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| 3GPP TR 23.700-71 V0.2.0 (2022-04) |

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| Technical Report | |
| 3rd Generation Partnership Project;  Technical Specification Group Services and System Aspects;  Study on enhancement to the 5GC LoCation Services (LCS);  Phase 3;  (Release 18) | |
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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

The scope of this Technical Report is to study further enhancements to the to the 5GC LoCation Services including the following aspects:

- Investigate potential architectural enhancements to location service (e.g. in scenarios like edge computing, and other), i.e. support Positioning Signalling via user plane.

- Investigate potential architectural enhancements to location service (e.g. in scenarios like edge computing, and other), i.e. reduction of location service latency, signalling overhead and location estimate exposure.

- Study how the location services can benefit from NWDAF reporting and how the NWDAF use cases can benefit from location services, e.g. enhanced accuracy in certain UE location or population flow statistics data that require UE locations smaller than TA/cell

- Study enhancements to support low power positioning (e.g. for RedCap) including the requirements related to low power high accuracy positioning described in TS 22.104 [7].

- Study necessary enhancement to support regulatory requirement i.e. the network should not notify the UE by any means during the LCS session.

- Study enhancement to support the Flexible and Efficient Periodic and Triggered Location for UE power saving purpose.

- In collaboration with RAN, study specific network functionality related to use of Positioning Reference Units (PRUs) as defined by RAN WGs and study how 5GS to support a specific UE (i.e. Reference UE) to improve the accuracy of positioning, and reduce the signalling:

- Study enhancements to support the location service continuity for UE mobility, i.e. between EPS and 5GS;

- For 5G with satellite access, in collaboration with RAN, study LCS architectural enhancement to support network verified UE location, and to meet location services related requirements defined in TS 22.261 [8].

# 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 23.271: "Functional stage 2 description of Location Services (LCS)".

[5] 3GPP TS 23.273: " 5G System (5GS) Location Services (LCS); Stage 2".

[6] 3GPP TS 38.305: " Stage 2 functional specification of User Equipment (UE) positioning in NG-RAN".

[7] 3GPP TS 22.104: "Service requirements for cyber-physical control applications in vertical domains".

[8] 3GPP TS 22.261: "Service requirements for the 5G system".

[9] 3GPP TS 23.288: "Architecture enhancements for 5G System (5GS) to support network data analytics services".

[10] 3GPP TS 23.548: "5G System Enhancements for Edge Computing; Stage 2".

[11] S3i210282: "LS OUT on UE location aspects in NTN" https://www.3gpp.org/ftp/TSG\_SA/WG3\_Security/TSGS3\_LI/2021\_81e-a/Docs/s3i210282.zip.

[12] RP-213690: "New WI: NR NTN (Non-Terrestrial Networks) enhancements" .

[13] OMA-AD-SUPL-V2\_0: "Secure User Plane Location Architecture Approved Version 2.0".

[14] OMA-TS-ULP-V2\_0\_6: "User Plane Location Protocol Approved Version 2.0.6".

[15] 3GPP TS 37.355: “LTE Positioning Protocol (LPP)”

# 3 Definitions of terms, symbols 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].

Definition format (Normal)

**<defined term>:** <definition>.

**example:** text used to clarify abstract rules by applying them literally.

## 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].

Abbreviation format (EW)

<ABBREVIATION> <Expansion>

LMF Location Management Function

LPP LTE Positioning Protocol

LPPe LPP extension

LCS LoCation Service

# 4 Architectural Assumptions and Requirements

## 4.1 Architecture assumptions

Editor's note: This clause will document the general architecture assumptions for the study.

The existing 5G LCS architecture is the bases for further enhancement work, with following add on assumption:

- Positioning methods may be Access Network specific, although commonalties should be encouraged between Access Networks.

## 4.2 Architecture requirements

Editor's note: This clause will document the agreed principles for the study.

The following requirements are applicable to further enhance the existing 5GC LCS architecture defined in TS 23.273 [5]:

- The further enhancement to the 5GC LCS architecture should incorporate flexible modular components with open interfaces that facilitate equipment interoperability and the architectural requirements based on evolution of service providing capabilities

- The further enhancement to the 5GC LCS architecture should be future proof.

# 5 Key Issues

## 5.1 Key Issue #1:Architectural Enhancement to support User Plane positioning

### 5.1.1 Introduction

The key target of this KI is to identify the LCS features and enhancements required to support user plane positioning.

Positioning Signalling via user plane has several benefits, such as:

- It has a more efficient communication overload with a direct connection from LCS server to UE.

- It may not require gNodeB, AMF, LMF signalling processing of RRC, NG-AP and HTTP/2 protocol stacks. A single session may handle all the transactions.

- It can have multiple choices depending on UE support. For example, both 3GPP LPP and OMA LPPe can be possible in positioning methods' choices.

To deploy user plane positioning, it involves the following considerations:

- Different use cases like emergency/non-emergency, other regulatory cases like lawful interception and MO-LR cases, etc.

- Different deployment options including centrally deployed or local deployment ,i.e, deployed the edge data network.

- Whether the solution is end to end or restricted to only certain entities (e.g. UE and LMF, LMF and LCS Client).

For user plane positioning deployment, two options are identified, although other options are also possible:

Option 1: User plane positioning functionality (e.g. LMF) in the central network.

Option 2: The user plane positioning functionality can be deployed "in scenarios like edge computing" of the edge data network to provide positioning in the edge and fits into the architecture in TS 23.548 [10].

This KI is to address architectural changes allowing user plane positioning deployment, including central deployment or deployment at the edge e.g.:

- Discovery of user plane capability and configuration and selection of PDU Sessions (if needed) to be used for the communication between UE and user plane positioning.

- Whether and how to enhance existing 5GS LCS architecture or related procedures to support MO-LR, MT-LR, Deferred MT-LR and regulatory-related positioning procedures when user plane positioning is involved.

- Interaction with legacy LCS call flows and security aspect

- Requirements on transport protocol e.g., if reliable transport and in sequence delivery is required.

- Interaction (if any) between user plane and existing control plane solution.

- User plane as a possible enhancement to control plane.

## 5.2 Key Issue #2: enhanced positioning architecture for NPN deployment

### 5.2.1 Description

For NPN network deployments, the following technical issues will be studied:

- How to realize low latency positioning procedure under NPN deployment.

- How to realize low complexity positioning procedure under NPN deployment.

- How to achieve reliable and secure location result delivery and exposure, e.g. UE location not exposed to the public network.

## 5.3 Key Issue #3: Local Area Restriction for an LMF and GMLC

### 5.3.1 Description

In some scenarios, an GMLC and an LMF might be restricted to supporting location services in a local area, i.e. the LMF needs to be selected within the same local area of the GMLC. The objective of this KI is to investigate how to support the local area restriction for GMLC and LMF.

NOTE: This KI is not applicable to an NPN.

## 5.4 Key Issue #4: Interaction between Location Service and NWDAF

### 5.4.1 Description

NWDAF can generate different analytics data, e.g. UE mobility analytics, WLAN performance analytics. 5GC NF (e.g. AMF, PCF) can request analytics data from NWDAF for decision making. But whether and how location service can be benefit from NWDAF is not studied yet. For example, whether the existing analytics generated by NWDAF (e.g. WLAN performance analytics) can be used to improve the location service performance, e.g. to assist the LMF to select the positioning method or decide more accurate assistance data?

Furthermore, based on Table 6.7.2.2.1 and Table 6.7.2.3.1 of TS 23.288 [9], the UE location collected and included in the analytics data by the NWDAF is TA or cell. But in some use cases, analytics in granularity of TA or cell level is not sufficient. Considering location service can provide more accurate UE location information, it is needed to study how does the location service provides such information to NWDAF.

To support the aspects above, this key issue will study:

- How to provide the NWDAF with location information with finer granularity than TA/cell level, e.g. which NF in the location architecture supports the interface to the NWDAF, whether existing location procedures can be re-used or not;

- Whether the privacy check can be skipped or not when the NWDAF requests location information via LCS services, if not, how to perform the privacy check in LCS;

- Whether existing data analytics generated by the NWDAF can be used to improve location service performance and how, e.g. assist the LMF to select the positioning method, decide more accurate assistance data, reduce signalling cost and delay etc.;

- Identify use cases where new or existing data analytics from the NWDAF can be used for improving location service performance. Regulatory requirements (e.g. different location accuracy requirements from FCC in different cases) will be taken into account.

NOTE: Coordinated activities between the study FS\_eNA\_Ph3 and this study are needed. Any new data analytics agreed as part of this Key Issue that need to be provided by NWDAF need to be studied and agreed in FS\_eNA\_Ph3.

## 5.5 Key Issue #5: Assistance data provisioning for low power high accuracy GNSS positioning

### 5.5.1 Description

The GNSS assistance data could help reduce UE GNSS receivers' power consumption and increase the position accuracy. Nowadays, UE usually gets the assistance data from internet through user-plane. However, using a user plane based way means that UE must active a PDU Session, which leads to higher power consummation. Moreover, it may not apply to Redcap UEs, as some of them may not support to establish a PDU Session.

The distance between the UE GNSS receivers and GNSS reference receiver should be sufficiently short to make sure the GNSS assist data provided by the reference receiver are valid and accurate. However, GNSS reference receivers are not widely implemented in some countries, which makes it hard to provide high accuracy GNSS positioning service for UE GNSS receivers in some areas.

This key issue aims at studying the possible method to get nearby GNSS assistance data inside 3GPP, to mitigate a lack of implementation of GNSS reference receivers.

The following aspects will be studied:

- How could the core network (i.e. LMF) get the nearby GNSS assistance data from 3GPP domain to mitigate a lack of implementation of GNSS reference receivers to help reduce power consumption and increase the positioning accuracy?

- Whether and how existing procedures, protocols or interfaces can be re-used or enhanced to make UE get the nearby GNSS assistance data?

## 5.6 Key Issue #6: UE Positioning without UE/User Awareness

### 5.6.1 Description

There are regulatory cases (e.g. helping with police enquires), in that UE should not be notified by any means during the LCS session. But how to support the requirement has not been considered.

For some IoT or RedCap devices, when power saving is more important than fulfilling the LCS request, how to obtain UE location without notifying the UE especially when UE is in CM-IDLE or RRC\_INACTIVE state is also not considered.

To support the requirements above, this key issue will study:

- Which NF and how to decide not to notify UE/User during the LCS session, e.g. what information is considered to make the decision;

- Functionality and procedure enhancements to guarantee not to notify UE/User during the LCS session when UE is in CM\_CONNECTED, CM\_IDLE or RRC\_INACTIVE state;

- What UE location information is provided to LCS Client/ AF to fulfil the LCS QoS when the UE is in CM\_IDLE or RRC\_INACTIVE state and if the UE is not notified during the LCS procedure.

## 5.7 Key Issue #7: support of Positioning Reference Units and Reference UEs

### 5.7.1 Description

Based on RAN WG conclusion in Rel-17, positioning reference units (PRUs) with known locations can enhance the positioning performance. PRUs may be used to assist positioning of UEs by e.g. providing measurement information related to RAN nodes. This key issue aims to study the system level impact to support PRUs.

The accuracy of positioning heavily relies on the number of Line of Sight (LoS) paths, so positioning in the indoor environment is complex, as there are many factors that reduce the possibility of LoS path. It is resource consuming and complicated to deploy sufficient RAN nodes (e.g. pRRUs or gNBs) to provide enough LoS path, considering the complex environment with possible changes. Consequently, a simplified node, referred to as a Reference UE, is required to provide more potential LoS paths for positioning.

The following aspects will be studied for PRUs:

- What information of the PRUs needs to be obtained by 5GC and how can the 5GC become aware which PRU(s) are available.

- How can 5GC determine and enable particular (e.g. candidate) PRU(s) from the available PRU(s).

- How are the location service procedures performed to improve positioning accuracy using PRU(s). This can include using PRUs to assist positioning of one UE or using PRUs to assist positioning of many or all UEs.

The following aspects will be studied for Reference UEs:

- Whether and how the 5GS can assist with the selection of Reference UE supporting the 5G location services provided to a different UE.

- The specific entities and mechanisms in the 5GC whose functionality need to be updated to account for the Reference UE operation as part of the location service.

NOTE 1: Coordination with RAN WG may be required.

NOTE 2: Whether PRU and Reference UE can be the same entity should be determined during normative phase.

## 5.8 Key Issue #8: support of location service continuity in case of UE mobility

### 5.8.1 Description

For commercial location service, in particular the use case on vehicle(V2X) UE, it is very likely that UE moves between EPS and 5GS, and continuous UE positioning (periodical location service/LDR) is required.

Following UE mobility scenarios are considered under this key issue:

- UE mobility between EPS and 5GS (bi-direction).

- UE mobility between NG-RAN node.

The following "Types of Location Request" should be considered in the scope of WT#6:

- Mobile Terminated Location Request, and in detail covers:

- Immediate Location Request (Response Time "no delay" and "low delay" are excluded)

- Deferred Location Request (both periodic location service, and event based location request)

- Mobile Originated Location Request

The following issues will be studied:

- How to handle the UE location service context in case of UE mobility (e.g. context in the AMF, MME, LMF, E-SMLC).

- Configuration update of the positioning information/configuration on the source and target RAN nodes in case of UE mobility.

- How to enhance the cancellation of the existing positioning procedure in case of UE mobility.

## 5.9 Key Issue #9: Support of Positioning Requirements Related to Satellite Access

### 5.9.1 Description

In Rel-17, the 5GS system has been enhanced to support the service requirements of 5GC with satellite access (in the WID: Architecture aspects for using satellite access in 5G).

In R-17, when a UE is using NR satellite access, in order to ensure to meet the regulatory requirements, the network will verify whether the PLMN selected by the UE is allowed to operate in the country of the UE location based on the UE location information.

Besides, the broadcast TAI(s) and the TAI where the UE is geographically located, if known, will be provided as part of ULI by NG-RAN to the AMF. Using UE-generated location information (e.g. GNSS/A-GNSS) to determine the TAI where the UE is geographically located can be accurate but may be unreliable as has been evaluated by SA WG3.

When UE access 5G via satellite access, some services with regulatory requirements, e.g. emergency calls service and lawful interception, require a trusted/reliable methods to determine with sufficient accuracy the UE location. Any method which relies solely on UE-generated location information may not be reliable unless the information provided by the UE can be verified by the network. But how does the network verify the UE location has not been considered, so this key issue will study:

- What kind of location information can represent the UE location that meets required accuracy in NR satellite access (e.g. doing verification based on the location information to meet regulatory requirements)?

- In collaboration with RAN, for the reliability of the location verification by the network for regulated services (LI, emergency) and given SA WG3-LI requirements defined in S3i210282 [11], further study how the 5GC LCS can ensure that network verification of UE location is performed with reliable method, that does not rely solely on UE-generated location information, and the result of such network verification of UE location meets aforementioned requirements;

- In collaboration with RAN on their work on network verified UE location, study whether existing core network verification mechanisms needs enhancement and conditions (which NF, when, how, etc.);

- How to further enhance the LCS to verify location services related requirements defined in TS 22.261 [8];

NOTE: The work of this key issue needs collaboration with RAN. Considering SA WG2 Rel-18 work begins earlier than RAN and RAN will make decision related to the work by RAN#98 as indicated in NR\_NTN\_enh WID in RP-213690 [12], thus SA WG2 can start discussing solutions first and make conclusion in collaboration with RAN.

## 5.10 Key Issue #10: Support of Reduced Latency

### 5.10.1 Description

Reduction of latency is useful for many user cases and needs to be end-to-end. For example, very low latency for positioning that may be supported by procedures defined by RAN1 and RAN2 would be nullified by extra time in establishing a positioning session with a target UE or in returning a location estimate to an LCS Client or AF.

The following aspects will be studied:

- Reducing end to end latency for an immediate location request (5GC-MT-LR, 5GC-MO-LR)

- Reducing end to end latency for a deferred location request (periodic or triggered 5GC-MT-LR)

NOTE: Reducing latency should focus on aspects related to signalling and procedures involving the 5GCN and not on aspects completely within NG-RAN which are under RAN control.

## 5.11 Key Issue #11: Enhance the Triggered Location for UE power saving purpose

### 5.11.1 Description

Some use cases only need the UE location to be tracked when the UE is within a set of pre-defined areas, e.g. when UE is within one big city or a campus. For power saving purpose, it is beneficial to only allow UE location tracking when the UE enters one such area.

This Key Issue will study:

- How to provide location service only when the UE is within a pre-defined area, including border district and central district in this area;

- How to define and identify the pre-defined areas, and:

- Which entity provide such pre-defined areas to the LCS system and how?

## 5.12 Key Issue #12: support of low power and/or high accuracy positioning

### 5.12.1 Description

SA1 considers low power high accuracy positioning is an integral part of a considerable number of industrial applications. The total energy needed for a specific operation time for such a low power high accuracy positioning optimized IoT-device is a combination of energy for positioning (varies depending on the used positioning method), energy for communication/synchronization and a difficult to predict factor to take additional losses through e.g. security, power management, microcontroller, and self-discharge of batteries into account.

Low power and/or high accuracy positioning may need specific handing in the system level, depending on the localization requirements of an LCS Client or AF.

Reduction of power consumption can be useful for IIoT and CIoT UEs and is generally preferable for any UE to improve battery lifetime. Reduction of power consumption may or may not be associated with high accuracy.

Following issues are proposed for study:

- How to identify localization QoS for low power and/or high accuracy positioning;

- Whether new information is needed in subscription data for low power and/or high accuracy positioning;

- Whether LCS QoS should be enhanced to support LPHAP;

- How to handle UE connection management/mobility management, for power saving purpose, when supporting low power and/or high accuracy positioning;

- Positioning procedure optimization:

- Reducing UE power consumption for an immediate location request (5GC-MT-LR, 5GC-MO-LR)

- Reducing UE power consumption for a deferred location request (periodic or triggered 5GC-MT-LR)

- Reducing UE power consumption in association with high accuracy positioning

# 6 Solutions

Editor's note: This clause is intended to document the agreed architecture solutions and a mapping of solutions to key issue(s) in clause 6.0. Each solution should clearly describe which of the key issues it covers and how.

## 6.0 Mapping Solutions to Key Issues

Editor's note: This clause describes the mapping between solutions and key issues.

Table 6.0-1: Mapping Solutions to Key Issues

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Key Issues | | | | | | | | | | | | | | |
| Solutions | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |  |  |  |
| 1 | X |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 2 | X |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 3 | X |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 4 |  | X |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 5 |  | X |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 6 |  |  | X |  |  |  |  |  |  |  |  |  |  |  |  |
| 7 |  |  | X |  |  |  |  |  |  |  |  |  |  |  |  |
| 8 |  |  | X |  |  |  |  |  |  |  |  |  |  |  |  |
| 9 |  |  | X |  |  |  |  |  |  |  |  |  |  |  |  |
| 10 |  |  |  | X |  |  |  |  |  |  |  |  |  |  |  |
| 11 |  |  |  | X |  |  |  |  |  |  |  |  |  |  |  |
| 12 |  |  |  | X |  |  |  |  |  |  |  |  |  |  |  |
| 13 |  |  |  | X |  |  |  |  |  |  |  |  |  |  |  |
| 14 |  |  |  |  |  | X |  |  |  |  |  |  |  |  |  |
| 15 |  |  |  |  |  |  | X |  |  |  |  |  |  |  |  |
| 16 |  |  |  |  |  |  | X |  |  |  |  |  |  |  |  |
| 17 |  |  |  |  |  |  | X |  |  |  |  |  |  |  |  |
| 18 |  |  |  | X |  |  |  |  | X |  |  |  |  |  |  |

## 6.1 Solution #1: Positioning protocol transport over User Plane

### 6.1.1 Introduction

This solution addresses Key Issue #1 on Architectural Enhancement to support User Plane positioning.

### 6.1.2 Functional Description

The AMF, UE and LMF are enhanced to initiate setup of a User Plane connection between a selected LMF and UE and to provide LMF and UE with needed information to establish a secure connection. The information includes e.g. IP address of LMF, S-NSSAI, identity of the DNN to be used for the connection, temporary UE identifier (not the same as used N2 or other reference points), and security credentials. The AMF, UE and LMF are enhanced to transport LPP over a UP protocol. Once the LCS-UP connection is established the LMF selects either to use the LCS-UP procedure per 6.1.3.3 or to use CP procedure per TS 23.273 [5] clause 6.11.1. Within one LPP session the same transport shall be used.

Editor's note: It is FFS what security mechanism is used and it is subject to SA3’s conclusion.

### 6.1.3 Procedures

### 6.1.3.1 Establish LCS-UP connection between UE and LMF

The flow below shows how a secure LCS-UP connection between UE and LMF is established.



Figure 6.1.3.1-1: Connection establishment between UE and LMF

1. At applicable Registration events and when an LCS procedure is initiated, AMF may decide to select an LMF and request the UE and the selected LMF to establish an LCS-UP connection to be used for transfer of LPP signalling. The decision may be based on e.g., UE capabilities, UE location, subscription information and LMF capabilities.

2. The AMF sends a Nlmf\_Location\_UPConfig Request towards the LMF to request set up of a LCS-UP connection. The message may include e.g. S-NSSAI and a temporary UE identifier.

3. The LMF sends a LCS UP Info message to the UE via the serving AMF by invoking the Namf\_Communication\_N1N2MessageTransfer service operation. The LCS UP Info message may include e.g. IP address of LMF, S-NSSAI, DNN identity, temporary UE identifier and security credentials.

4. The AMF forwards the LCS UP Info in a DL NAS TRANSPORT message.

5. The UE and LMF establish a secure connection.

6. The LMF sends Nlmf\_Location\_UPConfig Response message to AMF to inform of outcome of connection setup.

7. The AMF stores the LCS-UP connection context as part of UE context.

After establishing the connection, UE and LMF may maintain the connection for later message transfer via user plane.

### 6.1.3.2 Modify LCS-UP connection between UE and LMF

The flow below shows how a secure LCS-UP connection between UE and LMF is modified. Flow describes change of LMF but applies also when source and target LMF is the same. The procedure can also be used to terminate LCS-UP connection to Source LMF by AMF not selecting any Target LMF.



Figure 6.1.3.2-1: Connection modification between UE and LMFs

1a. [Conditional] The LMF discovers a need to change LMF or re-establish LCS-UP connection. The LMF sends an Nlmf\_Location\_UPNotify message that includes UP Info that indicates the reason for modification. The address of the AMF was provided to LMF as a “Notification Target Address” in latest Nlmf\_Location\_UPConfig message.

1b. [Conditional] At applicable Registration events and when an LCS procedure is initiated, AMF may detect a need to reselect LMF used for LCS-UP signalling. The detection may be based on e.g., UE capabilities, UE location, subscription information and LMF capabilities. Further at AMF relocation the target AMF needs to inform the LMF using LCS-UP signalling of the AMF change.

2. [Conditional] If AMF reallocation has occurred this step is skipped. Otherwise, step 2 to 7 of 6.1.3.1 is performed between AMF, UE, and Target LMF with addition that UE also terminate connection to Source LMF.

3. The AMF sends a Nlmf\_Location\_UPConfig Request towards the source LMF. The message may include a request for the Source LMF to terminate a specific LCS-UP connection to the UE if connection is still active. Alternatively, it may include information about AMF reallocation.

4. [Conditional] If the LCS-UP connection to source LMF is still active source LMF terminates the connection to the UE.

5. The LMF sends Nlmf\_Location\_UPConfig Response message to AMF to confirm connection termination or acknowledge change of AMF.

### 6.1.3.3 UE Assisted and UE Based Positioning Procedure over LCS-UP

The flow below shows a positioning procedure used by an LMF to support UE based positioning, UE assisted positioning and delivery of assistance data. The procedure is based on use of the LPP protocol defined in TS 37.355 [20] between the LMF and UE.



Figure 6.1.3.3 -1: UE Assisted and UE Based Positioning Procedure over LCS-UP

1. The LMF use the LCS-UP connection to transfer of a Downlink (DL) UP TRANSFER message to the UE. The message includes a LPP message. The LPP message may request location information from the UE, provide assistance data to the UE or query for the UE capabilities.

2. The UE stores any assistance data provided in the Downlink Positioning message and performs any positioning measurements and/or location computation requested by the Downlink Positioning message.

3. [Conditional] The UE use the LCS-UP connection to transfer of a Uplink (UL) UP TRANSFER message carrying includes a LPP message to the LMF to return any location information or returns any capabilities.

### 6.1.4 Impacts on services, entities, and interfaces

Editor's note: This clause lists impacts to services, entities, and interfaces.

The solution impacts the following network functions:

- AMF that need to support triggering of LCS-UP connection setup, modification & termination.

- LMF that need to support procedure to setup, modification & termination of LCS-UP connection. Transfer of LPP messages over LCS-UP.

- UE that need to support: Procedure to setup, modification & termination of LCS-UP connection. Transfer of LPP messages over LCS-UP.

- UDM that need to add info in Subscriber info if LCS-UP transport is supported.

- NRF that need to add info in NF profile LMF support LCS-UP transport.

## 6.2 Solution #2: Discovery of User Plane service Cooperated with 3GPP LCS Features

## 6.2.1 Introduction

This solution addresses the KI “Key Issue #1:Architectural Enhancement to support User Plane positioning”.

## 6.2.2 Functional Description

As described in clause 5, User Plane positioning gives benefits including a simpler protocol stack, less overload, better performance, extra LPPe support, etc. When there is overloaded LCS signaling over N1 and/or NL1 interfaces, like massive emergency cases, LMF can offload the traffic to the user plane to enhance capacity.

LMF can perform legacy 3GPP LCS features independently. User Plane features can also be used independently with OMA User Plane specifications.

With many features defined by OMA, since UE can’t take uplink measurements, to fulfill positioning methods like RTT, the User Plane has to cooperate with Control Plane LMF to collect both uplink and downlink measurements.

User Plane cooperated with the 3GPP LCS control plane can be named ‘LCUP’ (LCs User Plane).



**Figure 6.2.2.1 LMF and LCUP can be deployed independently and can cooperate with each other**

Independent LMF handles requests as per legacy 3GPP LCS specifications.

For independent User Plane entity, it could perform end to end location service (possibly following legacy OMA specifications) without 5GC impact:



Details of independent user plane function is out of this solution scope.

In this solution, only user plane invoked by LMF to enhance the 3GPP 5G LCS procedures is referred as ‘LCUP’. This solution makes it compatible that LCUP could also act as independent user plane while cooperating with LMF.For LCUP cooperated with LMF, it can achieve the following benefits:

1. Both uplink and downlink measurements can be collected
2. User Plane and Control Plane can have feature reusability, e.g. sharing the same algorithm calculation.

NOTE: detailed cooperation interface between LMF and LCUP is out of the solution scope and could be implementation specific.

To keep legacy LCS procedures’ compatibility, for the cooperated LMF and LCUP instances, LMF should still perform the entry point and response route for 5GS LCS procedures, including MO-LR, MT-LR, Deferred MT-LR and regulatory-related positioning when user plane positioning is involved.

Since there could be multiple LMF and LCUP instances, when LCUP cooperated with LMF, UE needs to discover the correct instance of LCUP. With 3GPP LCS MT-LR/NI-LR/MO-LR procedures, when AMF has selected an LMF instance - LMFi to serve an LCS request about a UE, when the UE establishes user plane interaction with an LCUP, the UE should perform user plane session with an LCUPi cooperated with LMFi. This means UE should discover the LCUP instance working with the serving LMF instance.

For the cooperated case, LMF can perform the offload operation to switch the LPP traffic to User Plane.

LMF can provide information to UE, and allows the UE to establish a UP connection to a proper LCUP through the following means:

1. LMF can send SUPL INIT to UE through OME-defined push mechanisms and activate the UP session with its cooperated LCUP.
2. Since different push mechanisms are hard to choose for different devices and different use cases (emergency with UDP push, IMS with SIP push, etc), for LPP offload in Rel.18, it is straightforward that the LCUP related information be delivered over LPP itself. LMF can treat cooperated LCUP information and contents in SUPL INIT as part of assistance data in LPP provide assistance message.
   1. The provide assistance data message can be unsolicited or in response to a request assistance message from UE
   2. The LPP offload instruction in the LCUP assistance can be imperative or instructive. Imperative means UE can choose to offload the traffic or receive failure; instructive means UE would better to offload the traffic but may still be served by LMF over control plane.
3. For cases that UE supports User Plane but doesn’t support LPP, LMF can also provide LCUP information to AMF using Namf\_Communication\_N1N2MessageTransfer and AMF forward it to UE with DL NAS TRANSPORT.

Besides the contents in SUPL INIT, LCUP assistance data can also include:

1. The pre-provisioned or unique FQDN of the LCUP cooperating with serving LMF
2. Security attributes of LCUP for TLS connection establishment

Meanwhile, LCUP service should only be provided to capable UEs. UE capability of User Plane can be exposed in a similar way as its legacy 3GPP LCS capability:

1. The capabilities of a target UE to support user plane may be signaled by the UE to a serving PLMN or to an SNPN at the AS, NAS during registration of the UE.
2. Some of these positioning capabilities may be transferred subsequently to an LMF with enhanced LPP signaling.

Such capability information could be transferred to LMF from:

1. AMF in the DetermineLocation Request enhancement when UE provides the UP capability during registration.
2. LPP message to LMF in capabilities exchange

As per [13][14], UE could use pre-configured FQDN and/or runtime parameter(s) received in SUPL INIT or LPP assistance to discover the LCUP.

Since UE uses FQDN to discover the User Plane server, URSP, EASDF rules and different FQDN resolution can be used to locate the LCUP:

1. As one of the options, each LCUP instance cooperated with the LMF can be assigned to a unique FQDN. LMF can provide the corresponding FQDN as part of the assistance data to the UE. UE can also retry the user plane in case of an overloaded error reply of the control plane request.
2. For UEs which can only use provisioned (H-SLP) FQDN and related trusted certificate settings, before the traffic offload, the serving LMF can act as a DNS server and respond to the DNS query to reply the cooperated LCUP.
   1. If LCUP is bounded to certain area like in localized LCS, LMF can use the same serving cell identity to choose the LCUP as its cooperated instance.
   2. For the more specific cases that LMF is pre-configured with LCUP instance, after LMF offload instruction to UE. UE performs the LCUP DNS query. EASDF rules can attach UE IP in the ECS (EDNS Client Subnet) and forward the provisioned FQDN’s DNS query to all related LMF instances. Through BSF or co-location with GMLC/LRF/RDF to fetch SIP header in emergency IMS case, LMF could maintain its serving UE IP list to decide the DNS query result. Only when UE IP in ECS exists in the serving UE IP list, the LMF would reply with its cooperated LCUP IP. Then UE can use the LCUP assistance delivered from serving LMF to establish User Plane session with the cooperated LCUP instance.

In conclusion, the solution to the cooperation of LMF and LCUP can be summarized as follows:

1. LMF performs the entry point and response route of LCS procedures
2. OAM provisions LMF with the assistance information (including FQDN, etc.) of its cooperated LCUP instance(s).
3. LMF provides LCUP assistance to UE either through OMA defined push mechanism or LPP assistance delivery
4. With knowledge of LCUP service, URSP configured in the UE may indicate which PDU session is used to establish the connection with LCUP.
5. With Edge DNS Client (EDC) functionality in the UE, EASDF rules has the flexibility to match the DNS query to correct LCUP provisioned to the cooperated LMF instance.
   1. When each cooperated LCUP can have its unique FQDN so that UE can have direct access, it could be pre-configured in LMF for all its LCUP assistance delivery.
   2. When applying DNS query feature to LMF, when triggered by MT/MO/NI procedures, after offload instruction, serving LMF can reply the DNS query with its cooperated LCUP assistance information based on either serving area or UE IP/identity.

When LCUP is used with 3GPP LCS MT/NI/MO procedures, LMF can offload the LPP traffic to LCUP by the following means to activate UP connection from UE :

1. LMF can use LPP assistance delivery containing LCUP information
2. LMF can use OMA defined push mechanisms. This is compatible with legacy SUPL capability of UE.
3. LMF can also use Namf\_Communication\_N1N2MessageTransfer to AMF which forwards LCUP info to UE with DL NAS TRANSPORT.

After UE gets the cooperated LCUP assistance data of its serving LMF:

1. UE starts LCUP DNS query either with pre-provisioned, or from OMA defined push mechanism or LPP assistance delivery:
   1. If the FQDN of LCUP could uniquely identify an LCUP instance, such instance would be the serving LCUP cooperated with the currently serving LMF. OAM can perform pre-provision.
   2. With localized LCS cases where LCUP and/or LMF are bounded to the serving area, LMF can use UE’s serving cell ID to match its serving area and respond to DNS queries with its cooperated LCUP assistance information.
   3. LMF can also maintain serving UE IP list from BSF query or SIP IP header of SIP INVITE with co-location with LRF/RDF in emergency IMS call. LMF can use UE IP to match ECS in LCUP DNS query to know whether it is the serving LMF so that its cooperated LCUP assistance can be replied for the DNS query.
2. UE connects to the LCUP over the user plane through the N6 interface
3. UE establishes TLS connection possibly with LCUP assistance data or pre-configured trusted certificates
4. UE can start OMA specified SUPL positioning procedures besides the control plane MT/MO/NI procedures.

### 6.2.3 Procedures

#### 6.2.3.1 LMF Offload traffic to Cooperated LCUP



1. The external location services client sends a request to the GMLC for a location for the target UE identified by an GPSI or an SUPI.

2. The GMLC invokes a Nudm\_UECM\_Get service operation towards the home UDM of the target UE to be located with the GPSI or SUPI of this UE.

3. The UDM returns the network addresses of the current serving AMF.

4. The GMLC invokes the Namf\_Location\_ProvidePositioningInfo service operation towards the AMF to request the current location of the UE. The service operation includes the SUPI, and client type and may include the required QoS, Supported GAD shapes and UE UP capability.

5. If the UE is in CM IDLE state, the AMF initiates a network triggered Service Request procedure as defined in clause 4.2.3.3 of TS 23.502 [19] to establish a signaling connection with the UE.

6. The AMF selects an LMF based on the available information as defined in clause 5.1 or based on AMF local configuration. The LMF selection takes the 5G-AN currently serving the UE into account. The selection may use an NRF query.

7. The AMF invokes the Nlmf\_Location\_DetermineLocation service operation towards the LMF to request the current location of the UE.

8. LMF offloads the LPP traffic to its cooperated LCUP by one of the methods in clause 6.2.2.

8.a The cooperated LMF can perform one or more of the positioning procedures with RAN defined by 3GPP.

8.b The cooperated LCUP can perform one or more of the positioning procedures with UE defined by OMA.

9. The LMF returns the Nlmf\_Location\_DetermineLocation Response towards the AMF with the combined result from cooperated LMF and LCUP.

10. The AMF returns the Namf\_Location\_ProvidePositioningInfo Response towards the GMLC/LRF.

11. The GMLC sends the location service response to the external location services client.

#### 6.2.3.2 LMF Activates UE with UP Connection to LCUP



1. URSP rules can be provisioned as an example in TS 23.503:

|  |  |  |
| --- | --- | --- |
| Rule Precedence =4  Traffic Descriptor:  Application descriptor=App1  Connection Capabilities="internet", "supl" | Route Selection Descriptor Precedence =1  Network Slice Selection: S-NSSAI-a  DNN Selection: DNN\_1  Access Type preference: Non-3GPP access | This URSP rule associates the application "App1" and the Connection Capabilities "internet" and "supl" with DNN\_1, S-NSSAI-a over Non-3GPP access.  It enforces the following routing policy:  When the "App1" requests a network connection with Connection Capability "internet" or "supl", the UE establishes (if not already established) a PDU Session with DNN\_1 and S-NSSAI-a over Non-3GPP access. After that, the UE routes the traffic of "App1" over this PDU Session. |

1. URSP rules are applied to UE
2. The start of 3GPP LCS procedures contained in TS 23.273
3. Request comes to LMF with UE identity in inputData of Nlmf\_Location\_DetermineLocation request. When UE provides the user plane capability in registration, the request could take such capability in its parameters.
   1. LMF can use UE id to query BSF for UE ip; in emergency IMS call, E-CSCF forwards SIP INVITE to GMLC/LRF. Through GMLC/LRF, LMF can also get the UE ip from SIP header of the SIP INVITE.
4. LMF gets UE user plane capability and provides LCUP information through either LPP or NAS. LMF can also reuse legacy 2G/3G/4G SUPL mechanisms by sending SUPL INIT to UE with attempts to activate user plane connection.
   1. LPP capability exchange is used to fetch UE user plane capability if Nlmf\_Location\_DetermineLocation doesn’t show such capability; LMF can also use solicited or unsolicited assistance data delivery to transfer LCUP information to UE.
   2. In (rare) cases that UE doesn’t support LPP but supports user plane, DL\_NAS\_TRANSPORT can be used to query UE user plane capability and delivery the LCUP assistance information.
   3. To be compatible with legacy SUPL implementation in UE, especially when LMF has knowledge of UE user plane capability by OAM provision or other means, LMF can use OMA defined push mechanisms and send SUPL INIT message to activate the user plane session.

6, 7, 8. PDU session and EASDF rule execution as per TS 23.548

1. If FQDN in DNS query is uniquely mapped to one LCUP instance, the LCUP address is replied. This applies to cases when such FQDN is transferred from LMF to UE at step 5. But this may not apply to pre-provisioned H-SLP/E-SLP in UE. Such pre-configuration follows OMA SUPL specifications whose FQDN and trusted certificates override the runtime parameter transferred through step 5 or other means.
   1. If FQDN could be mapped to multiple LCUP instances, EASDF attached UE ip in ECS field and forward the DNS query to related LMF/LCUP instances. The serving LMF/LCUP instance could match UE ip among its serving UE requests and reply its LCUP address. This address is the correct LCUP instance that UE should establish user plane session.
2. DNS result is replied to UE
3. UE continues to establish secure user plane session. After secure connection established, user plane messages can be transferred, e.g, SUPL POS INIT for option c in step 5.

Editor's Note: Further details are FFS

### 6.2.4 Impacts on services, entities, and interfaces

Editor's Note: Any further possible impacts are FFS

## 6.3 Solution #3: User plane location capability transfer and positioning via user plane

### 6.3.1 Introduction

This solution addresses Key Issue 1 on Positioning via user plane transmission. In this solution, capability t transmission is updated to cover ‘user plane location capability’. If network determines to use user plane for positioning, the network should send the information (e.g. address information) of the user plane positioning function to UE to enable the user plan connection.

### 6.3.2 Functional Description

In this solution, we assume there is a UPLF (User Plane Location Function, e.g. a SUPL based function integrated in LMF) in the network, to which UE needs to establish a user plane connection if user plane positioning is to be used.

Before a UE establishes the user plane connection, it is required to send user plane location capability to the network so that the network knows that the UE supports positioning via user plane then can determine to use user plane for positioning. Thus, the existing capability transfer should cover the ‘user plane location capability’.

During the MO or MT positioning procedure, after the network determines to use user plane positioning, the network should indicate the UE to use user plane for positioning with the address information of UPLF integrated in LMF. With the address information, UE can establish a secure connection with the UPLF, and via this secure connection, position messages can be transferred between UE and the UPLF. The established user plane connection may be reused for subsequent user plane position messages transmission trigged by UE or UPLF, e.g. if UE does not move to a new place, does not have new QoS requirements and uses the same positioning method via the user plane.

### 6.3.3 Procedures

#### 6.3.3.1 User plane location capability transfer

During the MO-LR or MT-LR procedures, LMF may request the UE to provide the user plane location capability. Figure 6.3.3.1.-1 presents the capability transfer procedure, where the *ProvideCapabilities* message should support to carry ‘user plane location capability’.



Fig 6.3.3.1-1. Capability transfer

1. AMF sends Nlmf\_Location\_DetermineLocation Request to the LMF

2. LMF sends a *RequestCapabilities* message to UE

3. UE provide its ‘user plane location capability’ in a *ProvideCapabilities* message to LMF if it supports user plane location.Positioning method and modes may also be included.

#### 6.3.3.2 5GC-MT-LR Procedure via user plane



Fig 6.3.3.2-1. 5GC-MT-LR Procedure via user plane

1~10. Step 1-step 10 of figure 6.1.2-1 in TS 23.273.

11. The AMF invokes the Nlmf\_Location\_DetermineLocation service operation towards the LMF to request the current location of the UE..

12. LMF sends a *RequestCapabilities* message to UE.

13. UE provides its user plane location capability to LMF. Positioning methods and Positioning modes may also be included.

14. Based on the user plane location capability of the UE, the Positioning methods and modes the UE supports, the load balance of the control plane, LMF decides to continue the position procedure via user plane. The interaction between UPLF and LMF take place internally in the LMF.

15. LMF sends a user plane positioning information to AMF to indicate UE to use user plane positioning. The information may include the FQDN or IP address of the UPLF, the S-NSSAI and DNN for the PDU session used for user plane positioning, the digital certificate used to establish secure connection, the identity to be used in the head of user plane messages (e.g. GPSI, SUPI or IP address). Also, the LMF may require the UE to report the IP address of the PDU session used for user plane positioning. If UE supports more than one positioning methods, LMF may also indicate UE which type of positioning methods should use the user plane connection, while others may use the control plane (e.g. user plane for sensor method and control plane for NR-based positioning method ). The UPLF assistance information transfer can be based on NAS or enhanced LPP.

16. When AMF receive the message from LMF, AMF sends the user plane positioning information to UE.

17. If there is no suitable existing PDU session, UE establishes a PDU session with the S-NSSAI and DNN received from the positioning information. UE may reject to establish the PDU session and send a failure indication message to the network.

18. If the suitable PDU session exists, UE sends an acknowledgement to network to confirm that user plane position is chosen, and the IP address of the PDU session may also be included in the acknowledgement.

19. AMF sends this acknowledgement to the LMF.

20. UE establishes a connection with UPLF, and then LPP message can be transferred between UE, UPLF and LMF for the calculation of UE position.

Editor's Note: Further details of LPP transfer via User Plane are FFS.

21~23. Step 9~11 of figure 6.1.1-1 in TS 23.273.

Editor’s Note: It is for FFS how LMF determines to choose the user plan method.

#### 6.3.3.2 5GC-MO-LR Procedure via user plane

For MO-LR procedure, user plane location capability may be included in the MO-LR request message, in this case there is no need for LMF to require UE to report its capability, and LMF could make the decision whether user plane is chosen immediately after receiving the Nlmf\_Location\_DetermineLocation message.

Figure 6.3.3.2-2 presents the 5GC-MO-LR procedure via user plane, of which the principle is similar with 5GC-MT-LR Procedure via user plane. The difference is, in step 4, the user plane location capability can be carried by the Nlmf\_Location\_DetermineLocation message.



Fig 6.3.3.2-2. 5GC-MO-LR Procedure via user plane

### 6.3.4 Impacts on services, entities, and interfaces

The solution impact the following network functions:

* New NF called "UPLF" is required to establish the connection with UE and transfer the user plane (e.g. SUPL) signalling between UE and LMF. This UPLF is integrated with LMF;
* UE supports to send user plane location capability to LMF, receives user plane positioning information from LMF, support setup and release of UP connection and supports to perform positioning via user plane location connection;
* LMF supports user plane location service by interacting with UPLF and supports to transfer the user plane positioning information to UE;

## 6.4 Solution #4: Direct communication between LMF and RAN node

### 6.4.1 Introduction

This solution aims to address the key issues#2: enhanced positioning architecture for NPN deployment. Particularly this solution address the following questions:

- How to realize low latency positioning procedure under NPN deployment.

- How to achieve reliable and secure location result delivery and exposure, e.g. UE location not exposed to the public network.

### 6.4.2 Functional Description

The following is the architecture figure in this solution



Figure 6.4.2: Reference architecture for Location Services

In this solution, the LMF has Nx interface with the RAN node and Ny interface with the GMLC. The Nx interface is to exchange directly the Network Positioning Message between the RAN and LMF for network assisted or network based positioning procedure, and obtaining Network Positioning Message for Non-UE Associated Network Assistance Data procedure, without going through the AMF. The Ny interface is used to exposure the UE location to GMLC directly without going through the AMF.

The TNL association between the RAN node and the LMF is pre-established via configuration. For UE associated Network Positioning Message the AMF provides the RAN NxAP UE ID to LMF. The LMF allocates LMF NxAP UE ID and establishes NxAP association between the RAN node and LMF.

The GMLC notification address is provided from AMF to LMF. The LMF notifies the UE location estimation towards the GMLC directly.

Editor Note: It is FFS how to handle the Network Positioning Messages for UE Assisted and UE Based Positioning

Editor Note: It is FFS how to handle the UE mobility

Editor's Note: According to 5G core architecture only AMF has SCTP connection to RAN. No other NF can reach RAN without AMF using SCTP. Impacts of such large change require investigation both in RAN and outside of LCS work before proceeding.

Editor note: It is FFS whether proposal of direct interface between RAN node and LMF is in the scope of rel-18

NOTE: This solution assumes that the LMF and the RAN node are in the same trusted domain.

### 6.4.3 Procedures

#### 6.4.3.1 Network Assisted Positioning Procedure



Figure 6.4.3-1: Mobile Terminated Network Assisted Positioning Procedure

1. Based on configuration the TNL association may be pre-established between the RAN node and the AMF.

2. The GMLC invokes the Namf\_Location\_ProvidePositioningInfo service operation towards the AMF to request the current location of the UE. The service operation includes the SUPI, and client type and may include the required QoS and Supported GAD shapes.

3. If the UE is in CM IDLE state, the AMF initiates a network triggered Service Request procedure as defined in clause 4.2.3.3 of TS 23.502 [19] to establish a signalling connection with the UE.

4. The AMF selects the LMF and invokes the Nlmf\_Location\_DetermineLocation service operation towards the LMF to request the current location of the UE. This service operation may include the RAN node ID, the TNL Address and the RAN NxAP UE ID. This service operation may also include the GMLC notification address to receive the UE location.

5. The LMF response Nlmf\_Location\_DetermineLocation response.

void.

6. The LMF sends a Network Positioning message in the Nx Transport message via the TNL association to the RAN node to request position related information from the RAN node. The LMF allocates an LMF NxAP UE ID and includes both the RAN NxAP UE ID and the LMF NxAP UE ID in the Nx Transport message

7. The target RAN node returns any position related information to the LMF in a Network Positioning message included in an Nx Transport message. The Nx Transport message includes the LMF NxAP UE ID.

8. The LMF invokes the Nlmf\_EventExposure\_Notification service operation towards the GMLC notification address received from AMF in step 4.

#### 6.4.3.2 Obtaining Non-UE Associated Network Assistance Data



Figure 6.4.3.2: Non-UE Associated Network Assistance Data procedure

1. Based on configuration the TNL association may be pre-established between the RAN node and the AMF .

2. The LMF sends a Network Positioning message in the Non UE associated Nx Transport message via the TNL association to the RAN node to request position related information from the RAN node.

3. The target RAN node returns any position related information to the LMF in a Network Positioning message included in an Non UE associated Nx Transport message.

### 6.4.4 Impacts on services, entities, and interfaces

LMF:

* Establish TNL association and NxAP association with the RAN node
* Exchange the Network Positioning message with RAN node over the TNL association
* Send the UE location to the GMLC

AMF:

* Provides TNL address and RAN NxAP UE ID to the LMF

RAN node:

* Establish TNL association and NxAP association with the LMF
* Exchange the Network Positioning message with LMF over the TNL association

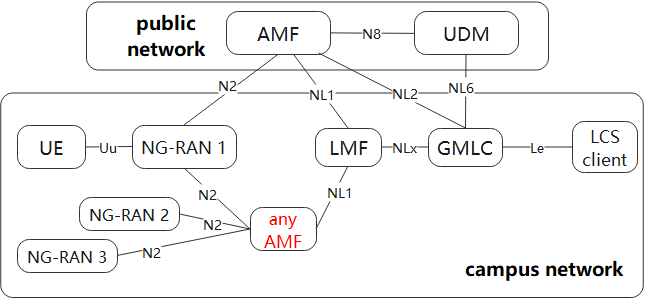
## 6.5 Solution #5: LCS architecture with “any AMF”

### 6.5.1 Introduction

This solution is applicable to LCS procedure including MO-LR, MT-LR, and LDR. When network based positioning method is selected by LMF, the signalling between LMF and NG-RAN, LMF and GMLC, are not transmitted to the AMF in the public network.

### 6.5.2 Functional Description

Architecture for this solution is illustrated as below.



When UE registers to the network, NG-RAN 1 is the serving RAN node for the UE. NG-RAN 1 shall select an AMF in the public network, based on operator’s configuration.

Current LCS design assumes NG-RAN report UE measurement to AMF (NRPPa message) and then to LMF. Because the NG-AP message may not be cyphered, it is likely the information will be sniffed by other entity in the transport network, which leads to exposure concern.

It is proposed to update the NRPPa signalling as follows:

During the location request procedure, if network based positioning method is selected by LMF, for UE associated NRPPa signalling, it is transmitted via the serving AMF. For non UE associated NRPPa signalling, it is transmitted using “any AMF” deployed in the campus network.

The description of using “any AMF” is specified in TS 38.305:

*An LMF can interact with any gNB reachable from any of the AMFs with signalling access to the LMF in order to obtain location related information to support the NR RAT-Dependent positioning methods. The information can include timing information for the TRP in relation to either absolute GNSS time or timing of other TRPs and information about the supported cells and TRPs including PRS schedule.*

*Signalling access between the LMF and gNB may be via any AMF with signalling access to both the LMF and gNB..*

“any AMF” is an AMF defined in TS 23.501, and needs to support the following functionality in this solution.

* handling of Namf\_nonUEN2message transfer service from LMF;
* NG-AP message capsulation and decapsulation for UL and DL non UE associated NRPPa message;

Other functionalities supported by the AMF may not be needed in “any AMF”

Editor note: It is FFS whether the NG-RAN node needs to establish NGAP association with the “any AMF”

Topology of NG-RAN, “any AMF” and LMF are configured by the operator. LMF is configured with “any AMF” address. NG-RAN nodes in the campus network establishes TNL association with “any AMF” in the campus network.

### 6.5.3 Procedures

#### 6.5.3.1 (same as TS 23.273, clause 6.11.2 Network Assisted Positioning Procedure)

The AMF illustrated in this call flow is the serving AMF of the UE



#### 6.5.3.2 (same as TS 23.273, clause 6.11.3 Obtaining Non-UE Associated Network Assistance Data)

The AMF illustrated in this call flow is “any AMF” deployed in the campus network. LMF is configured with “any AMF” address. NG-RAN nodes in the campus network establishes TNL association with “any AMF” in the campus network.



### 6.5.4 Impacts on services, entities, and interfaces

LMF:

* configured with “any AMF” address.
* if network based positioning method is selected by LMF, for UE associated NRPPa signalling, it is transmitted via the serving AMF. For non UE associated NRPPa signalling, it is transmitted using “any AMF” deployed in the campus network.

NG-RAN:

* establishes TNL association with “any AMF”.

## 6.6 Solution #6: LMF selection based on LMF ID

### 6.6.1 Introduction

This solution aims to address the key issues#3: Local Area Restriction for an LMF and GMLC. In this solution the LMF discovery and selection mechanism is enhanced to use LMF ID as input parameter.

### 6.6.2 Functional Description

In this solution, the GMLC is configured with an LMF ID of the LMF located within the same local area of the GMLC. The LMF may register itself in the NRF. The GMLC provides the LMF ID to AMF in Namf\_Location\_ProvidePositioningInfo service operation. The AMF uses the LMF ID to discover the LMF via NRF query or local configuration and invokes the Nlmf\_Location\_DetermineLocation service operation to request the current location of the UE.

### 6.6.3 Procedures



Figure 6.6.3-1: 5GC-MT-LR procedure

1. The external location services client sends a request to the GMLC for a location for the target UE identified by an GPSI or an SUPI.

2. The GMLC invokes a Nudm\_UECM\_Get service operation towards the home UDM of the target UE to be located with the GPSI or SUPI of this UE.

3. The UDM returns the network addresses of the current serving AMF.

4. The GMLC invokes the Namf\_Location\_ProvidePositioningInfo service operation towards the AMF to request the current location of the UE. The service operation includes the SUPI, and client type and may include the required QoS and Supported GAD shapes. The service operation may also include the LMF ID if it is configured in the GMLC.

5. If the UE is in CM IDLE state, the AMF initiates a network triggered Service Request procedure as defined in clause 4.2.3.3 of TS 23.502 [19] to establish a signalling connection with the UE.

6. The AMF selects the LMF based on the LMF ID received from GMLC. The selection may use a NRF query or local configuration.

7-11. Same steps 7-11 in TS 23.273 clause 6.1.1.

### 6.6.4 Impacts on existing entities and interfaces

GMLC:

* Configured with LMF ID in the same location area
* Send the LMF ID to AMF in Namf\_Location\_ProvidePositioningInfo service operation

AMF:

* Select the LMF according to the LMF ID received from the GMLC

## 6.7 Solution #7: LMF selection based on client or AF identifier

### 6.7.1 Introduction

This solution is to address KI#3: Local Area Restriction for an LMF and GMLC.

LMF selection functionality is used by the AMF to determine an LMF for location estimation of the target UE. In some local cases, operators may deploy specific LMF and GMLC for enterprises for some customized or privacy requirements. But the UEs of different enterprises may share the same AMF or AMF pool. In order to select the right LMF for specific enterprise, AMF could use new identifiers which can map between enterprise and specific LMF.

### 6.7.2 Functional Description

Based on the scenarios mentioned above, AMF may use client identifiers or AF identifiers as one of the additional factors during the LMF selection, as specified in clause 5.1 in TS 23.273. The client and AF request the location information of the target UE, whose identifiers are assigned by the operator. The selection policy can be configured locally at AMF, or by querying NRF.

If the LMF selection is performed at the AMF by querying NRF, LMF shall register with the client or AF identifier(s) that the LMF can serve.

### 6.7.3 Procedures

N/A

### 6.7.4 Impacts on services, entities, and interfaces

AMF:

* take AF or client identifier(s) into account during the LMF selection;

AF:

* provide the AF identifier(s) in location service procedures;

UE:

* provide the client or AF identifier(s) to AMF in location service procedures;

LMF:

* Register in NRF with serving AF or client identifier(s).

## 6.8 Solution #8: LMF Selection based on GMLC service area

### 6.8.1 Introduction

This solution addresses KI#3: Local Area Restriction for an LMF and GMLC.

### 6.8.2 Functional Description

The existing LMF selection mechanism is re-used with the following enhancements:

- When AMF selects LMF: a new factor considered for LMF selection is added, i.e. GMLC service area consisting of one or more TA(s) which is locally configured in AMF.

- When AMF selects target LMF: if the GMLC is restricted to supporting local services in a local area, it selects target LMF able to support location in the same local area.

### 6.8.3 Procedures

The existing LMF Change Procedure in clause 6.4 in TS 23.273 is re-used.

### 6.8.4 Impacts on services, entities, and interfaces

AMF: consider GMLCS service area when selecting LMF.

LMF: if the LMF is restricted to supporting local services in a local area, it selects target LMF in the same local area.

## 6.9 Solution #9: local LMF and GMLC selection

### 6.9.1 Introduction

This solution enables dedicated LMF and GMLC selection for the UE positioning in the local network.

### 6.9.2 Functional Description

Two options are proposed for the AMF to select a local LMF and local GMLC:

* based on operator’s configuration. An example could be a mapping table of UE identity e.g. MSISDN and LMF/GMLC address is stored at AMF.
* Fetch from UDM, UE LCS subscription storing its serving local LMF and local GMLC address.

### 6.9.3 Procedures

#### 6.9.3.1 (is TS 23.273 clause 6.1.2 5GC-MT-LR Procedure for the commercial location service)



Other steps are same as in TS 23.273, except step 10:

10. AMF, based on local configuration, e.g. mapping table mapping table of UE identity e.g. MSISDN and LMF address, or the UE LCS subscription data where includes a dedicated LMF ID, selects an LMF.

### 6.9.4 Impacts on services, entities, and interfaces

AMF:

* based on operator’s configuration. An example could be a mapping table of UE identity e.g. MSISDN and LMF/GMLC address is stored at AMF.
* Fetch from UDM, UE LCS subscription storing its serving local LMF and local GMLC address.

## 6.10 Solution #10: Support interaction between location service and NWDAF

### 6.10.1 Introduction

This solution addresses KI#4: Interaction between Location Service and NWDAF.

### 6.10.2 Functional Description

This solution reuses the existing architecture and interfaces to support interaction between location service and NWDAF:

- Based on description in clause 4.3.2 in TS 23.273, the LCS service supports NFs to access LCS services from a GMLC. So the Ngmlc interface is re-used when NWDAF obtains UE location by invoking LCS services.

- Based on description in clause 4.2.0 in TS 23.288, any 5GC NF can request network analytics information from NWDAF. So the Nnwdaf interface is re-used when LMF obtains data analytics from the NWDAF. In this solution, the LMF selects positioning method based on WLAN performance analytics from the NWDAF.

### 6.10.3 Procedures

#### 6.10.3.1 NWDAF accesses location service



Figure 6.10.3.1-1: NWDAF accesses location service based on existing mechanism

1. NWDAF invokes Ngmlc\_Location\_ProvideLocation Request to GMLC.

2. The GMLC performs steps 2-23 in clause 6.1.2 or steps 2-29 in clause 6.3.1 in TS 23.273.

3. The GMLC sends Ngmlc\_Location\_ProvideLocation Response to NWDAF.

Editor’s NOTE: whether and how to improve the procedure is FFS, e.g. how to perform privacy check.

Editor’s NOTE: whether and how the NWDAF selects a particular UE is FFS.

#### 6.10.3.2 LMF obtains data analytics from NWDAF

The procedure in clause 6.11.4 in TS 23.288 can be re-used.

### 6.10.4 Impacts on services, entities, and interfaces

LMF: selects positioning method based on data analytics from NWDAF.

## 6.11 Solution #11: Interaction Enhancement between LCS and NWDAF

6.11.1 Introduction

This solution addresses the KI “Key Issue #4: Interaction between Location Service and NWDAF”.

6.11.2 Functional Description

TS 23.273 defines LCS QoS to have the following attributes

- Location Accuracy

- Response time

- QoS Class

Among these, the QoS Class attribute gives the requirement on the other attributes like accuracy or response time. It could take values Best Effort, Multiple QoS Class or Assured. While the Best Effort class is the least stringent one, the other two require the LMF to determine how accurate its location estimate is.

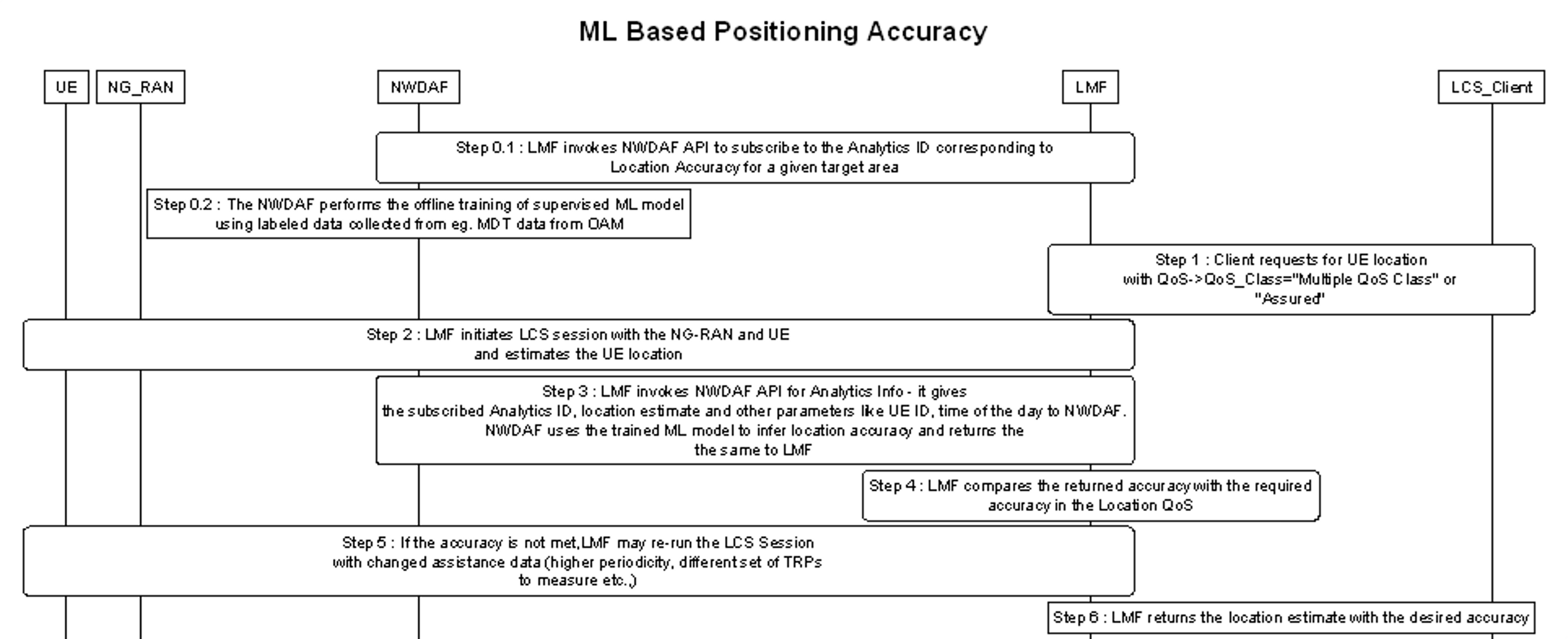
For example,

- in case of “Multiple QoS Class”, if the accuracy is less than what is required, the LMF shall rerun the estimate with more measurements etc., to achieve the accuracy required

- in case of “Assured” QoS Class, the procedure fails if the accuracy required is not met

This is a data analytics-based solution that shall run in the NWDAF where a Machine Learning model is trained using data like positioning estimate, positioning method used, assistance data, UE ID, time of the day etc. and corresponding accuracy. This model is then subsequently used by the LMF to determine if its location estimate meets the accuracy required and take appropriate action. To enable this, the LMF makes use of a Service Based API that is exposed by the NWDAF.

6.11.3 Procedure



Step 0.1: The LMF invokes NWDAF API to subscribe to the Analytics ID corresponding to Location Accuracy for a given target area, this acts as a trigger for the NWDAF to do the offline training of the corresponding ML model

Editor's Note: Whether to use new Analytics ID or reuse existing one is FFS and may need to be decided in coordination with eNA\_ph3

Step 0.2: The NWDAF performs the offline training of the model using supervised data. It may also access labeled data collected from eg.MDT for its training purposes. The training is complete waiting for analytics request from the LMF for that Analytics ID

Step 1: LCS Client requests UE location with QoS Class as either “Multiple QoS Class” or “Assured” alongwith the location accuracy required.The expected behaviour from the LMF is as given in section 6.11.2.

Step 2: The LMF initiates the LCS session as given in TS 23.273 and derives the UE location estimate

Step 3: The LMF then queries the NWDAF for the location estimate accuracy giving as inputs the subscribed Analytics ID, location estimate and other parameters like UE ID, assistance data, time of the day etc., The NWDAF uses the corresponding model trained in Step: 0.2 and provides the location accuracy as the output to the LMF.

Note-1: The training done in Step-0.2 gives the ML model the ability to predict the location accuracy without the need for a reference location estimate. This is made possible by the extensive training done using various accuracy/reference values, which result in the computing of weights in the ML model. Such a trained model can then be used for an inference/prediction of the location accuracy in this step. An internal PoC has shown very encouraging results using such an ML model

Note-2: The NWDAF and related aspects of this solution to be further discussed in FS\_eNA\_Ph3, as part of Key Issue #9: Enhancement of NWDAF with finer granularity of location information given in TR 23.700-81

Step 4: LMF compares the location accuracy got in step 3 with the required location accuracy got in step 1 from the LCS Client.

Step 5: If the required location accuracy is not met, the LMF may take subsequent actions like re-executing the LCS procedure with more stringent parameters (for example : higher periodicity measurements)

Step 6: The LMF returns the location estimate with the required accuracy

6.11.4 Impacts on services, entities, and interfaces

Editor's Note: Any further possible impacts are FFS

## 6.12 Solution #12: Supporting analytics for location accuracy

### 6.12.1 Description

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

As part of the location services requirements defined in 3GPP TS 22.071, one of the main requirements for the LCS service is the support of Location Accuracy.

The location accuracy is provided in terms of horizontal, vertical accuracy and response time. In general the accuracy of the location depends on the positioning technology used, the varying radio environments (e.g. considering multipath propagation), the type of environment where the location is measured (dense urban area or rural area).

The location accuracy required by each service varies and can vary from location accuracy up to 200km for weather services to location accuracy of up to 50m for Asset Location, route guidance, navigation. Further information is provided in Table 4.1 of 3GPP TS 22.071.

When a location client requires a location accuracy the location client may include in the request to the GMLC:

- A response time (no delay, low delay, delay tolerant)

- Horizontal and/or vertical accuracy requirements (in meters)

- LCS QoS Class (best effort, assured or multiple QoS corresponding to a priority of QoS accuracy)

When the LMF determines the location the LMF also determines the accuracy of the location and also whether the location requirements are met which are sent to the GMLC. The GMLC responds to the client the accuracy of the location measurement can be met.

Analytics from the NWDAF can be enhanced to allow a location client to be aware if a location accuracy can be met. Example consumers of such analytics is as follows:

- LMF uses the analytics to identify the best positioning method to use to determine a location in a specific area, taking into account UE capabilities, QoS requirements and operator policies.

- The location client can determine to upgrade/downgrade the requested LCS QoS taking into account the analytics of location accuracy

- The location client can adapt the application service accordingly. For example, a navigation service can take into account areas where location accuracy cannot be met when providing route guidance.

### 6.12.2 Procedures

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

A consumer (e.g. a location client) requests from the NWDAF analytics for “Location Accuracy Sustainability”. The request may also include the following as Analytic Filters:

- A target area

- A target UE, group of UEs or any UE

- Time of Day

- An LCS QoS Class or Horizontal/Vertical Accuracy requirement (denotes the requested LCS QoS or Horizontal/Vertical accuracy requirement

- Optionally a positioning method used

- A location accuracy threshold, i.e., report accuracy analytics only if the location accuracy exceed an horizontal or a vertical accuracy threshold (in meters)

When the NWDAF receives the request the NWDAF collects data by the LMF taking into account the consumer request. The NWDAF invokes a new SBI (e.g. Nlmf\_Event\_Exposure) and requests data from the LMF identified by a new Event ID “e.g. Location Measurement Accuracy request”. The LMF based on the Event ID requested provides information on accuracy of a measurement of a location when a location measurement is made by the LMF.

Editor's Note: Whether the LMF can provide measurement information to NWDAF for location accuracy is FFS.

Editor's Note: Additional Data Producers to provide measurement information for location accuracy are FFS (e.g. GMLC providing measurement information).

The LMF provides measurements reports to the NWDAF as follows:

- If the request target any UE the LMF provides measurements report for any location request received by the LMF by a location client (the request is received via the GMLC)

- If the request target a specific UE, the LMF provides measurements report when the LMF receives a location request from a location client that targets the specific UE.

- If the request includes a requested LCS QoS class or horizontal/vertical accuracy the LMF provides a meaurements report when the LMF receives a location request from a location client with the requested accuracy

- If the request includes a positioning method, the LMF provides measurements report when the LMF determines the location using the position method used.

The procedure is shown below:



**Figure 6.12.2.1-1: Procedure to derive analytics for location accuracy sustainability**

1. A Consumer requests analytics for location accuracy sustainability from the NWDAF. The request may include a target area, a time of day, a target UE (or group of UEs or any UE). The request may also include, to report analytics for a specific LCS QoS requirement or horizontal/vertical accuracy.

2. The NWDAF finds the LMF serving the UE (if the analytics request includes a target UE or the LMF serving a target area (if the request in step 1 is for any UE and a target area is included in the request).

3. The NWDAF sends a request to the LMF to provide location measurement accuracy data (the request may be a subscription or a one time request). The NWDAF includes in the request to the LMF information to satisfy the requirements of the consumer in step 1.

4a-4c. The LMF is triggered to provide a location request from a location client as per procedure in 3GPP TS 23.273 [x]. The LMF derives the location of the UE.

5. The LMF determines that the location measured is for a UE or an area where the NWDAF has subscribed to report location measurements. The LMF reports the location accuracy to the NWDAF.

6. The data are provided to the NWDAF

7. The NWDAF derives analytics for location accuracy .

8. The NWDAF provides analytics to the consumer.

The following input data are required by the NWDAF to measure location measure accuracy.

**Table 6.12.2.1-1: Location measurement accuracy data collected by NWDAF**

|  |  |  |
| --- | --- | --- |
| **Information** | **Source** | **Description** |
| Location Measurement accuracy data | LMF | Includes information on the Position Method used, the requested LCS QoS or horizontal/accuracy and whether the location accuracy request was satisfied |
| Timestamp | LMF | The time where the location was measured by the LMF |
| UE Location | AMF | The location area of the UE when the location measurement was made |

The analytics output to the consumer may include one of the following:

**Table 6.12.2.1-1: "Location Accuracy Sustainability" statistics**

|  |  |
| --- | --- |
| **Information** | **Description** |
| List of Accuracy Analytics (1..max) |  |
| >Applicable Area | A list of TAIs or Cell IDs within the Location information that the analytics applies to. |
| >Applicable Time Period | The time period within the Analytics target period that the analytics applies to. |
| >The requested LCS QoS | The analytics provide a delta against the request measurement accuracy level from a consumer |
| > List of SUPIs | A list of SUPIs experiencing the same analytics accuracy |
| > Positioning Method | The positioning method used to measure location |
| > Percentage of analytics accuracy above/below requested thresholds | A percentage indicating if the requested analytics accuracy is met |

**Table 6.12.2.1-2: "Location Accuracy Sustainability" predictions**

|  |  |
| --- | --- |
| **Information** | **Description** |
| List of Accuracy sustainability Analytics (1..max) |  |
| >Applicable Area | A list of TAIs or Cell IDs within the Location information that the analytics applies to. |
| >Applicable Time Period | The time period within the Analytics target period that the analytics applies to. |
| > The requested LCS QoS | The analytics provide a delta against the request measurement accuracy level from a consumer |
| > List of SUPIs | A list of SUPIs experiencing the same analytics accuracy |
| > Positioning Method | The positioning method used to measure location |
| > Percentage of analytics accuracy above/below requested thresholds | A percentage prediction indicating if the requested analytics accuracy is met |
| >Confidence | Confidence of the prediction. |

### 6.12.3 Impacts on services, entities and interfaces

Editor's note: This clause captures impacts on existing 3GPP nodes and functional elements.

- New Nlmf event notification service to allow the NWDAF to retrieve location measurement reports from the LMF.

## 6.13 Solution #13: Architecture enhancement for the interaction between LCS and NWDAF

### 6.13.1 Introduction

The solution is intended to address and resolve Key Issue 4: Interaction between Location Service and NWDAF.

Here are three schemes that can be a potential basis to support the finer granularity location information interaction between LCS and NWDAF, i.e., AMF interacts with NWDAF, GMLC interacts with NWDAF, and LMF interacts with NWDAF. This solution aims to enhance the interfaces between AMF and NWDAF.

The interaction between AMF and NWDAF is enhanced to support the delivery of the finer granularity location information, including the finer geographical location, velocity, accuracy, and other necessary information. When the location information request is received in AMF from NWDAF, the AMF has a responsibility to distinct the requested granularity to determine whether it is necessary to initiate a request to LMF.

To solve the aforementioned issue, this solution proposes a scheme to support location information delivery between LCS architecture and NWDAF.

### 6.13.2 Architecture



Figure 6.13.2-1: Interaction between LCS and NWDAF architecture

Figure 6.13.2-1 is similar to Figure 4.2.1-1 in TS 23.273 [5] and additionally supports the enhancement of the service-based interface between AMF and NWDAF.

Editor's note: Whether the interface between NWDAF and GMLC can be supported is FFS.

Enhanced Service Based Interfaces proposed in this solution comprise:

**Nnwdaf:** Service-based interface exhibited by NWDAF.

**Namf:** Service-based interface exhibited by AMF.

In addition, this solution utilizes the existing service operations defined in TS 23.502 [3] and TS 23.273 [5] for the Nlmf and Nudm service based interfaces.

Editor’s Note: How to perform privacy check based on this architecture is FFS.

### 6.13.3 Procedures

#### 6.13.3.1 One-time Collection Procedure

Figure 6.13.3.1-1 illustrates the one-time data collection from NWDAF to LCS architecture. In this scenario, it is assumed that the target UE(s) is identified using a SUPI or GPSI. This procedure is applicable to a request from NWDAF for immediately location collection.



Figure 6.13.3.1-1: AMF provides UE location information to NWDAF (One-time Collection)

1. The NWDAF invokes a Nudm\_UECM\_Get service operation towards the home UDM of the target UE to be located with the GPSI or SUPI of the UE.

2. The UDM returns the address of the current serving AMF for the target UE.

3. The NWDAF invokes the Namf\_Location\_ProvidePositioningInfo service operation towards the AMF to request the location of the UE. The service operation includes the SUPI, the required location granularity, and may include the collection type, an indication of velocity information and the required QoS, which includes accuracy, latency, and QoS class.

4. The AMF determines whether the required location granularity can be provided by AMF itself. If the granularity is at TA/cell level, the AMF process step 4-a to report the location information to NWDAF. Otherwise, the AMF process step 4-b selects an LMF based on NRF query or configuration in AMF. In addition, the AMF determines whether to initiate one-time or continuous location information collection.

5. The AMF invokes the Nlmf\_Location\_DetermineLocation service operation towards the LMF to request the location information of the UE. The service operation includes an LCS Correlation identifier, the access type and may include the required QoS, which includes accuracy, latency, and QoS class.

6. The LMF initiates the positioning procedure toward UE.

7. The LMF returns the Nlmf\_Location\_DetermineLocation Response towards the AMF to return the location information of the UE. The service operation includes the location estimate and may include velocity estimate, the age of location information, the timestamp, achieved QoS, which includes accuracy, latency and QoS class.

8. The AMF returns the Namf\_Location\_ProvideLocation Response towards the NWDAF to return the location information of the UE.

#### 6.13.3.2 Continuous Collection Procedure

Figure 6.13.3.2-1 illustrates the continuous data collection from NWDAF to LCS architecture using event reporting. In this architecture, it is assumed that the target UE(s) is identified using a SUPI or GPSI. This procedure is applicable for the request from NWDAF for the deferred location reporting.



Figure 6.13.3.2-1: AMF provides UE location information to NWDAF (Continuous Collection)

1. The NWDAF invokes a Nudm\_UECM\_Get service operation towards the home UDM of the target UE to be located with the GPSI or SUPI of the UE.

2. The UDM returns the address of the current serving AMF of the target UE.

3. The NWDAF invokes the Namf\_Location\_ProvidePositioningInfo service operation towards the AMF to request the location of the UE. The service operation includes the SUPI, the required location granularity and may include the collection type, the event type, an indication of velocity information and the required QoS, which includes accuracy, latency, and QoS class.

4. The AMF determines whether the required location granularity can be provided by AMF itself. If the granularity is at TA/cell level, the AMF process step 4-a to report the location information to NWDAF. Otherwise, the AMF process step 4-b selects an LMF based on NRF query or configuration in AMF. In addition, the AMF determines whether to initiate one-time or continuous location information collection.

5. The AMF invokes the Nlmf\_Location\_DetermineLocation service operation towards the LMF to request the location information of the UE. The service operation includes an LCS Correlation identifier, the access type and may include the event type, the required QoS, which includes accuracy, latency, and QoS class.

6. The LMF initiates the positioning procedure towards UE.

7-8. The AMF includes in the notification to the UE the type of deferred location request in the case of periodic or triggered location. The UE returns a result to the LMF.

9-10. The LMF may report the current location information, including the age of location information, the timestamp, event type, location estimate, velocity estimate, achieved QoS accuracy and QoS class, to the AMF and then to the NWDAF according to the periodic location reporting rule.

11. The UE monitors for the occurrence of the trigger or periodic event requested in step 7. When a trigger or periodic event is detected, the UE needs to connect to LMF and report its location information.

12-13. The UE sends an event reporting to the LMF. This event report may include the event type, location estimate, velocity estimate.

14. One or more UE positioning may be needed in this scenario.

15-16. The LMF reports the current location information, which may include the age of location information, the timestamp, event type, location estimate, velocity estimate, achieved QoS accuracy and QoS class.

### 6.13.4 Impacts on existing entities and interfaces

#### 6.13.4.1 Impacts on AMF

- Capability to initiate positioning procedure when location information granularity can not be provided solely by the AMF.

- Provides finer granularity location data than TA/cell level and other information, e.g., location estimate, velocity estimate, timestamp, achieved QoS information.

#### 6.13.4.2 Impacts on NWDAF

- Enhanced interface with AMF to request and obtain finer granularity location data than TA/cell level.

Editors’ Note: How the user consent in NWDAF procedures and the privacy check in LCS prcedures works in this architecture is FFS.

## 6.14 Solution #14: Unawareness positioning

### 6.14.1 Introduction

This solution addresses KI#6: UE Positioning without UE/User Awareness.

### 6.14.2 Functional Description

The principles of the solution are as follows:

- UE unaware positioning:

- If the UE is in CM\_IDLE or RRC\_INACTIVE state, the UE cannot be paged during the positioning procedure. In this case, the 5GC provides the latest stored UE location information to the LCS Client/AF if the requested accuracy is achieved.

- If the UE is in CM\_CONNECTED state, the LMF selects uplink positioning method (e.g. Uplink E-CID, Uplink NR-E-CID, UL-TDOA, UL-AoA) which requires the NG-RAN configures the UE to report the measurement information, e.g. E-UTRA RSRP, E-UTRA RSRQ measurements in UL E-CID. From UE point of view, it has no idea that the measurement is related to positioning, so UE unawareness can be achieved. Furthermore, the privacy check which requires interaction with UE is also skipped.

- The UE unaware positioning can be applied to the 5GC-MT-LR and NI-LR procedures.

- User unaware positioning:

- If the UE is in CM\_IDLE or RRC\_INACTIVE state, the UE can be paged during the positioning procedure.

- The User unaware positioning can be applied to any existing positioning procedure with the exception that the privacy check which requires interaction with user is skipped.

### 6.14.3 Procedures

#### 6.14.3.1 UE unaware positioning

To support UE unaware positioning, enhancements to the existing 5GC-MT-LR procedure and NI-LR procedure are described in this clause.

Enhancements to 5GC-MT-LR procedure for the regulatory location service in clause 6.1.1 in TS 23.273 are as follows:

- Step 1: the LCS Service Request includes the UE unaware indication.

- Step 4: the Namf\_Location\_ProvidePositioningInfo Request includes the UE unaware indication.

- If the UE is in CM\_IDLE or RRC\_INACTIVE state:

- Steps 5-9 are skipped.

- Step 10: the AMF rejects the location request with appropriate rejection cause or returns the Namf\_Location\_ProvidePositioningInfo Response which includes the latest UE location information.

- Step 11: the GMLC rejects the LCS Service Request if there is no UE location can fulfill the QoS. Otherwise, the GMLC returns the LCS Service Response with latest UE location.

- If the UE is in CM\_CONNECTED state:

- Step 7: the Nlmf\_Location\_DetermineLocation Request includes the UE unaware indication. The LMF selects positioning method based on the UE unaware indication.

Editor’s NOTE: If AMF does not know the UE is in RRC\_INACTIVE state, how to support UE unaware positioning is FFS.

Enhancements to 5GC-MT-LR procedure for the commercial location service in clause 6.1.2 in TS 23.273 are as follows:

- Steps 1a, 1b-1, 1b-2, 4, 5: the corresponding message includes the UE unaware indication.

- If the UE is in CM\_IDLE or RRC\_INACTIVE state:

- Steps 5-21 are skipped.

- Step 22: the AMF rejects the location request with appropriate rejection cause or returns the Namf\_Location\_ProvidePositioningInfo Response which includes the latest UE location information.

- Step 23-24: the GMLC rejects the LCS Service Request if there is no UE location can fulfill the QoS. Otherwise, the latest UE location is returned to LCS Client or AF.

- If the UE is in CM\_CONNECTED state:

- Steps 7-9 are skipped.

- Step 11: the Nlmf\_Location\_DetermineLocation Request includes the UE unaware indication. The LMF selects positioning method based on the UE unaware indication.

- Steps 20-21 are skipped.

Enhancements to 5GC-NI-LR procedure in clause 6.10.1 in TS 23.273 are as follows:

- Step 1: the AMF decides that the positioning is UE unaware based on configuration.

- Step 2: the Nlmf\_Location\_DetermineLocation Request includes the UE unaware indication. The LMF selects positioning method based on the UE unaware indication.

#### 6.14.3.2 User unaware positioning

To support user unaware positioning, enhancements to the existing procedures are described in this clause.

Enhancements to 5GC-MT-LR procedure for the commercial location service in clause 6.1.2 in TS 23.273 are as follows:

- Steps 1a, 1b-1, 1b-2, 4, 5: the corresponding message includes the user unaware indication.

- Steps 7-9, 20-21 are skipped.

Enhancements to Deferred 5GC-MT-LR procedure for Periodic, Triggered and UE Available Location Events in clause 6.3 in TS 23.273 are as follows:

- Steps 1a, 1b-1, 1b-2, 4, 5: the corresponding message includes the user unaware indication.

- Steps 11-12 are skipped.

### 6.14.4 Impacts on services, entities, and interfaces

GMLC:

- To support UE unaware positioning: receive UE unaware positioning indication from LCS Client and send the indication to AMF.

- To support user unaware positioning: receive user unaware positioning indication from LCS Client and send the indication to AMF.

AMF:

- To support UE unaware positioning:

- If UE is in CM\_IDLE or RRC\_INACTIVE state, the AMF does not page UE. The AMF rejects the request or returns the latest UE location to GMLC.

- If UE is in CM\_CONNECTED state, the AMF sends the UE unaware indication to LMF.

- To support user unaware positioning: the AMF does not send the NAS Location Notification Invoke Request to UE.

LMF:

- To support UE unaware positioning: receives the UE unaware indication from AMF and selects positioning method based on the indication.

LCS Client/AF:

- To support UE unaware positioning: send UE unaware positioning indication to GMLC.

- To support user unaware positioning: send user unaware positioning indication to GMLC.

## 6.15 Solution #15: PRU assisted LCS architecture and procedure

### 6.15.1 Introduction

This solution addresses Key Issue #7, especially on the enable of the PRU management in 5GC and utilize the PRU to enhance the LCS procedure.

### 6.15.2 Functional Description

The procedures in clause 6.15.3.1 is used for 5GC to obtain the available PRU(s)/Reference UE information. The procedures in 6.15.3.2 and 6.15.3.3 are used for the 5GC to choose the candidate PRU(s) and to use the candidate PRU(s) to enhance the location service procedure.

#### 6.15.2.1 PRU Information

The PRU information consists the following aspects:

Capability: indicate the capability a PRU supports positioning signal transmission capability and positioning measurement capability on Uu and PC5, based on that information, PRUs/Reference UE could be selected as candidate PRUs/Reference UE to assist the positioning of other UE.Note 1: The positioning signal transmission capability and signal measurement capability on PC5 relates to the study in RAN WG.

* Location information, e.g. whether absolute location coordinates are available and to which degree of accuracy. This is required if a PRU to be utilized for timing calibration or to be utilized to complete the insufficient LoS path. The location information may include other parameters, such as velocity information, time stamps or duration of valid location information etc.
* Mobility state, whether a PRU is fixed or mobile.
* State indication, e.g. ON/OFF: this indicates whether a PRU is enabled to assist positioning of the other UEs.

#### 6.15.2.2 PRU Information Acquisition

PRU information could be obtained by 5GC via three different ways:

1. Registration to AMF

A UE can be registered as a PRU. When a PRU registers to the network, the PRU information may be included in the UE context data and obtained by the AMF. After receive the PRU registration, the AMF sends message to NRF to indicate PRU existence in certain area (e.g., the TAI of the PRU location).

1. Registration to LMF

A UE can be configure as a PRU by a NF, e.g. LMF. LMF obtains PRU information via AMF. This information may be provided by the UE via LPP procedure. After receive the PRU registration, LMF sends message to NRF to indicate PRU existence in certain area (e.g., the TAI of the PRU location).

1. Subscription to UDM

A UE may be pre-configured as a PRU. Then, the PRU information may be included in the UE subscription data as a new parameter set and stored in UDM/UDR.

#### 6.15.2.3 PRU (de)/Activation

To save power, the PRU may not always be activated. 5GC may activate or deactivate the PRU(s) based on the location service requirements. This can be enabled by updating the state indication in the PRU information. For instance, LMF may determine to de/activate PRUs via AMF.

### 6.15.3 Procedures

#### 6.15.3.0 Architecture Assumption

It is assumed to reuse the existing architecture defined in Rel-17 LCS work (see TS 23.273).



Figure 6.15.3.1-0: Architecture Assumption.

#### 6.15.3.1 PRU Management

The PRU management procedure is used by 5GC to obtain the PRU information and to become aware which PRU(s)) are available in the network.

To manage PRU, three options could be considered:

* Option A: PRU registration to AMF.
* Option B.1: PRU registration to LMF.
* Option B.2: LMF obtains available PRU information via LPP procedures.

Option C: PRU information are pre-configured in the UDM.



Figure 6.15.3.1-1: PRU Management.

**Option A：PRU registration to AMF**

1a~2a. PRU initiate the registration procedure to the AMF, including the PRU capability as well as the User Location Information (i.e., CGI and TAI). The PRU may also include the mobility state (e.g., mobile or static) in its registration, so AMF can maintain all the available PRU with related information dynamically.

3a. After receive the PRU information, the AMF invokes the Nnrf\_NFManagement\_NFUpdate Request (PRU location, PRU existence indication) to NRF to indicate the PRU existence in certain areas (e.g., in one or multiple TAI(s)).

**Option B.1：PRU registration to LMF**

1b~2b. The UE provides an indication to the serving AMF whether it can function as a PRU. The serving AMF then registers the PRU to an LMF.

3b. After receive the PRU information, the LMF invokes the Nnrf\_NFManagement\_NFUpdate Request (PRU location, PRU existence indication) to NRF to indicate the PRU existence in certain areas (e.g., in one or multiple TAI(s)).

**Option B.2：PRU registration to LMF**

1b. LMF obtains available PRU information via LPP procedures.

2b. This step is same as step 3b in OptionB.1.

**Option C：PRUs information are maintained at the UDM.**

A UE may be pre-configured as a PRU with the PRU information included in the UE subscription data as a new parameter set and stored in UDM.

#### 6.15.3.2 PRU Activation/Deactivation

PRU activation/deactivation procedure is used by 5GC to enable/disable the candidate PRU(s) for assisting location service.



Figure 6.15.3.2-1: PRU activated or deactivated

1. Activation/deactivation of PRU(s) is triggered by LMF, such as based on LCS requirements, e.g. LCS QoS of target UEs cannot be met, or based on the location service procedure in clause 6.15.3.3.
2. LMF invokes the PRU activation request towards the PRU AMF. The operation request may include target UE location, PRU(s) information and triggering conditions.
3. AMF invokes a Nudm\_SDM\_Get service operation towards the UDM to obtain the privacy settings of the PRU(s). The UDM returns the PRU(s) privacy setting. AMF checks the PRU(s) Privacy profile.
4. AMF performs privacy check if the privacy profile indicates that the PRU(s) must be either notifies or verified.
5. AMF invokes the context management update operation request to UDM to update the PRU state information.
6. AMF receives the response from UDM.
7. The AMF activates the candidate PRU.
8. AMF returns PRU activation response towards LMF.

#### 6.15.3.3 Location service procedure by using PRU(s)

This clause describes the location service procedure with the assistance of PRU. Section 6.15.3.3.1 and 6.15.3.3.2 are based on the prerequisite that PRU(s) are managed by AMF, i.e., the AMF-centric. Section 6.15.3.3.3 and 6.15.3.3.4 are based on the prerequisite that PRU(s) are managed by LMF, i.e., the LMF-centric.

##### 6.15.3.3.1 AMF-centric MT-LR

The AMF-centric MT-LR requests PRU AMF to provide one or multiple candidates PRU(s) in the vicinity of target UE, e.g., the same cell or the neighbour cell, to improve positioning accuracy.

###### 6.15.3.3.1.1 MT-LR procedure based on Option A in clause 6.15.3.1



Figure 6.15.3.3-1: MT-LR procedure using PRU (AMF-centric).

Steps 1~4 are same as the steps 1-5 defined in clause 6.1.1 of TS 23.273.

1. The LMF invokes the Nnrf\_NFDiscovery\_Request Request towards NRF to request the PRU AMF. The service operation includes the target UE location information (e.g., the TAI of target UE), the indication to find the PRU AMF which could serve in the area around the target UE.
2. Based on the PRU AMF discovery indication and the target UE location information, the NRF return one or multiple PRU AMF(s) via Nnrf\_NFDiscovery\_Request Response.
3. LMF sends the PRU discovery request to PRU AMF to request the candidate PRU. The message includes the target UE location information and the target UE vicinal location (e.g., the neighbour cell of target UE).
4. Based on the message in step 7, the PRU AMF choose one or multiple candidate PRU(s) based on the target UE location, the target UE vicinal location, and the mobile state of PRU. The PRU AMF invokes PRU discovery response to LMF, includes one or multiple candidate PRU(s).
5. The LMF performs the activation procedure as defined in clause 6.15.3.2 to activate the desired PRU(s). LMF also performs one or more of the positioning procedures towards PRU as described in clauses 6.11.1, 6.11.2 and 6.11.3 of TS 23.273.
6. The LMF performs one or more of the positioning procedures towards target UE as described in clauses 6.11.1, 6.11.2 and 6.11.3 of TS 23.273.

###### 6.15.3.3.1.2 MT-LR procedure based on Option C in clause 6.15.3.1



**Figure 6.15.3.3-2: MT-LR procedure using PRU (AMF-centric).**

Steps 1~3 correspond to steps 1~4 defined in clause 6.1.1 of TS 23.273.

1. The AMF invokes Nudm\_SDM\_Get request to UDM to request PRU information of the UE(s) in the same or vicinal location with the target UE, e.g., within the target UE TAI(s).
2. UDM sends the Nudm\_SDM\_Get response to AMF, includes PRU information in the subscription information of the UE(s) in the same or vicinal location with the target UE. The AMF choose one or multiple candidate PRU(s) from those UE(s) in step 5, such as, based on the target UE location, PRU capability, location information and mobility state.
3. The target UE AMF invokes Nlmf\_Location\_DetermineLocation Request towards LMF, includes one or multiple candidate PRU information.
4. The LMF performs the activation procedure as defined in clause 6.15.3.2 to activate the desired PRU(s). LMF also performs one or more of the positioning procedures towards PRU(s) as described in clauses 6.11.1, 6.11.2 and 6.11.3 of TS 23.273.
5. The LMF performs one or more of the positioning procedures towards target UE as described in clauses 6.11.1, 6.11.2 and 6.11.3 of TS 23.273.

##### 6.15.3.3.2 AMF-centric MO-LR

The AMF-centric MO-LR requests PRU AMF to provide one or multiple candidates PRU(s) in the vicinity of target UE to improve positioning accuracy.

###### 6.15.3.3.2.1 MO-LR procedure based on Option A in clause 6.15.3.1



**Figure 6.15.3.3-3: MO-LR procedure using PRU/ (AMF-centric).**

Steps 1~4 are same as steps 1~4 defined in clause 6.2 of TS 23.273.

Steps 5~10 are same as steps 5~10 in clause 6.15.3.3.1.1.

###### 6.15.3.3.2.2 MO-LR procedure based on Option C in clause 6.15.3.1



**Figure 6.15.3.3-4: MO-LR procedure using PRU (AMF-centric).**

Steps 1~2 are same as the steps 1~2 defined in clause 6.2 of TS 23.273.

Steps 3~7 are same as steps 4~8 in clause 6.15.3.3.1.2.

##### 6.15.3.3.3 LMF-centric MT-LR

The LMF-centric MT-LR requests PRU LMF to provide one or multiple candidates PRU(s) in the vicinity of target UE to improve positioning accuracy. This procedure based on option#B in clause 6.15.3.1.



**Figure 6.15.3.3-5: MT-LR procedure using PRU (LMF-centric)**

Steps 1~4 correspond to steps 1~5 defined in clause 6.1.1 of TS 23.273.

1. The LMF invokes the Nnrf\_NFDiscovery\_Request Request towards NRF to request the PRU LMF. The service operation includes the target UE location information (e.g., the TAI(s) of target UE), the indication to find the PRU LMF which could serve the target UE positioning.
2. Based on the PRU LMF discovery indication and the target UE location information, the NRF return one or multiple PRU UE LMF(s) via Nnrf\_NFDiscovery\_Request Response.
3. LMF sends PRU discovery request to PRU LMF to request the PRU information. The message includes the target UE location information and the target UE vicinal location (e.g., the neighbour cell of target UE).
4. The PRU LMF choose one or multiple candidate PRU(s) based on the target UE location, PRU capability, location information and mobility state. The PRU LMF invokes PRU discovery response to LMF, includes one or multiple candidate PRU(s).
5. The LMF performs the activation procedure as defined in clause 6.15.3.2 to activate the desired PRU(s). LMF also performs one or more of the positioning procedures towards PRU(s) as described in clauses 6.11.1, 6.11.2 and 6.11.3 of TS 23.273.
6. The LMF performs one or more of the positioning procedures towards target UE as described in clauses 6.11.1, 6.11.2 and 6.11.3 of TS 23.273.

##### 6.15.3.3.4 LMF-centric MO-LR

The LMF-centric MO-LR request PRU LMF to provide one or multiple candidates PRU(s) in the vicinity of target UE to improve the positioning accuracy.



**Figure 6.15.3.3-6: MO-LR procedure using PRU (LMF-centric).**

Steps 1~4 are same as the steps 1~4 defined in clause 6.2 of TS 23.273.

Steps 5~10 are same as in clause 6.15.3.3.3.

### 6.15.4 Impacts on services, entities, and interfaces

UE:

- Support operate as PRU and send PRU information to 5GC.

AMF:

- store PRU information in the UE context.- when receive the PRU registration, sends message to NRF to indicate PRU existence in certain area.

- aware of the PRU information if there are UE(s) can be operated as PRU(s);

- choose one or multiple candidate PRU(s) and response to LMF

LMF:

- store PRU information.

- when receive the PRU registration, send message to NRF to indicate PRU existence in certain area.

- aware of the PRU information if there are UE(s) can be operated as PRU(s);

- choose one or multiple candidate PRU(s)

NRF:

- Support NF profile update once receive the PRU existence indication.

- Support selection of AMF(s)/LMF(s) that have registered with PRU.

UDM:

- store PRU(s) information.

## 6.16 Solution #16: Support of Positioning Reference Units

### 6.16.1 Introduction

This solution addresses the questions related to Positioning Reference Units (PRU) in KI#7: support of Positioning Reference Units and Reference UEs.

### 6.16.2 Functional Description

PRU Capability Verification:

- During Registration procedure, the UE includes PRU capability in the Registration Request. The AMF verifies the capability based on the subscription data received from UDM.

PRU Information Storage:

- The PRU information is stored in the LMF: after successful Registration procedure of PRU, the AMF initiates the 5GC-NI-LR procedure (only steps 2 - 4 of the procedure are performed) to store PRU information in the LMF.

- The PRU information is stored in the NRF: in order to support that the PRU assists positioning of all UEs, but not the UEs in the service area of the LMF storing the PRU information, the LMF may further store PRU information in the LMF profile in the NRF.

- The PRU information includes LCS correlation ID, serving cell ID, serving AMF ID, PRU measurements and PRU location.

PRU Utilization:

- The LMF decides to use the PRU to assist UE positioning based on the required QoS.

- The LMF obtain PRU measurements by initiating PRU positioning or request the information from the serving LMF of the PRU. The LMF obtains the serving LMF of the PRU from NRF.

### 6.16.3 Procedures

#### 6.16.3.1 PRU Registration



Figure 6.16.3.1-1: PRU Registration procedure

1. PRU sends Registration Request to AMF. The message includes PRU capability.

2. The AMF invokes a Nudm\_SDM\_Get service operation towards the UDM to obtain subscription data of the UE to verify whether the subscription data includes the PRU subscription. If not, the AMF rejects the Registration Request.

3. The AMF returns Registration Accept to PRU.

4. After the successful registration of PRU, the AMF invokes a Nlmf\_Location\_DetermineLocation Request to LMF. The request includes PRU indication and LCS correlation ID.

5. The LMF triggers UE positioning procedure to obtain measurements and location of PRU. The LMF stores the PRU information locally, e.g. PRU serving cell ID, serving AMF ID, LCS correlation ID, PRU measurements, PRU location.

6. The LMF invokes a Nlmf\_Location\_DetermineLocation Response to AMF.

7. [Conditional] If the LMF decides to store PRU information in the NRF, e.g. the serving cell of the PRU is near the boundary of the service area of the LMF, the PRU measurements can also be used by other LMF to assist UE positioning, the LMF invokes a Nnrf\_NFManagement\_NFUpdate Request to NRF. The service operation includes NF type=LMF, supported PRU information, e.g. PRU serving cell ID, PRU location, LCS correlation ID, serving AMF ID.

8. [Conditional] If step 7 is performed, the NRF returns a Nnrf\_NFManagement\_NFUpdate Response to LMF.

#### 6.16.3.2 PRU Utilization



Figure 6.16.3.2-1: PRU Registration procedure

0. The trigger for target UE positioning happens, e.g. the AMF receives Namf\_Location\_ProvidePositioningInfo Request service operation from GMLC or receives MO-LR Request from UE.

1. The AMF invokes a Nlmf\_Location\_DetermineLocation Request to LMF.

2. The LMF triggers UE positioning procedure to obtain measurements from PRU.

3. [Conditional] If the LMF decides to obtain PRU information from NRF, e.g. the PRU(s) stored in the LMF is not available to assist UE positioning, the LMF invokes a Nnrf\_NFDiscovery Request to NRF. The request includes NF type=LMF, cell ID or cell list, PRU indication.

4. [Conditional] The NRF returns a Nnrf\_ NFDiscovery Response to LMF. The response includes LMF ID and PRU information.

5. [Conditional] If LMF receives PRU information and the serving LMF of the PRU from NRF, the LMF sends the Nlmf\_Location\_DetermineLocation Request to the serving LMF of the PRU.

6. [Conditional] If step 5 is performed, the serving LMF of PRU triggers UE positioning procedure to obtain measurements from PRU.

7. [Conditional] If step 6 is performed, the serving LMF of PRU sends the Nlmf\_Location\_DetermineLocation Response to the serving LMF.

8. The LMF calculates UE location based on the measurements obtained from PRU in step 4 and step 7 and invokes a Nlmf\_Location\_DetermineLocation Response to AMF.

### 6.16.4 Impacts on services, entities, and interfaces

AMF:

- During Registration procedure, receive PRU capability from PRU and verify the capability using the subscription data.

- After PRU successful registration, AMF initiates the 5GC-NI-LR procedure (only steps 2 - 4 are performed) to store PRU information in LMF. The AMF includes PRU indication in step 2 of the 5GC-NI-LR procedure.

LMF:

- During the 5GC-NI-LR procedure, if PRU indication is received from AMF, the LMF stores PRU information locally or stores PRU information in NRF.

- Decide to use PRU to assist UE positioning based on the required QoS, obtain available PRU based on the locally stored information or from NRF.

- To obtain PRU measurements to assist UE positioning, initiate positioning procedure for PRU or request PRU measurements from serving LMF of the PRU based on the received information from NRF.

PRU:

- Send Registration Request including PRU capability to AMF.

NRF:

- Store information of the PRU which is in the service area of LMF in LMF profile.

- Provides PRU information to LMF.

## 6.17 Solution #17: Support for 5GS Localization via Reference UE

### 6.17.1 Introduction

This solution to KI#7 as described in cl 5.7 proposes a mechanism for the 5GS to assist determining the location of a set of UEs via another UE known as reference UE. The solution addresses use cases mentioned in cl 5.7 such as the set of UEs not having LoS path with the RAN node(s), or the opportunity to reduce the signalling involved in providing location services including positioning and tracking to a set of UEs.

### 6.17.2 Functional Description

At a high level, the functional description of this solution is as follows:

* The LCS architecture is leveraged to provide location services to a set of UEs via a reference UE that acts as a ProSe UE-to-Network Relay for location reporting.
* LMF is the entity in charge of performing the interactions with the ProSe Application Server and the PCF.
* The reference UE is configured or provisioned with special Relay Service Codes (RSCs) authorized for location reporting.
* The positioning of the set of UEs not configured as relays can be performed by the reference UE via sidelink positioning in RAN. This set of UEs are authorized to act as relayed UE for location reporting.

### 6.17.3 Procedures



0a. ProSe capabilities of the UEs are registered with the AMF beforehand. This may include the support for location reporting in addition to other ProSe capabilities. Also the LPI for ProSe based localization can be given by the UE’s at this stage, again to the AMF.

0b. The LCS client request location services for multiple UEs to the 5GS, either via a single or multiple location requests. After receiving the location request from the LCS client, the LMF starts the localization procedures as in a default scenario for periodic location requests, as shown in TS 23.273 [5], clause 6.3.1.

1. The LMF may identify a set of UEs for a certain group by considering all UEs within an area of interest, leaving any grouping or pairing to the direct discovery protocol of the ProSe as described in TS 23.304 [X].

2. The LMF checks the ProSe capabilities registered for the UEs in Step 0 with the AMF.

3. For the UEs supporting ProSe capabilities including also location reporting, the LMF interacts with the ProSe application server (or PCF) to initiate Relay operation for location reporting.

4. The ProSe application server (or the PCF) authorizes and configures a UE as the reference UE through which the other UEs (similar to ProSe Remote UEs) can relay location information to the 5GC and the LMF. The reference UE (acting similar to a ProSe UE-to-Network Relay as specified in TS 23.304 [x]) is configured or provisioned with special Relay Service Codes (RSCs) authorized for location reporting. This is provided by the PCF, already provisioned in the ME or configured in the UICC.

5. The ProSe application server (or the PCF) authorizes, configures or provisions other UEs with special RSCs authorized for location reporting. This is provided by the PCF, already provisioned in the ME or configured in the UICC.

6-7. The ProSe Relay Discovery on the UEs identified in Steps 1-3 is conducted with special RSCs based on either model A or Model B as specified in TS 23.304 [x]. Once discovered, the connections between the reference UE and the other UEs are established over PC5. It is not necessary to establish any UP PDU session for such special RSCs between the reference UE (or other UEs) and network as such RSCs may not be associated with any specific PDU session parameters.

NOTE 1: Steps 6 and 7 have a dependency on FS\_Ranging\_ARC and may need alignment with FS\_Ranging\_ARC conclusions for normative work.

8. The ProSe application server (or PCF) responds or notifies the LMF when the relay configuration is complete.

9. The LMF requests location data from multiple UEs via the reference UE.

NOTE 2: AS level procedures required between NG-RAN and the reference UE are determined by RAN WGs.

10. The reference UE initiates side-link based positioning over PC5 communication session established in step 7 for the multiple UEs (as instructed by the LMF in step 9). This may include obtaining position estimates from the group of UEs, which e.g. would carry out UE based positioning, obtaining positioning assistance data from these UEs or even executing a side-link based positioning method (and gaining position information of the group of UEs). Whatever the method used, the reference UE will collect this data through side-link in this step.

NOTE 3: Steps 10 and 11 have a dependency on FS\_Ranging\_ARC and may need alignment with FS\_Ranging\_ARC conclusions for normative work.

11. The reference UE will relay location reporting data back to the LMF. The signaling overhead reduction comes in positioning protocol messages (e.g. LPP) from the reference UE to the LMF. The location information from multiple UEs can be concatenated into a fewer positing protocol messages at the reference UE, in order to save signaling overhead.

12-14. Location information is passed onto the LCS client through the AMF and GMLC. These steps are not changed from the default location responses in clause 6.3.1 of TS 23.273.

### 6.17.4 Impacts on services, entities and interfaces

AMF

- To register the support for location reporting as part of ProSe capabilities from the UE.

- To register LPI from the UE.

LMF

- To support interactions with the ProSe Application Server and PCF.

- To support location request for multiple UEs.

GMLC

- To support location request for multiple UEs.

UE

- As a reference UE (similar to a ProSe UE-to-Network Relay) to be able to interpret RSCs for location reporting.

- As a reference UE to be able to concatenate location information of other UEs as LPP messages towards 5GC.

- Other UEs (similar to ProSe Remote UE) to be able to interpret RSCs for location reporting.

## 6.18 Solution #18: Location Verification for Satellite Access assisted by NWDAF Analytics

### 6.18.1 Introduction

This solution proposes a mechanism for location verification of the UE location provided via satellite access by leveraging NWDAF analytics in the 5GC. The solution addresses KI#9 as it enables the AMF to receive statistics and predictions on the UE location, hence making it easier to determine whether the potentially inaccurate location information provided by the UE is reliable and trustable or not.

### 6.18.2 Functional description

At a high level, the functional description of this solution is as follows:

* The UE provides an initial location to NG-RAN/AMF via satellite access, and the location verification process at the 5GC is triggered.
* The AMF discovers an NWDAF instance capable of providing UE related analytics on the UE that provided its location via satellite access. If available, the selected NWDAF instance should have analytics aggregation analytics to retrieve UE related analytics from other NWDAF instances.
* If the selected NWDAF instance has aggregator capabilities, it discovers and collects UE related analytics from other NWDAF instance(s) following the procedures specified in TS 23.288 [9].
* The NWDAF instance with potential aggregator capabilities aggregates analytics (if collected), derives its own analytics, and delivers them to the AMF.
* The AMF uses the received analytics as part of its decision on whether the UE location should be accepted or rejected as provided by the UE.

### 6.18.3 Procedures



**Figure 6.18.2-1: Procedure for location verification for satellite access assisted by NWDAF analytics**

1. UE reports location to the NG-RAN.

2. NG-RAN selects a suitable AMF based on UE location (e.g. AMF A, serving Country A).

3. NG-RAN indicates to the AMF the need to verify/confirm the UE location.

4. AMF retrieves the subscriber profile of the UE from the UDM.

5. If not done previously, AMF discovers NWDAF according to cl. 5.2 of TS 23.288 [9] and 6.3.13 of TS 23.501 [2], if available supporting analytics aggregation as described in cl. 6.1A.2 of TS 23.288 [9]. In addition, AMF uses NWDAF Serving Area information, and NWDAF location information to select the appropriate NWDAF instance.

6. AMF requests or subscribes to UE related analytics (e.g. expected UE behavior, abnormal behavior, UE mobility) for one or more Analytic IDs in a given Area of Interest from a NWDAF that covers the country where the UE reported its location.

7. [OPTIONAL] The selected NWDAF instance may register with the UDM for the UE that it is collecting data for and for the related Analytic ID(s).

8. [OPTIONAL] If needed and the selected NWDAF instance has analytics aggregation capability, the NWDAF for which the AMF requested analytics discovers other NWDAF instances that may provide relevant UE related analytics on the UE ID that provided its location in step 1.

9. [OPTIONAL] The aggregator NWDAF requests UE related analytics from other NWDAF(s) on the UE which initially provided its location information to NG-RAN.

10. [OPTIONAL] If needed, other NWDAFs contacted by the aggregator NWDAF may collect data from other NFs (AMFs, SMFs, etc.) related to this UE (e.g. previous locations in other countries, any reported UE abnormal behavior, etc.).

11. [OPTIONAL] The NWDAF(s) contacted by the aggregator NWDAF derive(s) UE related analytics for the UE in the area it is responsible for, e.g. (part of) a country.

12. [OPTIONAL] The NWDAF(s) contacted by the aggregator NWDAF report(s) their analytics (UE mobility, UE abnormal behavior, etc.) to the aggregator NWDAF.

13. The aggregator NWDAF performs aggregation of the reported analytics and derives analytics.

14. The aggregator NWDAF provides (potentially aggregated) analytics to the AMF

15. AMF decides whether the UE should or should not be allowed access given the currently reported location.

16. AMF interacts with NG-RAN and/or the UE to convey the decision. For example, based on the reported UE analytics (e.g. UE behavior), the AMF and/ or NG-RAN may behave as follows:

a) In case of UE in initial access, the AMF may accept or reject UE Registration Request to the UE reported location. In case of rejection, the AMF may provide a cause value to the UE and/or NG-RAN (e.g. “inaccurate/wrong Location”, “Location is not supported”, or any other naming).

b) AMF may forward the full, part or a modified version of the analytics (e.g. UE behavior) to NG-RAN which may act upon it. For example, NG-RAN may release the UE in case of an “unexpected UE location”.

c) AMF may decide to initiate UE release procedure with the NG-RAN, and indicates the cause of UE context release as UE (e.g. “inaccurate/wrong/unexpected UE Location”, “UE Location is not supported”, or any other naming).

Editor's note: The feasibility and reliability of the solution needs further discussion and to be checked with eNA\_Ph3 and 5GSAT\_Ph2 studies.

### 6.18.4 Impacts on services, entities and interfaces

## 6.x Solution #x: solution title

Editor's note: Select a solution title that describes the main solution characteristics as to avoid multiple solutions with same or too similar title.

### 6.X.1 Introduction

Editor's note: This clause lists the key issue(s) addressed by this solution, and briefly the main principles of the solution.

### 6.X.2 Functional Description

Editor's note: This clause further details the solution principles and any assumptions made.

### 6.X.3 Procedures

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

### 6.X.4 Impacts on services, entities, and interfaces

Editor's note: This clause lists impacts to services, entities, and interfaces.

# 7 Evaluation

Editor's note: This clause provides an evaluation of the solutions of clause 6.

## 7.x Key Issue #x: <Key Issue name>

The clause evaluates the solutions for KI#1 as following.

Editor's note: For each solution, the aspects regarding compatibility with procedures and services in previous release should be evaluated.

# 8 Conclusions

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

Annex A:  
Change history

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Change history** | | | | | | | |
| **Date** | **Meeting** | **TDoc** | **CR** | **Rev** | **Cat** | **Subject/Comment** | **New version** |
| 2022-02 | SA2#149e | S2-2201583 | - | - | - | Proposed skeleton agreed at SA2#149e | 0.0.0 |
| 2022-02 | SA2#149e |  |  |  |  | Inclusion of documents approved in SA2#149-e:  S2-2200350, S2-2201584, S2-2201585,S2-2201586, [S2-2201587](file:///C:\Meetings\SAWG2\Specs\_Temp\23700-71\TSGS2_149E_Electronic_2022-02\Docs\S2-2201587.zip), S2-2201588, S2-2201589, [S2-2201015](file:///C:\Meetings\SAWG2\Specs\_Temp\23700-71\TSGS2_149E_Electronic_2022-02\Docs\S2-2201015.zip), S2-2201590, S2-2201591, S2-2201592. | 0.1.0 |
| 2022-02 | SA2#150e |  |  |  |  | Inclusion of documents approved in SA2#150-e:  S2-2202625, S2-2202674, S2-2202709, S2-2202918, S2-2202977, S2-2203291,S2-2203292, [S2-2203293](file:///C:\\Meetings\\SAWG2\\Specs\\_Temp\\23700-71\\TSGS2_149E_Electronic_2022-02\\Docs\\S2-2201587.zip" \t "_blank), S2-2203294, S2-2203295, [S2-2203](file:///C:\\Meetings\\SAWG2\\Specs\\_Temp\\23700-71\\TSGS2_149E_Electronic_2022-02\\Docs\\S2-2201015.zip" \t "_blank)296, [S2-2203](file:///C:\\Meetings\\SAWG2\\Specs\\_Temp\\23700-71\\TSGS2_149E_Electronic_2022-02\\Docs\\S2-2201015.zip" \t "_blank)297, [S2-2203](file:///C:\\Meetings\\SAWG2\\Specs\\_Temp\\23700-71\\TSGS2_149E_Electronic_2022-02\\Docs\\S2-2201015.zip" \t "_blank)298, [S2-2203](file:///C:\\Meetings\\SAWG2\\Specs\\_Temp\\23700-71\\TSGS2_149E_Electronic_2022-02\\Docs\\S2-2201015.zip" \t "_blank)299, [S2-2203](file:///C:\\Meetings\\SAWG2\\Specs\\_Temp\\23700-71\\TSGS2_149E_Electronic_2022-02\\Docs\\S2-2201015.zip" \t "_blank)300, [S2-2203](file:///C:\\Meetings\\SAWG2\\Specs\\_Temp\\23700-71\\TSGS2_149E_Electronic_2022-02\\Docs\\S2-2201015.zip" \t "_blank)301, [S2-2203](file:///C:\\Meetings\\SAWG2\\Specs\\_Temp\\23700-71\\TSGS2_149E_Electronic_2022-02\\Docs\\S2-2201015.zip" \t "_blank)302, [S2-2203](file:///C:\\Meetings\\SAWG2\\Specs\\_Temp\\23700-71\\TSGS2_149E_Electronic_2022-02\\Docs\\S2-2201015.zip" \t "_blank)303, [S2-2203](file:///C:\\Meetings\\SAWG2\\Specs\\_Temp\\23700-71\\TSGS2_149E_Electronic_2022-02\\Docs\\S2-2201015.zip" \t "_blank)304, [S2-2203](file:///C:\\Meetings\\SAWG2\\Specs\\_Temp\\23700-71\\TSGS2_149E_Electronic_2022-02\\Docs\\S2-2201015.zip" \t "_blank)305, [S2-2203](file:///C:\\Meetings\\SAWG2\\Specs\\_Temp\\23700-71\\TSGS2_149E_Electronic_2022-02\\Docs\\S2-2201015.zip" \t "_blank)306, S2-2203600, [S2-2203](file:///C:\\Meetings\\SAWG2\\Specs\\_Temp\\23700-71\\TSGS2_149E_Electronic_2022-02\\Docs\\S2-2201015.zip" \t "_blank)601. | 0.2.0 |