methods making use of environmental information can be realized using ML based concepts. |
| * Qualcomm (R1-2205028)   We provide evaluations for both ML-based and ML-assisted positioning sub use cases. We consider the RFFP [4] as the ML-based positioning approach and we use it to show the gain that AI/ML can offer in extreme NLOS indoor scenarios. For the ML-assisted approach, we evaluate the ML likelihood fusion for DL-TDoA scheme and show its enhancements to outdoor positioning scenarios. |

### 1st round discussion

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.

While (2b) was described by some companies (e.g., vivo), it is observed that no companies evaluated (2b). Also with two ML models in the processing chain, it is more difficult to analyze performance of individual ML module and KPIs like AI/ML complexity. Thus it is proposed that (2b) is not included in the scope of evaluation study, with the understanding that this does not preclude (2b) from general discussion. In this case the evaluation only consider sub-use cases that use a single ML model. The single ML model may be located on the UE side or the network side, which is similar to the paradigm of existing positioning methods.

**Proposal 4.1.1-1**

For the purpose of evaluating AI/ML based positioning, only consider sub-use cases that use a single ML model.

|  |  |
| --- | --- |
|  | **Company** |
| Support |  |
| Not support | vivo |

|  |  |
| --- | --- |
| **Company** | **Comments** |
| vivo | A couple of comments:  1. It’s not clear about the definition of single ML mode. Does this proposal exclude evalution of a sub-use case where AI/ML model was updated? From our reading of companies‘ contributions, several compnaies mentioned/proposed to study on AI/ML model performance monitoring/updating/fine-tuing which may consider updated AI/ML model, it’s no reasonable to exclude such evaluation before we study it.  2. 3GPP is contribution driven and companies not interest in (2b) are not mandated to evaluate (2b). We’re not sure why we should exclude evaluation of (2b) if proponent companies want to bring results for discussion. |
|  |  |

**Proposal 4.1.1-2**

For any sub-use case evaluated for AI/ML based positioning, the ML model may be located on the UE side or the network side.

|  |  |
| --- | --- |
|  | **Company** |
| Support |  |
| Not support |  |

|  |  |
| --- | --- |
| **Company** | **Comments** |
|  |  |
|  |  |

Next two proposals attempt to define the sub-use cases in order to facilitate further discussion and down-selection.

**Proposal 4.1.1-3**

For the evaluation of AI/ML based positioning, one possible sub-use case uses the two-step approach:

* Step 1: the ML model is used to generate an output which is an intermediate quantity for position estimation.
  + FFS: possible measurement include: LOS/NLOS identification, TOA estimation;
* Step 2: Estimate the target UE’s position using an existing Rel-16/Rel-17 positioning method which utilizes the intermediate quantity.

|  |  |
| --- | --- |
|  | **Company** |
| Support |  |
| Not support | vivo |

|  |  |
| --- | --- |
| **Company** | **Comments** |
| vivo | A couple of comments:  1. What’s the intention of FFS sub-bullet under step 1? Is it to agree on only one type of measurement for evalution? Our understanding is that down-selection of sub-use cases as representative is under agenda 9.2.4.2. We suggest to remove the word FFS.  2. As we commented toward Proposal 4.1.1-1, we perfer not to exclude possibility of evaluation on using AI/ML in the 2nd step. So we suggest to add a sub-bullet note under step 2.  Our suggest modification is as follow.  For the evaluation of AI/ML based positioning, one possible sub-use case uses the two-step approach:   * Step 1: the ML model is used to generate an output which is an intermediate quantity for position estimation.   + ~~FFS:~~ possible measurement includes: LOS/NLOS identification, TOA estimation; * Step 2: Estimate the target UE’s position using an existing Rel-16/Rel-17 positioning method which utilizes the intermediate quantity.   + Using AI/ML model instead of Rel-16/17 positioning method is not precluded |
|  |  |

**Proposal 4.1.1-4**

For evaluation of AI/ML based positioning, one possible sub-use case uses the one-step approach where the ML model directly estimate the target UE’s position.

|  |  |
| --- | --- |
|  | **Company** |
| Support |  |
| Not support |  |

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| --- | --- |
| **Company** | **Comments** |
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|  |  |

For the two-step approaches, there are many variations, as can be seen in companies’ contributions. For example, the output of the ML model may be LOS/NLOS identification and probability, ToA, AoA, AoD. It should be discussed how to down-select to a specific sub-use case for evaluation.

**Question 4.1.1-5**

For the two-step approach, the ML output is:

1. LOS/NLOS identification
2. LOS/NLOS identification and ToA
3. AoA (for gNB side ML), AoD (for UE side ML)
4. Other (please explain)

Please select one option from above. For the purpose of down-selection, the option with the most support can be selected as the sub-use case for evaluation.

|  |  |
| --- | --- |
|  | **Company** |
| Option 1, LOS/NLOS |  |
| Option 2, LOS/NLOS, ToA |  |
| Option 3, AoA, AoD |  |
| Option 4, Other |  |

|  |  |
| --- | --- |
| **Company** | **Comments** |
| vivo | Our understanding is that down-selection of sub-use cases as representative is under agenda 9.2.4.2. Given the performance will be considered for selecting representative sub use case(s), we’re not sure we need to down select options now before actual evalution. |
|  |  |

For the one-step approach and two-step approach, it is desirable to further down-select to one as RAN1 focus, while the other one is optional and left up to supporting companies. This would concentrate companies’ resource to the most promising sub-use case. Please provide your input to the question below. After collecting companies’ response, RAN1 can decide whether/how to down-select.

**Question 4.1.1-6**

For down-selection of sub-use cases, please indicate your preference between the following:

1. One-step approach;
2. Two-step approach;

|  |  |
| --- | --- |
|  | **Company** |
| Option 1 |  |
| Option 2 |  |

|  |  |
| --- | --- |
| **Company** | **Comments** |
| vivo | Again, our understanding is that down-selection of sub-use cases as representative is under agenda 9.2.4.2. Given the performance will be considered for selecting representative sub use case(s), we’re not sure we need to down select options now before actual evalution. |
|  |  |
|  |  |

# Data Set

## Companies’ view from contribution

AI/ML is data driven, and the dataset is a key component in performance evaluation. RAN1 need to decide the dataset(s) for training, validation, testing, and inference.

In the following, companies’ input on this issue is presented.

|  |
| --- |
| * Huawei (R1-2203144)   **Proposal 7**: For AI/ML-based positioning evaluation, training inputs generated from simulation platform should be a baseline. |
| * ZTE (R1-2203252)   **Proposal 6**: In order to generate datasets for AI/ML based positioning, the following procedures for spatial consistency should be modeled,   * Section 7.5 of TR 38.901 defines the correlation distance for DS, ASD, ASA, SF, ZSA, ZSD; * Clause 7.6.3.1 of TR 38.901 introduces procedures to model the spatial consistency for cluster-specific and ray-specific random variables, LOS/NLOS state, and Indoor/Outdoor state; * Section 7.9.6 of TR 38.901 gives values to model the spatial consistency of absolute time of arrival.   **Proposal 7**: Generated datasets for training, validation, and test should be from the same simulation drop since there is no spatial consistency across multiple simulation drops.  **Proposal 8**: Set small grids for generating training data, i.e., only one training data is expected to be collected within one small grid.   * Baseline assumption for grid size is 0.5m; * Optional assumptions for grid size are 1m and 0.25m.   **Proposal 9**: The datasets for validation and test can be generated from UEs randomly distributed over the hall. |
| * Ericsson (R1-2203285)   **Proposal 8** Synthetic data set generated according to the InF channel models in TR38.901 is used for model training, validation, and testing. |
| * CATT (R1-2203455)   **Proposal 4**: For AI/ML-based positioning, 3GPP statistic models in TR 38.857 are used to construct the dataset in the first stage, and field data is considered in the next stage.  **Proposal 5**: For evaluating AI/ML-based positioning, the construction of dataset should consider the data with or without non-ideal factors, data from same/different TRP(s) and data from same/different scenario(s). |
| * Vivo (R1-2203554):   **Proposal 3:** For the purpose of link level and system level evaluation, statistical models (from TR 38.901 and TR 38.857) are utilized to generate dataset for AI/ML based positioning for model training/validation and testing.   * Field data measured in actual deployment for AI/ML model performance testing should be allowed and encouraged |
| * Xiaomi (R1-2203812)   **Proposal 2**: In the evaluation, generate the data set for the training in inF-DH with different parameters |
| * Samsung (R1-2203901)   **Proposal 5**: The impacting factors on the simulation shall be further studied, and some specific AI/ML related parameters (e.g. hyper-parameter) and space consistence shall be considered.  **Proposal 6**: The baseline dataset used for evaluation could be generated based on TR 38.901 and the simulation assumptions/scenarios specified in Rel-17 in TS 38.857. |
| * OPPO (R1-2204019)   **Proposal 4**: For the evaluation of AI/ML-based positioning accuracy improvement, the data sets of companies should be generated with the same values of the following parameters:   * *X drops* * *Y UEs per drop* * *FFS: values of X, Y* |
| * CAICT (R1-2204184)   **Proposal 3**: Dataset construction with simulated-based data should consider the data labelling process in real deployment. |
| * Apple (R1-2204242)   **Proposal 1**: The dataset should be generated by a system level simulator based on 3GPP simulation methodology |
| * Lenovo (R1-2204421)   **Proposal 4**: RAN1 to further study data construction methodology for the evaluation of the positioning AI/ML models, e.g., use unlabelled or labelled simulation data. |
| * NVIDIA (R1-2204844)   **Proposal 4**: Additional simulation methodology for generating synthetic data, such as digital twins, should be explored for the study of AI/ML based algorithms for positioning accuracy enhancements.  **Proposal 5**: Identifying existing sets of real data should be part of the evaluation work for the study of AI/ML based algorithms for positing accuracy enhancements.  **Proposal 6**: Companies are encouraged to contribute real data to evaluate AI/ML based algorithms for positioning accuracy enhancements. |
| * Qualcomm (R1-2205028)   **Proposal 6**: Companies are also encouraged to submit evaluations with ray tracing or with field data to understand the performance of AI/ML positioning methods in real world scenarios due to the known drawbacks of using statistical channels.  **Proposal 7**: Companies should agree on LSP and SSP settings for training and testing datasets. We propose training and testing datasets to initially have same LSP and SSP settings. Subsequent evaluations can investigate requirements of different settings on scenario and sub use case bases. |
| * Fujitsu (R1-2205080)   **Proposal 1**: In order to generate AI/ML-catered datasets with sufficient target channel properties for training, additional simulation parameter sets should be developed by adjusting and expanding the existing cases defined in TR38.857.  **Proposal 2**: For the evaluation on AI/ML for positioning accuracy enhancement, field data should be excluded during the study item phase. |

## 1st round discussion

Based on companies’ input, all companies support using dataset generated by 3GPP statistic models. Thus the following proposed.

**Proposal 5.2-1**

Synthetic dataset generated according to the statistical channel models in TR38.901 is used for model training, validation, and testing.

|  |  |
| --- | --- |
|  | **Company** |
| Support | vivo |
| Not support |  |

|  |  |
| --- | --- |
| **Company** | **Comments** |
|  |  |
|  |  |

Apple (R1-2204242) has the following proposal, which seems to reflect all companies’ intention.

**Proposal 5.2-2**

The dataset is generated by a system level simulator based on 3GPP simulation methodology.

|  |  |
| --- | --- |
|  | **Company** |
| Support | vivo |
| Not support |  |

One issue to discuss is, how to align the dataset generation among companies so that the evaluation can be calibrated between different companies.

* ZTE proposed: “Generated datasets for training, validation, and test should be from the same simulation drop since there is no spatial consistency across multiple simulation drops.”
* OPPO proposed: “For the evaluation of AI/ML-based positioning accuracy improvement, the data sets of companies should be generated with the same values of the following parameters:
  + *X drops*
  + *Y UEs per drop*
  + *FFS: values of X, Y“*
* Qualcomm proposed: “Companies should agree on LSP and SSP settings for training and testing datasets. We propose training and testing datasets to initially have same LSP and SSP settings. Subsequent evaluations can investigate requirements of different settings on scenario and sub use case bases.”

ZTE and Qualcomm proposals are similar and are captured below for discussion.

**Proposal 5.2-3**

As a starting point, the training, validation and testing dataset are from the same large-scale and small-scale propagation parameters setting. Subsequent evaluation can study the performance when the training dataset and testing dataset are from different settings.

|  |  |
| --- | --- |
|  | **Company** |
| Support | vivo |
| Not support |  |

|  |  |
| --- | --- |
| **Company** | **Comments** |
| vivo | In addition to the high level principle, we suggest to discuss on the details of settings for generating dataset. |
|  |  |

Regarding the issue of using field data from actual deployment or not in evaluation, companies’ view are summarized below:

* Support using field data: Vivo, NVIDIA, Qualcomm, CATT (statistic models in first stage, field data is considered in next stage)
* Do not support using field data: Ericsson, Fujitsu

Moderator proposes to collect more companies’ input with regard to this issue. It is noted that the question is only about the evaluation exercise. It does not affect general discussion about field data.

**Question 5.2-4**

Should field data from actual deployment be used in the Rel-18 study item for the purpose of evaluating the performance of AI/ML based positioning?

|  |  |
| --- | --- |
|  | **Company** |
| Yes | vivo |
| No |  |

Please add your comments below, if any:

|  |  |
| --- | --- |
| **Company** | **Comments** |
|  |  |
|  |  |

# Model Calibration

## Companies’ view from contribution

|  |
| --- |
| * Apple (R1-2204242)   **Proposal 3**: During the use case study phase, it is not necessary to define a common neural network architecture.  **Proposal 4**: RAN1 to discuss the AI input and associated pre-processing (e.g. normalization) needed for the different positioning use cases and their possible specification impacts. |
| * NVIDIA (R1-2204844)   **Proposal 7**: Baseline AI model(s) should be identified for the purpose of calibration in the study of AI/ML based algorithms for positioning accuracy enhancements. |
| * Fujitsu (R1-2205080)   Since the evaluation for an AI/ML model applied in wireless regime is a brand-new attempt, for the purpose of performance comparison among companies without confusion, a calibration for the evaluation procedures is recommended. There are two crucial factors for the simulation of an AI/ML application: the input dataset and the AI/ML model which extracts the features of the inputs; therefore, both of the two parts need some guidelines for calibration.  **Proposal 5**: A common set of simulation parameters per scenario should be used.  **Proposal 6**: Calibration to have comparable results among companies by using an AI/ML model is needed, and the reference model generation procedure need to be studied. |

## 1st round discussion

In the above, companies gave diverse views on whether to agree on a common (i.e., baseline) AI/ML model for performance evaluation. All companies are invited to share views about this issue.

**Question 6.2-1**

For a given sub-use case, should RAN1 define a common AI/ML model as a baseline/reference?

|  |  |
| --- | --- |
|  | **Company** |
| Yes |  |
| No |  |

Please add your comments below, if any:

|  |  |
| --- | --- |
| **Company** | **Comments** |
| vivo | We’d like to understand the intention of defining a reference AI/ML model. Is it to calibrate the evalution setup or AI/ML algorithm or what? |
|  |  |

# Conclusion

TBD

# References

1. RP-213599, “New SI: Study on Artificial Intelligence (AI)/Machine Learning (ML) for NR Air Interface,” 3GPP RAN#94e, December 2021.
2. R1-2203144 Evaluation on AI/ML for positioning accuracy enhancement Huawei, HiSilicon
3. R1-2203252 Evaluation assumptions on AI/ML for positioning ZTE
4. R1-2203285 Evaluations on AI-Pos Ericsson
5. R1-2203455 Discussion on evaluation on AI/ML for positioning CATT
6. R1-2203554 Evaluation on AI/ML for positioning accuracy enhancement vivo
7. R1-2203812 Initial views on the evaluation on AI/ML for positioning accuracy enhancement xiaomi
8. R1-2203901 Evaluation on AI ML for Positioning Samsung
9. R1-2204019 Evaluation methodology and preliminary results on AI/ML for positioning accuracy enhancement OPPO
10. R1-2204104 Discussion on evaluation of AI/ML for positioning accuracy enhancements use case FUTUREWEI
11. R1-2204153 Evaluation on AI/ML for positioning accuracy enhancement LG Electronics
12. R1-2204159 Evaluation assumptions and results for AI/ML based positioning InterDigital, Inc.
13. R1-2204184 Some discussions on evaluation on AI-ML for positioning accuracy enhancement CAICT
14. R1-2204242 Evaluation on AI/ML for positioning accuracy enhancement Apple
15. R1-2204299 Discussion on evaluation on AI/ML for positioning accuracy enhancement CMCC
16. R1-2204421 Discussion on AI/ML Positioning Evaluations Lenovo
17. R1-2204575 Evaluation on ML for positioning accuracy enhancement Nokia, Nokia Shanghai Bell
18. R1-2204797 Evaluation for positioning accuracy enhancements Intel Corporation
19. R1-2204837 Evaluation on AI/ML for positioning accuracy enhancement Fraunhofer IIS, Fraunhofer HHI
20. R1-2204844 On evaluation assumptions of AI and ML for positioning enhancement NVIDIA
21. R1-2205028 Evaluation on AIML for positioning accuracy enhancement Qualcomm Incorporated
22. R1-2205066 Initial view on AI/ML application to positioning use cases Rakuten Moible
23. R1-2205080 Discussion on evaluation related issues for AI/ML for positioning accuracy enhancement Fujitsu

# Appendix A. Simulation parameters in TR 38.857 (Rel-17)

Table 6-1: Common scenario parameters applicable for all scenarios

|  |  |  |
| --- | --- | --- |
|  | FR1 Specific Values | FR2 Specific Values |
| Carrier frequency, GHz | 3.5GHz | 28GHz |
| Bandwidth, MHz | 100MHz | 400MHz |
| Subcarrier spacing, kHz | 30kHz for 100MHz | 120kHz |
| gNB model parameters |  |  |
| gNB noise figure, dB | 5dB | 7dB |
| UE model parameters |  |  |
| UE noise figure, dB | 9dB – Note 1 | 13dB – Note 1 |
| UE max. TX power, dBm | 23dBm – Note 1 | 23dBm – Note 1  EIRP should not exceed 43 dBm. |
| UE antenna configuration | Panel model 1 – Note 1  Mg = 1, Ng = 1, P = 2, dH = 0.5λ, (M, N, P, Mg, Ng) = (1, 2, 2, 1, 1) | Baseline:  Multi-panel Configuration 1 and Panel Configuration a – Note 1  - Multi-panel Configuration 1: (Mg, Ng) = (1, 2); Θmg,ng=90°; Ω0,1=Ω0,0+180°; (dg,H, dg,V)=(0,0)  - Panel Configuration a:  - Each antenna array has shape dH=dV=0.5λ  - Config a: (M, N, P) = (2, 4, 2),  - the polarization angles are 0° and 90°  - The antenna elements of the same polarization of the same panel is virtualized into one TXRU  Optional:  4-panels UE:  - The antenna elements of the same polarization of the same panel is virtualized into one TXRU |
| UE antenna radiation pattern | Omni, 0dBi | Antenna model according to Table 6.1.1-2 in TR 38.855 |
| PHY/link level abstraction | Explicit simulation of all links, individual parameters estimation is applied. Companies to provide description of applied algorithms for estimation of signal location parameters. | |
| Network synchronization | The network synchronization error, per UE dropping, is defined as a truncated Gaussian distribution of (T1 ns) rms values between an eNB and a timing reference source which is assumed to have perfect timing, subject to a largest timing difference of T2 ns, where T2 = 2\*T1  – That is, the range of timing errors is [-T2, T2]  – T1: 0ns (perfectly synchronized), 50ns (Optional) | |
| UE/gNB RX and TX timing error | (Optional) The UE/gNB RX and TX timing error, in FR1/FR2, can be modeled as a truncated Gaussian distribution with zero mean and standard deviation of T1 ns, with truncation of the distribution to the [-T2, T2] range, and with T2=2\*T1:  - T1: X ns for gNB and Y ns for UE  - X and Y are up to sources  - Note: RX and TX timing errors are generated per panel independently  Apply the timing errors as follows:  - For each UE drop,  - For each panel (in case of multiple panels)  - Draw a random sample for the Tx error according to [-2\*Y,2\*Y] and another random sample for the Rx error according to the same [-2\*Y,2\*Y] distribution.  - For each gNB  - For each panel (in case of multiple panels)  - Draw a random sample for the Tx error according to [-2\*X,2\*X] and another random sample for the Rx error according to the same [-2\*X,2\*X] distribution.  - Any additional Time varying aspects of the timing errors, if simulated, can be left up to each company to report.  - For UE evaluation assumptions in FR2, it is assumed that the UE can receive or transmit at most from one panel at a time with a panel activation delay of 0ms. | |
| Note 1: According to TR 38.802  Note 2: According to TR 38.901 | | |

**Table 6.1-1: Parameters common to InF scenarios**

|  | | **FR1 Specific Values** | | **FR2 Specific Values** |
| --- | --- | --- | --- | --- |
| Channel model | | InF-SH, InF-DH | | InF-SH, InF-DH |
| Layout | Hall size | InF-SH:  (baseline) 300x150 m  (optional) 120x60 m  InF-DH:  (baseline) 120x60 m  (optional) 300x150 m | | |
| BS locations | 18 BSs on a square lattice with spacing D, located D/2 from the walls.  - for the small hall (L=120m x W=60m): D=20m  - for the big hall (L=300m x W=150m): D=50m | | |
| Room height | 10m | | |
| Total gNB TX power, dBm | | 24dBm | 24dBm  EIRP should not exceed 58 dBm | |
| gNB antenna configuration | | (M, N, P, Mg, Ng) = (4, 4, 2, 1, 1), dH=dV=0.5λ – Note 1 | (M, N, P, Mg, Ng) = (4, 8, 2, 1, 1), dH=dV=0.5λ – Note 1  One TXRU per polarization per panel is assumed | |
| gNB antenna radiation pattern | | Single sector – Note 1 | 3-sector antenna configuration – Note 1 | |
| Penetration loss | | 0dB | | |
| Number of floors | | 1 | | |
| UE horizontal drop procedure | | Uniformly distributed over the horizontal evaluation area for obtaining the CDF values for positioning accuracy, The evaluation area should be  - (baseline) at least the convex hull of the horizontal BS deployment.  - (optional) It can also be the whole hall area if the CDF values for positioning accuracy is obtained from whole hall area. | | |
| UE antenna height | | Baseline: 1.5m  (Optional): uniformly distributed within [0.5, X2]m, where X2 = 2m for scenario 1(InF-SH) and X2= for scenario 2 (InF-DH) | | |
| UE mobility | | 3km/h | | |
| Min gNB-UE distance (2D), m | | 0m | | |
| gNB antenna height | | Baseline: 8m  (Optional): two fixed heights, either {4, 8} m, or {max(4,), 8}. | | |
| Clutter parameters: {density , height ,size } | | Low clutter density:  {20%, 2m, 10m}  High clutter density:  - Baseline): {40%, 2m, 2m} for fixed UE antenna height and gNB antenna height  - (Optional): {40%, 3m, 5m}  - (Optional): {60%, 6m, 2m} | | |
| Note 1: According to Table A.2.1-7 in TR 38.802 | | | | |

# Appendix B. Simulation parameters in TR 38.855 (Rel-16)

**6.1 Scenarios and system parameters for positioning evaluations**

For evaluating baseline performance, scenarios (with various options/configurations) are defined below for RAT-dependent positioning techniques for NR positioning study

- Scenario 1. Indoor Office for FR1 and FR2 (Open office)

- Scenario 2. UMi street canyon for FR1 and FR2 (ISD 200m)

- Scenario 3. UMa (ISD 500m) for FR1 only (Macro cell only deployment scenario)

**Table 6.1.1-4: Scenario 2: Urban micro (UMi) scenario parameters**

|  |  |  |
| --- | --- | --- |
|  | **FR1 Specific Values** | **FR2 Specific Values** |
| Layout | Hexagonal grid, 19 or 7 macro sites, 3 sectors per site, ISD = 200m, Note 1  Wrap-around is applied, Note 2 | |
| Total gNB TX power, dBm | 44dBm | 37dBm per panel  EIRP should not exceed 73dBm |
| gNB antenna configuration | (M, N, P, Mg, Ng) = (8, 8, 2, 1, 1), (dH, dV) = (0.5, 0.8)λ, - Note 1 | (M, N, P, Mg, Ng) = (4, 8, 2, 2, 2), (dH, dV) = (0.5, 0.5)λ, (dg,H,dg,V) = (4.0, 2.0)λ, - Note 1 |
| gNB antenna radiation pattern | Directional, 8dBi – Note 1  Table 6.1.1-5 | Directional, 8dBi – Note 1  Table 6.1.1-5 |
| Channel model | UMi Street Canyon – Note 3 | |
| Penetration loss | For outdoor UEs: 0dB | |
| Number of floors | All UEs are on the ground. | |
| UE drop procedure | 100% outdoor uniformly distributed over the horizontal area | |
| UE mobility (for modeling Doppler effects) | Outdoor: 3km/h | |
| UE height, m | 1.5m | |
| Min. gNB-UE distance (2D), m | 10m | |
| gNB antenna height | 10 m by default. Companies can bring results with uniform distribution [5-20]m​ | |
| Note 1: According to 3GPP TR 38.802  Note 2: In case if interference considerations are not properly taken into account for 7 sites companies are encouraged to provide results for 19 sites.  Note 3: According to 3GPP TR 38.901 | | |

**Table 6.1.1-6: Scenario 3: Outdoor macro (UMa) scenario parameters**

|  |  |
| --- | --- |
|  | **FR1 Specific Values** |
| Layout | Hexagonal grid, 3 sectors per site, 7 or 19 macro sites, ISD = 500m – Note 1  Wrap-around is applied. Note 2 |
| Total gNB TX power, dBm | 49dBm |
| gNB antenna configuration | (M, N, P, Mg, Ng) = (8, 8, 2, 1, 1), (dH, dV) = (0.5, 0.8)λ – Note 1  Applicable for 2GHz and 4 GHz carrier frequency. |
| gNB antenna radiation pattern | Directional, 8dBi – Note 1, Table 6.1.1-5 |
| Channel model | UMa scenario – Note 3 |
| Penetration loss | For outdoor UEs: 0dB For indoor UEs: 20dB+0.5d2D-in – Note 3 |
| Number of floors, (floor height) | 8, (3m) |
| Antenna Height: | Uniformly distributed [20-50] m – Note 4  25m + α, where α~uniform[-5, 25] |
| UE Height | 3(nfl – 1) + 1.5 m – Note 4  where, nfl ~ uniform(1,Nfl) and Nfl = 8 |
| UE dropping procedure | 50% indoor and 50% outdoor uniformly distributed over the horizontal area (separate statistic) |
| Min. gNB-UE distance (2D), m | 35m |
| UE mobility (for modeling Doppler effects) | For indoor UEs: 3km/h  For outdoor UEs: 60km/h |
| Note 1: According to 3GPP TR 38.802  Note 2: In case if interference considerations are not properly taken into account for 7 sites companies are encouraged to provide results for 19 sites.  Note 3: According to 3GPP TR 38.901  Note 4: According to 3GPP TR 37.857 | |