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| Technical Report |
| 3rd Generation Partnership Project;Technical Specification Group Services and System Aspects;Study on Core Network Enhanced Support for Artificial Intelligence (AI)/Machine Learning (ML)(Release 19) |
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# Foreword

This Technical Report has been produced by the 3rd Generation Partnership Project (3GPP).

The contents of the present document are subject to continuing work within the TSG and may change following formal TSG approval. Should the TSG modify the contents of the present document, it will be re-released by the TSG with an identifying change of release date and an increase in version number as follows:

Version x.y.z

where:

x the first digit:

1 presented to TSG for information;

2 presented to TSG for approval;

3 or greater indicates TSG approved document under change control.

y the second digit is incremented for all changes of substance, i.e. technical enhancements, corrections, updates, etc.

z the third digit is incremented when editorial only changes have been incorporated in the document.

In the present document, modal verbs have the following meanings:

**shall** indicates a mandatory requirement to do something

**shall not** indicates an interdiction (prohibition) to do something

The constructions "shall" and "shall not" are confined to the context of normative provisions, and do not appear in Technical Reports.

The constructions "must" and "must not" are not used as substitutes for "shall" and "shall not". Their use is avoided insofar as possible, and they are not used in a normative context except in a direct citation from an external, referenced, non-3GPP document, or so as to maintain continuity of style when extending or modifying the provisions of such a referenced document.

**should** indicates a recommendation to do something

**should not** indicates a recommendation not to do something

**may** indicates permission to do something

**need not** indicates permission not to do something

The construction "may not" is ambiguous and is not used in normative elements. The unambiguous constructions "might not" or "shall not" are used instead, depending upon the meaning intended.

**can** indicates that something is possible

**cannot** indicates that something is impossible

The constructions "can" and "cannot" are not substitutes for "may" and "need not".

**will** indicates that something is certain or expected to happen as a result of action taken by an agency the behaviour of which is outside the scope of the present document

**will not** indicates that something is certain or expected not to happen as a result of action taken by an agency the behaviour of which is outside the scope of the present document

**might** indicates a likelihood that something will happen as a result of action taken by some agency the behaviour of which is outside the scope of the present document

**might not** indicates a likelihood that something will not happen as a result of action taken by some agency the behaviour of which is outside the scope of the present document

In addition:

**is** (or any other verb in the indicative mood) indicates a statement of fact

**is not** (or any other negative verb in the indicative mood) indicates a statement of fact

The constructions "is" and "is not" do not indicate requirements.

# 1 Scope

This study will focus on the following objectives:

- AI/ML cross-domain coordination aspects on whether and how to consider 5GC enhancements to LCS to support AI/ML based Positioning considering conclusions of the RAN study in TR 38.843 [6].

NOTE 1: UE data collection, model delivery and transfer to the UE and model identification/management are not within the scope of the study.

NOTE 2: Whether and how the scope could be extended in the future with additional AI/ML cross-domain coordination aspects will be decided based on expected future SA plenary decisions considering the outcome of the related work in the involved RAN WGs(s).

- Whether and what 5GC enhancements are needed to enable 5G system, including the AF, to assist in collaborative AI/ML operations involving NWDAF for Vertical Federated Learning (VFL).

NOTE  3: For Vertical Federated Learning, RAN and UE aspects are out of scope.

- Whether and how to enhance 5GC to support NWDAF-assisted policy & QoS control.

- Whether and how to enhance 5GC to address network abnormal behaviour, i.e. signalling storm, with the assistance of NWDAF.

# 2 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

- References are either specific (identified by date of publication, edition number, version number, etc.) or non‑specific.

- For a specific reference, subsequent revisions do not apply.

- For a non-specific reference, the latest version applies. In the case of a reference to a 3GPP document (including a GSM document), a non-specific reference implicitly refers to the latest version of that document *in the same Release as the present document*.

[1] 3GPP TR 21.905: "Vocabulary for 3GPP Specifications".

[2] 3GPP TS 23.501: "System Architecture for the 5G System; Stage 2".

[3] 3GPP TS 23.502: "Procedures for the 5G system, Stage 2".

[4] 3GPP TS 23.503: "Policy and Charging Control Framework for the 5G System".

[5] 3GPP TS 23.288: "Architecture enhancements for 5G System (5GS) to support network data analytics services".

[6] 3GPP TR 38.843: "Study on Artificial Intelligence (AI)/Machine Learning (ML) for NR air interface".

[7] 3GPP TS 23.273: "5G System (5GS) Location Services (LCS)".

# 3 Definitions of terms and abbreviations

## 3.1 Terms

For the purposes of the present document, the terms given in TR 21.905 [1] and the following apply. A term defined in the present document takes precedence over the definition of the same term, if any, in TR 21.905 [1].

- **Horizontal Federated Learning (HFL):** a federated learning technique without exchanging/sharing local data set, wherein the local data set in different FL clients for local model training have the same feature space for different samples (e.g. UE IDs).

- **Vertical Federated Learning (VFL):** a federated learning technique without exchanging/sharing local data set, wherein the local data set in different VFL Participant for local model training have different feature spaces for the same samples (e.g. UE IDs).

Editor's note: whether different feature space required for VFL is FFS.

- **Label:** A label is the property of interest that is to be learned in supervised machine learning.

Editor's note: the label definition is to be reviewed and extended if needed.

- **VFL Active Participant:** An NF with labels for a VFL training task that may have related inputs data.

Editor's note: whether and how VFL server is different from VFL Active Participant is FFS. If they are the same, one term needs to be selected.

- **VFL Passive Participant:** An NF with the required inputs data without the required labels for a VFL training task. There can be multiple passive participants in VFL.

Editor's note: It is FFS whether and how VFL client is different from VFL passive Participant. If they are the same, one term needs to be selected.

Editor's note: whether there is a VFL coordinator is FFS.

Editor's note: the terminology definition will be updated.

## 3.2 Abbreviations

For the purposes of the present document, the abbreviations given in TR 21.905 [1] and the following apply. An abbreviation defined in the present document takes precedence over the definition of the same abbreviation, if any, in TR 21.905 [1].

AP Active Participant

HFL Horizontal Federated Learning

PP Passive ParticipantVFL Vertical Federated Learning

# 4 Architectural Assumptions and Requirements

The present study will not consider service-based interfaces with RAN and with UE.

The architecture for the present study shall comply with the existing NWDAF framework as specified in TS 23.288 [5], and 5GS framework as specified in TS 23.501 [2], TS 23.502 [3] and TS 23.503 [4].

The architecture for the present study shall comply with the existing Location Service Architecture as specified in TS 23.273 [7].

NOTE 1: The study will consider the related work done by SA WG5, CT WG4 and reuse it when possible.

NOTE 2: Security aspects are to be addressed by SA WG3.

Regarding AI/ML cross-domain coordination aspects, work will be based on the possible requirements defined by RAN WGs considering the conclusions in TR 38.843 [6].

NOTE 3: UE data collection, model delivery and transfer to the UE and model identification/management are not within the scope of the study.

# 5 Use Cases, Motivations and Key Issues

## 5.1 Use Cases

### 5.1.0 Guidelines

Use cases as captured in the following sub-clauses are related to Key Issue #2, Key Issue #3 and Key Issue #4. Table 5.2.0-1 shows the mapping of Key Issues to Use Cases.

NOTE 1: Capturing use cases for Key Issue #4 is optional.

NOTE 2: For KI#1, use cases are based on Positioning accuracy enhancements, case 2b and case 3b (as defined in TR 38.843 [6]). No additional use cases for KI #1 will be defined in this TR.

### 5.1.1 Use Case #1: NWDAF-assisted QoS enhancement

Currently, the QoS parameters are determined by the PCF based on its knowledge, e.g. AF requirements, analytics provided by the NWDAF, etc. After applying the determined QoS parameters to the service, the PCF may determine whether or not the current QoS can fully satisfy the service requirements based on the Service Experience analytics provided by the NWDAF. If the current QoS cannot satisfy the service requirements, the PCF may update the QoS parameters and informs the new parameters to SMF. Then the PCF may require new Service Experience analytics to check whether the updated QoS parameters can satisfy the service requirements. Based on this current framework, it may require several iterations to work out the ideal QoS parameters.

Using its knowledge based on data collection, NWDAF can assist the PCF in determining QoS parameters that can achieve the expected service experience requirements.

### 5.1.2 Use Case #2: Enhancements to QoS Determination with NWDAF Assistance

A use case is provided for how the network can benefit from the NWDAF-assistance for QoS determination and setup for the purpose of optimising the overall network performance and signalling based on operator's policy.

After UE registers with the 5GS, a PDU session set up might be required. Each PDU session is associated with a default QoS rule which provides a default QoS treatment for data flows. Currently the characteristics of the default QoS is determined by the subscribed default values (for parameters such as 5QI, ARP) which the SMF may obtain from the UDM. The default QoS rule might be sufficient for basic browsing or instant messaging over IP, whereas it may not able to satisfy the relatively high service requirements, i.e. of video streaming applications which require better QoS treatment. For example, for V2X and XRM services, the applications may require transmitting traffic with Guaranteed Bit Rate (GBR) or to use certain standardised 5QI values even for non-GBR QoS flows. Therefore, the default QoS requirements may not be able to support such applications.

When the QoS flows with different requirements from the default flow are required, modification to the PDU session and thereby to establish a new QoS flow with the required characteristics might be needed. Such modification will result in significant system-wide signalling, including NAS signalling messages between the UE and the 5GC, signalling within 5GC (i.e. signalling between SMF, UPF, PCF), signalling between 5GC and RAN, and also the RRC messages between the RAN and the UE, etc.

In order to optimise the network performance by determining QoS in a more intelligent manner, it would be beneficial for the 5GC to leverage NWDAF assistance. For example, when the UE or network trigger PDU session establishment or modification for a new QoS flow with QoS requirements driven by a user or service, it would be beneficial if the QoS characteristics are determined by the network by considering the predictions and measurements of some UE and network related information and also service related information (e.g. service requirements provided by the AF). The information considered by the 5GC could be some patterns in terms of frequency of use of one or more services and the potential QoS requirements to be emerged from the UE subsequently, the QoS sustainability of the UE or of an area the UE belongs to, the corresponding UE locations, the service requirements provided by the AF, etc. Therefore, the PDU session and QoS flow can be established or modified in a more 'future proof' and multiple-service-compatible manner and reduce the potential modifications of the existing QoS flow and the corresponding policy control, e.g. PCC rules.

Based on this use case, potential enhancements to 5GC functionality e.g. of the NWDAF, PCF, to enhance the policy control and QoS by considering operator's policies, will improve the network performance and UE experience significantly.

### 5.1.3 Use Case #3: NWDAF assistance in device signalling storm prevention and mitigation

In some scenarios, e.g. NB-IoT CP optimization scenario, UEs send small data over NAS signalling. In case e.g. the application on the NB-IoT UEs is not implemented correctly, e.g. report data at the same time, the NB-IoT devices in some area may be active at the same time so that a large amount of NAS signalling may be transmitted into the network, which may cause signalling storm in that area during that period of time.

Indeed, negotiation with the application provider to mitigate the signalling is useful. However, this use case considers that many e.g. IoT application providers will emerge into the market, and some of them may not conduct such mitigation.

In such case, NWDAF can provide some analytics or prediction on behaviours of e.g. NB-IoT devices and the network status within some area of interest to help network to handle these e.g. NB-IoT devices to avoid signalling storm.

NWDAF has already provided some Analytics IDs related to abnormal behaviours and load status for network, e.g. "NF load information", "Abnormal behaviour", "Suspicions of DDoS attack", "Session Management Congestion Control Experience", etc. in TS 23.288 [5] to assist in protecting the network from signalling storm and abnormal network functions from different aspects. However, the prevention of signalling storm caused by large amount of signalling e.g. NB-IoT scenario with the assistance of NWDAF is not studied. Apparently, existing Analytics IDs may not be enough for the network to handle a signalling storm. Further investigation is required on how to prevent and mitigate signalling storm in e.g. NB-IoT scenario.

### 5.1.4 Use Case #4: Motivation and Support for VFL in 5GC

It is well known in the AI/ML literature that VFL is a federated learning setting where multiple parties perform training on data sets that share the same sample space but differ in feature space. Because of this, an alignment in sample and feature spaces among participating entities is usually required before applying VFL. VFL further allows to perform joint training without exposing raw data, with each entity owning its own model but not needing the same model architectures. This is a way in which VFL differs from HFL. TS 23.288 [5] provides NWDAF specification support for HFL but no VFL support is available, and the existing procedures defined for HFL may be enhanced to support VFL, as mentioned in cl. 5.2.4.

This use case proposes to support VFL in 5GC for analytics derivation leveraging sample and optionally (if needed) feature alignment between the entities participating in VFL, and where the main entity facilitating the VFL operation is NWDAF and other entities may be other NWDAF instances. In a multi-vendor scenario, this would allow participating NWDAF instances to collaborate in VFL without the need for model sharing.

Some of the motivations to introduce VFL in 5GC are as follows:

- VFL may support distributed inference.

- A more flexible technique: In VFL vendor specific local models and features can be deployed in each participant, so that it is possible that each participant selects or configures the local model to be used, as such vendor or operator specific local models and features, including not standardized features, are simpler to implement comparing with HFL.

In one PLMN where multiple NWDAFs are deployed, each NWDAF instance may perform data collection according to their available data sources. Depending on the Analytics ID and the deployment scenario however, the different NWDAF instances may share the same sample space or train on different sample spaces. VFL would be beneficial on the former case. Furthermore, in VFL each NWDAF instance does not collect the same input data for the same Analytics ID.

### 5.1.5 Use Case #5: NWDAF support for observed service experience analytics based on VFL

When NWDAF provides observed service experience analytics, as in other analytics that require input data from the AF, policies in the PLMN and or the AF may prevent raw data to be exchanged directly between NWDAF and an external AF, as NWDAF is in the PLMN and the AF is outside the PLMN and the user data has high privacy protection needs.

Furthermore, NWDAF and AF may have different features of the same sample identity, which is a requirement of VFL. In such cases, VFL can be very helpful to break the data isolation and enable joint training between NWDAF and AF. However, regardless of the entities involved in VFL, the application of VFL among two entities requires alignment of samples and features to make sure the above VFL requirement is addressed.

Additionally, since the inference for VFL is also a distributed inference, no raw data will be shared in the inference as well as in the training. Each entity uses local data to do the inference. And the output will be gathered to get the final result.

The use case for observed service experience analytics is illustrated as follows. It provides the real user feedback to the network so that the network could self-optimize and offer customized services according to the true user needs. Due to the issue of data privacy, the AF(s) and NWDAF may not be able to exchange the data directly (The NWDAF may interact with several AFs, e.g. to provide Service Experience for a Network Slice). By leveraging VFL technology with the situation that the datasets of distributed nodes, NWDAF and AF can jointly participate to train an ML model for observed service experience. And they would do inference after the training respectively to generate the final result.

NWDAF and AF(s) would collect their local training data, respectively (e.g., access speed, network access delay for NWDAF, stall time, frame rate for AF). Note that data collection at the AF is out of the scope of this use case.

Two scenarios are identified in this case:

Scenario 1: NWDAF initiates VFL training process.

Scenario 2: AF initiates VFL training process.

This use case is also applicable for other analytics where AF and NWDAF can collaborate, e.g., DN Performance Analytics.

NOTE 1: This use case is applicable only if the AF is capable of participating in VFL procedure as a training entity. AF ML model training specification is out-of-scope.

NOTE2: When an AF initiates the VFL, then only one AF is involved. When the NWDAF initiates the VFL, then multiple AFs can be involved.

### 5.1.6 Use Case #6: Analytics-assisted prevention of abnormal NF behaviour causing signalling storm and mitigation of its impact in the network

The presented use case is to elaborate on how analytics can assist entities in 5GC e.g., NFs, OAM, etc., to prevent and mitigate the impact of abnormal behaviour i.e., signalling storm in the network.

The network may, based on the analytics, discover abnormal NF behavior, i.e., signalling storms, and begin an enforcement action that can contribute to prevention of signaling storm or mitigation the impact of it.

## 5.2 Key Issues

### 5.2.0 Mapping of Key Issues to Use Cases

Table 5.2.0-1: Mapping of Key Issues to Use Cases

|  |  |
| --- | --- |
| Key Issues | Use cases |
|  |  |
| 3 | 1, 2 |
| 4 | 3 |
|  |

### 5.2.1 Key Issue #1: Enhancements to LCS to support Direct AI/ML based Positioning

This key issue aims to provide solutions for whether and how to consider enhancements to support AI/ML based positioning for case 2b, 3b as defined in TR 38.843 [6], which will investigate the following aspects:

- Study whether and how an AI/ML model for direct AI/ML positioning (i.e. case 2b/3b) is handled:

- Which entity trains the model for direct AI/ML positioning and if the entity that train the model and the consumer are different, how the model consumer gets the trained AI/ML model;

- Which entity act as the model consumer that will use the trained model to perform inference and/or derive UE position;

- Define procedures for data collection with objective to train AI/ML models for direct AI/ML positioning.

- Whether and how to support direct AI/ML positioning at LMF with additional 5GC enhancements.

- How to monitor model performance for ML models used for direct AI/ML based positioning.

NOTE 1: UE data collection, model delivery and transfer to the UE and model identification/management are not within the scope of this key issue.

NOTE 2: Any data to be collected from UE/RAN by LMF for the model training/model inference/model performance monitoring for LMF-side model is assumed to be defined by RAN WGs.

NOTE 3: Any potential impacts for case 1/2a/3a in TR 38.843 [6], are out of the scope and any potential alignment work will be based on the possible requirements defined by RAN WGs considering the conclusions in TR 38.843 [6].

### 5.2.2 Key Issue #2: 5GC Support for Vertical Federated Learning

This key issue aims to provide solutions for enabling 5GC support for vertical federated learning (VFL) involving NWDAF and/or AF, where no raw data need to be exchanged but some level of coordination is still required when training and inference are performed on local models. In particular, datasets used for each local model need to share the same samples while holding different features.

In Rel-18, ML model sharing between NWDAFs has been studied as a part of Horizontal Federated Learning. However, federated learning between NWDAF and AF has not been studied (e.g. when the NWDAFs and/or AFs are in different domains, locations, regions etc).

Vertical Federated Learning (VFL) can be considered as an alternative mechanism for distributed functionalities of an ML model. Note that, as scoped in Rel-19, NWDAF and/or AF may be involved for VFL.

This Key Issue aims to study architecture enhancement to support VFL, which allows the cooperative AI/ML training and inference with the following aspects:

- Identify VFL use cases and under which conditions, and for which entities these VFL use cases show that VFL is justified to train ML models.

- Whether and how to support architecture enhancement for supporting VFL for model training and/or inference. In particular:

- Whether and how the existing NF discovery and selection needs to be enhanced.

- Whether and how ML Model training and/or inference related procedures need to be enhanced to support VFL.

- Whether and how to do performance monitoring for the ML model trained via VFL.

- Whether and how to provide ML Models to the participants in the VFL training process.

- How to support sample and feature alignment among the participating network entities when performing VFL.

NOTE 1: Application layer-based VFL requiring communication between AFs and/or UEs application client, is out of scope.

NOTE 2: During the study on this KI, consultation with SA WG3 is required for handling security aspects.

NOTE 3: RAN and UE aspects are out of scope.

NOTE 4: The existing procedures defined for Horizontal FL in TS 23.288 [5] will be taken into account when studying the procedure for VFL.

### 5.2.3 Key Issue #3: NWDAF-assisted policy control and QoS enhancement

The NWDAF can gather quite a lot of data from 5GC NFs, AF and OAM and thus may further assist the PCF in making PCC decisions (which traditionally determine QoS parameters based on its own data and knowledge as well optional statistics and predictions collected from the NWDAF).

This key issue aims to study whether and what is additionally needed to be supported in order to enhance 5GC NF operations related to policy control and QoS with the assistance of the NWDAF.

In this key issue, the following aspects will be studied:

- Identification of use cases where policy control and QoS can be further enhanced with assistance from NWDAF.

- Whether and how to introduce new 5GC functionality e.g. of the NWDAF and/or PCF to enhance the policy control and QoS, considering operator's policies.

- Whether and what additional input information is needed by the NWDAF for providing an assistance to policy control and QoS, and how to gather it.

- Whether and what output information, on top of already provided, the NWDAF can provide to assist with policy control and QoS enhancements.

- Whether and how to evaluate the quality of the enhanced NWDAF assistance to policy control and QoS.

NOTE 1: The study will focus primarily on existing enforcement mechanisms when available and identify new ones only when no existing ones can be used.

### 5.2.4 Key Issue #4: NWDAF enhancements to support network abnormal behaviours (i.e. signalling storm) mitigation and prevention

This key issue aims to provide solutions for prediction, detection, prevention, and mitigation of network abnormal behaviours, i.e. signalling storm, with the assistance of NWDAF. In particular, the following aspects will be addressed:

- Identify scenarios that can result in a signalling storm situation

- Whether and how existing analytics or new analytics can be used to assist detection and/or prediction of signalling storm, including aspects of input /output data that needs to be collected/provided by the NWDAF.

What NF(s) will be consumer of such analytics and whether and how they can use them.

- Whether and how signalling storm can be prevented and/or mitigated based on the inputs provided by NWDAF.

NOTE 1: In terms of data access right, privacy and security improvement, cooperation with SA WG3 is needed.

NOTE 2: The study of this key issue will consider the study/work done by SA WG5 and CT WG4 in this regard already and collaborate with SA WG5/CT WG4 regarding the handling of abnormal network behaviours.

# 6 Solutions

## 6.0 Mapping of Solutions to Key Issues

Table 6.0-1: Mapping of Solutions to Key Issues and Use Cases

|  |  |  |
| --- | --- | --- |
|  | Key Issues | Use cases (optional) |
| Solutions | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 5 | 6 |
| #1 | X |  |  |  |  |  |  |  |  |  |
| #2 | X |  |  |  |  |  |  |  |  |  |
| #3 | X |  |  |  |  |  |  |  |  |  |
| #4 | X |  |  |  |  |  |  |  |  |  |
| #5 | X |  |  |  |  |  |  |  |  |  |
| #6 | X |  |  |  |  |  |  |  |  |  |

## 6.1 Solution #1: Direct AI/ML based Positioning for case 2b/3b

### 6.1.1 Description

This solution is for Key Issue#1: Enhancements to LCS to support Direct AI/ML based Positioning.

For Direct AI/ML based Positioning in LMF side, it will be the LMF that provides the estimated UE location based on AI mechanism. In this solution, it is proposed that NWDAF containing AnLF is collocated with the LMF.

The ML model for inference in LMF can be retrieved from the NWDAF containing MTLF by reusing the existing procedure defined in TS 23.288[5].

To train the ML model for AI/ML based positioning requested by the LMF, the NWDAF containing MTLF will collect training data from data sources.

NOTE : The data for model training for AI/ML based positioning will be discussed and defined by RAN WGs and SA2 will align with RAN WGs.

### 6.1.2 Procedures

#### 6.1.2.1 Direct AI/ML based Positioning in LMF collocated with AnLF



Figure 6.1.2.1-1: Direct AI/ML based Positioning in LMF collocated with AnLF

0-2. UE may trigger 5GC-MO-LR Procedure, or LCS client may trigger 5GC-MT-LR Procedure as defined in TS 23.273[7], with the difference that the AMF may select an LMF supporting the capability of AI/ML based positioning.

Editor's note: Whether the AMF needs to select an LMF supporting the capability of AI/ML based positioning is FFS.

3. Based on LMF’s AI/ML based positioning related capability and measurement data reported from UE (case 2b) or RAN (case 3b), the LMF determines whether to use legacy UE positioning methods as defined in TS 23.273[7] or AI/ML based positioning method to derive UE location information. If decides to use AI/ML based positioning method, then the following steps 4-7 will be performed.

4. If the LMF decide to use AI/ML based positioning and there is no appropriate ML model for AI/ML based positioning available, then the LMF will retrieve an ML model for AI/ML based positioning from the NWDAF containing MTLF by invoking Nnwdaf\_MLModelProvision\_Subscribe as defined in TS 23.288[5].

5. The NWDAF containing MTLF sends the trained ML model information for AI/ML positioning to the LMF/AnLF by invoking Nnwdaf\_MLModelProvision\_Notify as defined in TS 23.288[5].

Editor's note: Whether the NWDAF containing MTLF trains the ML model before step 4 is FFS, and how to trigger corresponding data collection by the MTLF for ML model training is FFS.

Editor's note: The procedures for the LMF to do MTLF discovery and selection and model sharing are FFS.

6. Dependent on the different positioning methods (e.g. UE assisted or Network assisted positioning) as defined in clause 6.11, TS 23.273, the LMF will collect different measurement data from UE (case 2b) or RAN (case 3b) for model inference to obtain UE location.

7. The LMF performs model inference operation to derive UE location information based on the data collected from the UE (case 2b) or RAN (case 3b).

8-9. The LMF sends the estimated UE location information to UE or LCS client via AMF as defined in TS 23.273.

### 6.1.3 Impacts on services, entities and interfaces

LMF

- Determine to use AI/ML based positioning to obtain UE location, based on LMF’s AI/ML based positioning related capability and measurement data types reported from UE or RAN;

- Perform model inference to retrieve UE location based on the collected data.

NWDAF containing MTLF:

- Collect training data for AI/ML based positioning.

- Train ML model for AI/ML based positioning.

## 6.2 Solution #2: Support for AI/ML Direct Positioning Training, Inference and Data Collection with LMF-side models

### 6.2.1 Description

This solution addresses KI#1. The solution presents three different aspects regarding 5GC support for AI/ML Direct Positioning with LMF-side models, namely training, inference and data collection procedures. The solution addresses Case 2b and 3b as defined in TR 38.843 [6].

The main features of the solution are as follows:

- LMF requests training data from NWDAF.

- NWDAF or LMF may perform the AI/ML training.

- NWDAF may share a trained model with LMF.

- When a UE location is requested, LMF performs AI/ML inference on the trained model.

In addition, this solution allows LMF to be co-located with NWDAF containing MTLF/AnLF for model training/model inference.

### 6.2.2 Procedures

Clauses 6.2.2.1, 6.2.2.2 and 6.2.2.3 show step-by-step procedures for training, inference and data collection aspects of AI/ML Direct Positioning with LMF-side models, respectively.

NOTE: In all procedures of this solution, LMF may be a standalone NF or co-located with NWDAF containing MTLF/AnLF for model training/model inference (i.e. no interaction between the LMF with the co-located NWDAF needs to be defined).

#### 6.2.2.1 Training procedure for AI/ML Direct Positioning with LMF-side models



Figure 6.2.2.1-1: Training procedure for AI/ML Direct Positioning with LMF-side models

The training procedure for AI/ML Direct Positioning with LMF-side models in Figure 6.2.2.1-1 is described step by step below.

1. LMF subscribes to training data from NWDAF for an AI/ML model to be used for direct positioning. The training data subscription may be a request for analytics using the existing services, or a request for a model, or for other type of data relevant for training. Several optional parameters as defined in TS 23.288 [5] may be provided as service operation inputs.

NOTE 1: The training data subscription may be triggered by LMF receiving a previous request from another network entity. The trigger itself is not depicted in Figure 6.2.2.1-1 as it is not considered part of the training procedure itself.

Editor's note: Details of the training data subscription from LMF to NWDAF are FFS.

Editor's note: Whether and which analytics ID and what data may be requested by LMF to NWDAF for model training is FFS.

2. Data collection is performed to train the model(s) for direct positioning by the NF performing training. If the model is trained by LMF, LMF may use measurements already available at LMF or new measurements, and possibly additional data such as analytics, to train the model. If the model is trained by NWDAF, NWDAF may collect the necessary data from NFs to train the model.

NOTE 2: The data collected from UE and NG-RAN is in RAN WGs scope.

Editor's note: Whether, how and what data are collected for training from NFs by the LMF and by the NWDAF are FFS.

3. [CONDITIONAL] If the training data subscription from LMF in step 1 requires a model to be trained, NWDAF containing MTLF may train the AI/ML model.

4. NWDAF provides a training data notification to LMF. Depending on the request in step 1, the notification may contain the requested trained AI/ML model for direct positioning if step 3 is executed, or NWDAF may provide along the notification the requested analytics and/or data to the LMF for step 5 to be executed.

5. [CONDITIONAL] If the AI/ML model for positioning has not been trained and has not been provided in step 4, LMF trains the AI/ML model.

Editor's note: It is FFS whether LMF, NWDAF, or both train the model. If LMF trains the model, it is FFS why LMF may collect data from NWDAF

#### 6.2.2.2 Inference procedure for AI/ML Direct Positioning with LMF-side models



Figure 6.2.2.2-1: Inference procedure for AI/ML Direct Positioning with LMF-side models

This procedure assumes that a trained AI/ML model is available in LMF for Direct Positioning, i.e. the procedure in Figure 6.2.2.1-1 has already taken place. The inference procedure for AI/ML Direct Positioning with LMF-side models in Figure 6.2.2.2-1 is described step by step below.

1. Steps 1 to 11 in cl. 6.1.2 of TS 23.273 [7] are followed.

NOTE: In this solution, it is assumed that the location services consumer need not be aware that AI/ML direct positioning is used by the network to estimate the UE location.

2. AI/ML Direct Positioning preparations are performed to support Case 2b and Case 3b defined in TR 38.843 [6]. This step is out of SA2 scope.

3. Data collection is required to perform inference for AI/ML Direct Positioning and estimate the UE location according to Cases 2b and 3b.

Editor's note: Whether and how any data collection for inference from NFs is performed in the 5GC is FFS.

4. AI/ML Direct Positioning inference is performed at LMF.

5. Steps 13 to 24 in cl. 6.1.2 of TS 23.273 [7] are followed to deliver the estimated UE location to the consumer.

### 6.2.3 Impacts on services, entities and interfaces

NWDAF:

- Enhance support for model training services to enable AI/ML positioning training and inference at LMF.

LMF:

- Support for training/inference for AI/ML Direct Positioning and data collection.

## 6.3 Solution #3: Training of the AI/ML positioning model

### 6.3.1 Functional Description

A request of LMF-side model that outputs location of a specific UE is provided by the service consumer. After training of the ML model, the NWDAF provides the trained ML model to the service consumer (e.g. LMF) and the service consumer can perform inference afterwards.

Although the service consumer can obtain UE location from AMF/LCS, but the accuracy may not be enough. Therefore, an enhancement of the existing NWDAF is needed, to train the ML model with measurement data and provide a more accurate location estimate of an UE.

### 6.3.1.1 Input of model training

|  |  |  |
| --- | --- | --- |
| Information | Source | Description |
| Measurements | TBD |  |
| >Measurement data | The measurement data collected by LMF. |
| >Positioning method | The positioning method corresponding to the measurement data. |
|  >Time stamp | Time stamp of measurement data |
| Ground truth data |  TBD | The Ground truth data for the LMF-side model training |

Table 6.3.1.1-1: Data Collected for LMF-side model training.

The information may collect by the NWDAF for LMF-side model training is defined in Table 6.x.1.1-1.

Editor's note: It is FFS to determine what and how data to be collected for LMF-side model training. Coordination with RAN WG is needed.

Editor's note: The ground truth data for LMF-side model is ground truth UE location, and how to collect the ground truth UE location is FFS.

The trained LMF-side model shall be able to calculate UE location.

### 6.3.2 Procedures

The NWDAF can provide trained LMF-side model to consumer as follow:

NWDAF consumer

NWDAF

1. Nnwdaf\_ModelProvision\_subscribe

2. Data collection

3. Model training

4. Nnwdaf\_ModelProvision\_notify

5. Inference

If the consumer request a trained model in step 1, the NWDAF provides the trained model to the consumer with the training input data information to help the consumer perform inference.

1. NWDAF consumer(e.g. LMF) subscribe to NWDAF by using existing procedure to obtain LMF-side model.
2. The NWDAF collects training data specified in the Table 6.3.1.1-1.

Editor's note: It is FFS to determine the data collection procedure for model training.

1. The NWDAF performs model training base on the collected training data.
2. The NWDAF provides the trained model to the consumer with the training input data information to help the consumer perform inference.
3. The consumer can perform inference afterwards.

NOTE: Whether and how to trigger inference is not in the scope of this solution.

Editor's note: Whether the LMF is a standalone NF or co-located with AnLF for model inference is FFS.

### 6.3.3 Impacts on existing services, entities and interfaces

To implement the proposed solution, the NWDAF should support the proposed model training with input data(listed in table 6.3.1.1-1) collection capability. The trained model shall have the ability to calculate UE location. Besides, the NWDAF shall be able to provide the trained model to consumer.

## 6.4 Solution 4: Data Collection Framework for Direct AI/ML positioning

### 6.4.1 Description

Editor's note: This clause will describe the solution principles and architecture assumptions for corresponding key issue(s). Sub-clause(s) may be added to capture details.

The current LCS framework allows the LMF to collect positioning measurement related data from UE and the RAN via control plane by providing positioning related data in a container within RRC/NAS and N2 messages. In addition, the positioning measurement related data may be provided via a user plane connection between the UE and the LMF. If LMF decides to use user plane the LMF indicate to the UE to use user plane for positioning with the information to establish a secure connection. The current framework is shown in Figure 6.x.1-1.



Figure 6.4.1-1 - Current framework for data collection for positioning

The LMF currently obtains measurement data from UE/RAN node only when the LMF receives a request to identify a location of a specific UE (based on the service request sent by an AMF) which is originated from LCS client or UE. As such there is no triggering from model training entities (e.g. NWDAF containing MTLF) for measurement data collection and no framework currently defined to transfer data to model training entities (e.g. NWDAF containing MTLF) for model training. In addition, the LMF can only obtain measurement data from UE/RAN per UE granularity based on the per UE location estimate request from LCS client or UE, but the data collection for model training may be per area granularity for efficiency.

As such the following data collection framework is proposed to be supported as described in Figure 6.4.1-2 below:



**Figure 6.4.1-2 - Data Collection Framework for positioning measurement data**

The LMF is used to collect measurement related positioning data.

Editor's note: Whether the DCCF is involved is FFS.

The main steps of the data collection procedure are as follows:

- An LMF receives a request to collect measurement related data for positioning. The request may include requirements for collecting measurement data which can include:

- UE identifiers: One or more UEs to collect measurement data and the type of data required

- Area of interest including Cell ID(s) and/or may TAI(s) (collect measurement data only when UEs are served by RAN nodes with specific Cell ID(s) or by RAN nodes within target area).

- One or more Event IDs where each Event ID correspond to type of data to collect and report.

NOTE 1: What data need to be collected depends on RAN agreements.

NOTE 2: Considering the operator's policies on UE data collection and exposure, the LMF ensures that no sensitive measurement data are exposed to 3rd parties.

Editor's note: Whether UE identifiers are included are FFS.

- Further requirements regarding how the data should be collected, e.g., the resolution of the data, how often the data should be collected, criteria on sending the data, the location information at which the data was generated, whether the quality of the data is to be reported, timestamp associated to each of the data points/sets, which are to be collected.

- The LMF collects data from UE and/or from RAN.

Editor's note: It is FFS whether and what data needs to be collected and how to collect the data from UE/RAN by the LMF. Coordination with RAN WGs is needed.

- The LMF may store the data in ADRF.

- The LMF may transfer the collected data to model training enetities (e.g. NWDAF containing MTLF).

### 6.4.2 Procedures

Editor's note: This clause describes high-level procedures and information flows for the solution.

The procedure for configuring the UE and RAN node is as follows. For simplicity only the control plane procedure for reporting data is shown.



Figure 6.4.2-1 – Data collection via LMF

1. A consumer requires data to train an AI/ML model. The consumer may be an NWDAF containing MTLF.

Editor's note: Other consumers for collecting positioning measurement data are FFS

1. The consumer sends a request including an Event ID of the data needed to be collected, an area of interest (where data are to be collected) and target UEs (if data is to be collected by specific UEs)
2. The LMF considering the operator's policies on UE data collection and exposure, determines what data are needed to be collected from UE and or RAN.
3. The LMF discovers an AMF. The LMF may also identify which UEs served by an AMF.

Editor’s note: The potential impacts of the procedure on existing mechanisms of collecting data from UE/RAN by LMF is FFS.

Editor’s note: The interaction between the LMF and the consumer is FFS

5. LMF provides requested data to consumer

6. LMF may store data in ADRF

### 6.4.3 Impacts on services, entities and interfaces

Editor's note: This clause captures impacts on existing services, entities and interfaces.

- **LMF**: Needs to handle requests from consumer (e.g. NWDAF MTLF) to collect positioning related measurement data from RAN/UE

NOTE: There may be potential impacts on LPP and/or NRPPa for collecting data for AI based positioning, which needs to be coordinated with RAN WGs.

## 6.5 Solution #5: LMF selection to support the LMF-sided direct AI/ML positioning

### 6.5.1 Description

LMF selection functionality is supported by the AMF to determine an LMF for location estimation of the target UE. The LMF selection functionality is also supported by the LMF if it determines that it is unsuitable or unable to support location for the current UE based on the accurate requirement.

LMF reselection is a functionality supported by AMF when necessary, e.g. the current LMF has no capability to satisfied the location accurate requirement for the target UE. It is already mentioned by the TR 38.843 that using AI based positioning can improve the accuracy of the UE location in some scenario (e.g. NLOS case). Therefore, if the current LMF cannot generate the accurate UE location based on the legacy positioning method, the LMF reselection is needed to select a LMF that has the AI based positioning capability.

The LMF selection/reselection may be performed at the AMF or LMF based on the locally available information i.e. LMF profiles are configured locally at AMF or LMF, or by querying NRF.

The new factor may be considered during the LMF selection/reselection:

- LMF capabilities, including AI based positioning

- Accuracy of UE position generated by the LMF

Editor's note: Whether the AMF/LMF is involved in the selection of an LMF with AI capabilities is FFS.

Editor's note: Whether discovery information about an LMF with AI capabilities is stored in NRF is FFS.

In order to let AMF can authorize UE whether to use AI based positioning service. A new AI based positioning subscription data is introduced and stored in the UDM. When the AMF perform the LMF selection/reselection, it will retrieve the AI based positioning subscription data from the UDM and determine whether to select an LMF that need support the AI based positioning capability. The AI based positioning subscription data stored in the UDM is defined as following:

| Subscription data type | Field | Description |
| --- | --- | --- |
| AI Based Positioning Subscription data  | AI Based Positioning Service Authorization | Indicates whether the UE is authorized to use AI Based Positioning Service |

NOTE 1: How to support the LMF has the AI based positioning capability is not in the scope of this solution.

Editor's note: Whether the UE is aware of the LMF-side AI based positioning is used is FFS.

Editor's note: Whether the UE is needed to be authorized by the 5GC to use AI based positioning is FFS.

Editor's note: Whether any enhanced for the LMF selection is needed is FFS.

### 6.5.2 Procedures

The procedure will be built based on the procedures defined by the 3GPP TS 23.273 clause 5.1 for LMF discovery and selection with no flow modification.

### 6.5.3 Impacts on services, entities and interfaces

AMF: Enhanced to support the LMF discovery and selection/reselection based on the LMF AI based positioning capability.

LMF: Enhanced to support the AI based positioning capability.

UDM: Enhanced to store the AI based positioning subscription data to indicate whether the UE is authorized to use AI based positioning service.

## 6.6 Solution #6: LMF based ML model training and Inference

### 6.6.1 Description

This is a solution proposed for KI#1: Enhancements to LCS to support Direct AI/ML based Positioning.

In order to support the Direct AI/ML based positioning for case 2b, 3b, the LMF is required to be enhanced to support the AI/ML- based positioning. How LMF performs ML model training and inference, is based on implementation (out of scope of 3GPP).

LMF may collect data from UE, NG-RAN or NWDAF for model training and inference. LMF collects data from UE via either CP or UP solution with LPP protocol as described in TS 23.273 [7], LMF collects data from NG-RAN via NRPPa protocol as described in 23.273. LMF may also request NWDAF to expose some information that supported in TS 23.288 [5] to assist the AIML based positioning. How LMF uses the received parameters to perform ML model training and inference is based on implementation (out of scope of 3GPP).

Editor's note: Whether and which existing analytics or new analytics result is required to provide from NWDAF to LMF to support Direct AI/ML based Positioning in Rel-19 is FFS.

### 6.6.2 Procedures

This is the data collection procedure to support ML model training and inference for AI/ML based positioning in LMF.



Figure 6.6.2-1 Data collection for LMF based ML model training and inference

1. LMF requests from the UE to report the positioning measurement parameters as described in TS 23.273 [7]. UE reports positioning measurement parameters by using LPP protocol via either the CP or UP.
2. LMF requests NG-RAN to report the positioning measurement parameters as described in TS 23.273 [7]. NG-RAN reports positioning measurement parameters by using NRPPa protocol.
3. LMF requests NWDAF to expose the analytics result, for example, location Accuracy Analytics as described in clause 6.17 in TS 23.288 [5], UE mobility analytics in clause 6.7 in TS 23.288 [5].

Editor's note: Whether and which existing analytics or new analytics result is required to provide from NWDAF to LMF to support Direct AI/ML based Positioning in Rel-19 is FFS.

NOTE 1: There is no sequence of these 3 steps, LCS may trigger these steps in parallel.

NOTE 2: The collected measurement parameters from UE in step 1 and NG-RAN in step 2 is determined by RAN group. If there are new measurement parameters that provided by UE or NG-RAN in Rel-19 depends on RAN’s progress in Rel-19.

LMF will use the received parameters from UE, NG-RAN and NWDAF to perform ML model training or inference, and it will generate the target UE positioning as inference output. How LMF uses the received parameters to perform ML model training and inference is based on implementation (out of scope of 3GPP).

### 6.6.3 Impacts on services, entities and interfaces

NWDAF

Editor's note: Whether and which existing analytics or new analytics result is required to provide from NWDAF to LMF to support Direct AI/ML based Positioning in Rel-19 is FFS.

LMF

NOTE 3: The collected measurement parameters from UE in step 1 and NG-RAN in step 2 is determined by RAN group. If there are new measurement parameters that provided by UE or NG-RAN to LMF in Rel-19 depends on RAN’s progress in Rel-19.

## 6.X Solution #X: <Solution Title>

### 6.X.1 Description

Editor's note: This clause will describe the solution principles and architecture assumptions for corresponding key issue(s). Sub-clause(s) may be added to capture details.

### 6.X.2 Procedures

Editor's note: This clause describes high-level procedures and information flows for the solution.

### 6.X.3 Impacts on services, entities and interfaces

Editor's note: This clause captures impacts on existing services, entities and interfaces.

# 7 Overall Evaluation

Editor's note: This clause will provide a general evaluation and comparison of the solutions per Key Issue #<X>.

# 8 Conclusions

Editor's note: This clause will capture conclusions for the study.

Annex <X> (informative):
Change history

|  |
| --- |
| **Change history** |
| **Date** | **Meeting** | **TDoc** | **CR** | **Rev** | **Cat** | **Subject/Comment** | **New version** |
| 2024-01 | SA2#160AH-e | S2-2401826 | - | - | - | Proposed skeleton agreed for FS\_AIML\_CN at SA2#160AH-e | 0.0.0 |
| 2024-01 | SA2#160AH-e | - | - | - | - | Implementing following approved papers: S2-2401827, S2-2401828, S2-2401829, S2-2401830, S2-2401831, S2-2401832, S2-2401833, S2-2401834, S2-2401835. | 0.1.0 |
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