**MIoT Location in Roaming**

**Version 2.0**

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# 1 Introduction

## 1.1 Overview

This white paper describes the MIoT (Mobile Internet of Things) location in roaming using different network based technologies which are complementing the device based technologies like Global Navigation Satellite System (GNSS) such as the Global Positioning System (GPS).

The background for this PRD is the existence of a clear business that needs for the accurate location of various MIoT objects, whether those are in the home network or roaming. For example, the package delivery across borders with an embedded NB-IoT/LTE-M chip, could provide customers (almost) real-time information on where it is located, in case the location information is available to the home operator by the visited operator(s). Unfortunately, this is not the case at the moment. Therefore, it would be beneficial to have a document which illustrates the issues and provides feedback on the technical solutions available to solve this problem. This information can then be used by strategic/commercial people within GSMA to decide how the industry should tackle the issue in the real world.

## 1.2 Scope

The scope of this document is to describe:

- Location requirements for MIoT, specifically without GNSS capabilities
- Use case for location retrieval by the network
- Location technologies from the device and network perspective
- Implementation on 4G and 5G networks

## 1.3 Definitions

| Term | Description |
|------|-------------|
| M2M | Machine-to-Machine, a general term referring to any network technology allowing devices to communicate with each other. For example, two industrial robots connected to each other via Ethernet in a factory, is part of M2M but not MIoT. |
| MIoT | Mobile Internet of Things, a GSMA term which refers to the 3GPP standardised LPWA technologies using the licenced band (aka LTE-M, NB-IoT and EC-GSM-IoT, Extended Coverage GSM for Internet of Things). In 3GPP Release 13 and upwards, the Category of UEs that support power consumption optimisations, extended coverage and lower complexity are part of MIoT (CAT M1, CAT NB1 from Release 13 and CAT M2, CAT NB2 from Release 14). As this particular term is widely used throughout the GSMA, it is also utilized also in this document.<br><br>Not to be confused with the term "MIoT" which means 5G Massive IoT in 3GPP terminology. |
| Roaming | GSMA PRD BA.40 [2] states that roaming is defined as the ability for wireless customers to automatically make and receive voice calls, send and receive data, or access other services when travelling outside the geographical coverage area of their own home network, by means of using a visited network |

## 1.4    Abbreviations

| Term | Description |
|------|-------------|
| 3GPP | 3rd Generation Partnership Project |
| A-GNSS | Assisted- Global Navigation Satellite System |
| AMF | Access and Mobility Management Function (5G) |
| CGI | Cell Global Identifier |
| CN | Core Network |
| CI (D) | Cell Identity |
| CS | Circuit Switch |
| DB | Data Base |
| ECI | EUTRAN Cell Identifier |
| E-CID | Enhanced Cell ID Method |
| ECGI | E-UTRAN Cell Global Identifier |
| EPC | Evolved Packet Core |
| EPS | Evolved Packet System |
| EUTRAN | Evolved UMTS Terrestrial Radio Access Network |
| GMLC | Gateway Mobile Location Centre |
| GNSS | Global Navigation Satellite System |
| GPS | Global Positioning System |
| GPRS | General Packet Radio Service |
| GSM | Global System for Mobile Communications |
| GSMA | GSM Association |
| GTP | GPRS Tunnelling Protocol |
| HLR | Home Location Register |
| HPLMN | Home Public Land Mobile Network |
| HSS | Home Subscriber Server |
| HTTPS | Hypertext Transfer Protocol Secure |
| IDA | Insert Subscriber Data Answer |
| IDR | Insert Subscriber Data Request |
| IMSI | International Mobile Subscriber Identity |
| IP | Internet Protocol |
| IoT | Internet of Things |
| IWF | Interworking Function |
| IWK-SCEF | Interworking-SCEF |
| LBS | Location Base Service |
| LAC | Location Area Code |
| LCS | Location Service |
| LMF | Location Management Function (5G) |
| LPWA | Low Power Wide Area |

| Term | Description |
|------|-------------|
| LRF | Location Retrieval Function |
| LS | Location Server (SMLF / LMF) |
| LTE | Long Term Evolution |
| LTE-M | a.k.a. LTE MTC Cat M1, Long Term Evolution Machine Type Communication Category M1, but also including further Categories like Category M2. |
| LMU | Location Measurement Unit |
| M2M | Machine to Machine |
| MAP | Mobile Application Part |
| MCC | Mobile Country Code |
| MSC | Mobile Switch Centre |
| MIoT | Mobile IoT |
| MME | Mobility Management Entity |
| MSISDN | Mobile Station International ISDN Number |
| MT-LR | Mobile Terminated Location Request |
| MTC | Machine Type Communications |
| MSC | Mobile Switching Centre |
| NAS | Non-Access Stratum |
| NAT | Network Address Translation |
| NB-IoT | Narrowband IoT |
| NEF | Network Exposure Function (5G) |
| NF | Network Function |
| NI-LR | Network Induced Location Request |
| NPLI | Network Provided Location Information |
| NR | New Radio |
| NR CGI | New Radio Cell Global Identifier |
| OTDOA | downlink Observed Time Difference Of Arrival |
| OTT | Over The Top |
| PLMN | Public Land Mobile Network |
| OTT | Over The Top |
| PEI | Permanent Equipment Identity |
| PLA | Provide Location Answer |
| PLR | Provide Location Request |
| PMN | Public Mobile Network |
| PS | Packet Switch |
| PSM | Power Save Mode |
| RAT | Radio Access Technology |
| SCEF | Service Capability Exposure Function |
| SGSN | GPRS Support Node |

| Term | Description |
|------|-------------|
| SIM | Subscriber Identification Module |
| SMS-SC | Short Message Service-Service Centre |
| SMLC | Serving Mobile Location Centre |
| SMS | Short Message Service |
| SMSC | Short Message Service Centre |
| SUPI | Subscription Permanent Identifier |
| TCP | Transmission Control Protocol |
| UDM | Unified Data Management |
| UE | User Equipment |
| ULI IE | Uplink Information Extraction |
| U-TDOA | Uplink-Time Difference Of Arrival |
| VPLMN | Visited Public Land Mobile Network |

## 1.5 References

| Ref | Doc Number | Title |
|-----|-----------|-------|
| 1 | 3GPP TS 29.002 | Mobile Application Part (MAP) specification |
| 2 | 3GPP TS 23.032 | Universal Geographical Area Description (GAD) |
| 3 | 3GPP TS 23.271 | Location Services (LCS); Functional description (2/3/4G) |
| 4 | 3GPP TS 29.172 | Location Services (LCS); Evolved Packet Core (EPC) LCS Protocol (ELP) between the Gateway Mobile Location Centre (GMLC) and the Mobile Management Entity (MME); SLg interface |
| 5 | 3GPP TS 29.272 | Evolved Packet System; MME and SGSN Related Interfaces Based on Diameter Protocol |
| 6 | 3GPP TS 29.274 | Tunnelling Protocol for Control plane (GTPv2-C); Stage 3 |
| 7 | 3GPP TS 38.413 | NG-RAN; NG Application Protocol (NGAP) |
| 8 | 3GPP TS 23.273 | 5G System (5GS) Location Services (LCS) |
| 9 | 3GPP TS 36.305 | Functional specification of User Equipment (UE) positioning in E-UTRAN; Stage 2 |
| 10 | 3GPP TS 38.305 | Functional specification of User Equipment (UE) positioning in NG-RAN; Stage 2 |
| 11 | 3GPP TS29.518 | 5G System; Access and Mobility Management Services, stage3 (Namf_Location Service) |
| 12 | 3GPP TS 29.572 | 5G System; Location Management Services; Stage 3 (Nlmf_Location) |
| 13 | 3GPP TS 29.328 | IP Multimedia (IM) Subsystem Sh interface; Signalling flows and message contents |
| 14 | 3GPP TS 29.329 | Sh Interface based on the Diameter protocol; Protocol details |

# 2 Requirements

## 2.1 Location technologies

The picture hereafter describes different alternatives in order to locate different devices.

They are complementary solutions, maximising accuracy for GNSS (Global Navigation Satellite System) and minimising power consumption and device cost for the network solutions.

The first set of location technologies is based on the device which could use:

- a GNSS component (able to retrieve geographical coordinates) using satellite systems and provide such location to a location server. It provides very high accuracy but also requires a lot of high energy and it has a high device cost aspect.
- the mobile network information like cells (current and optionally adjacent cells) to provide location information (Cell-Id) to a location server.
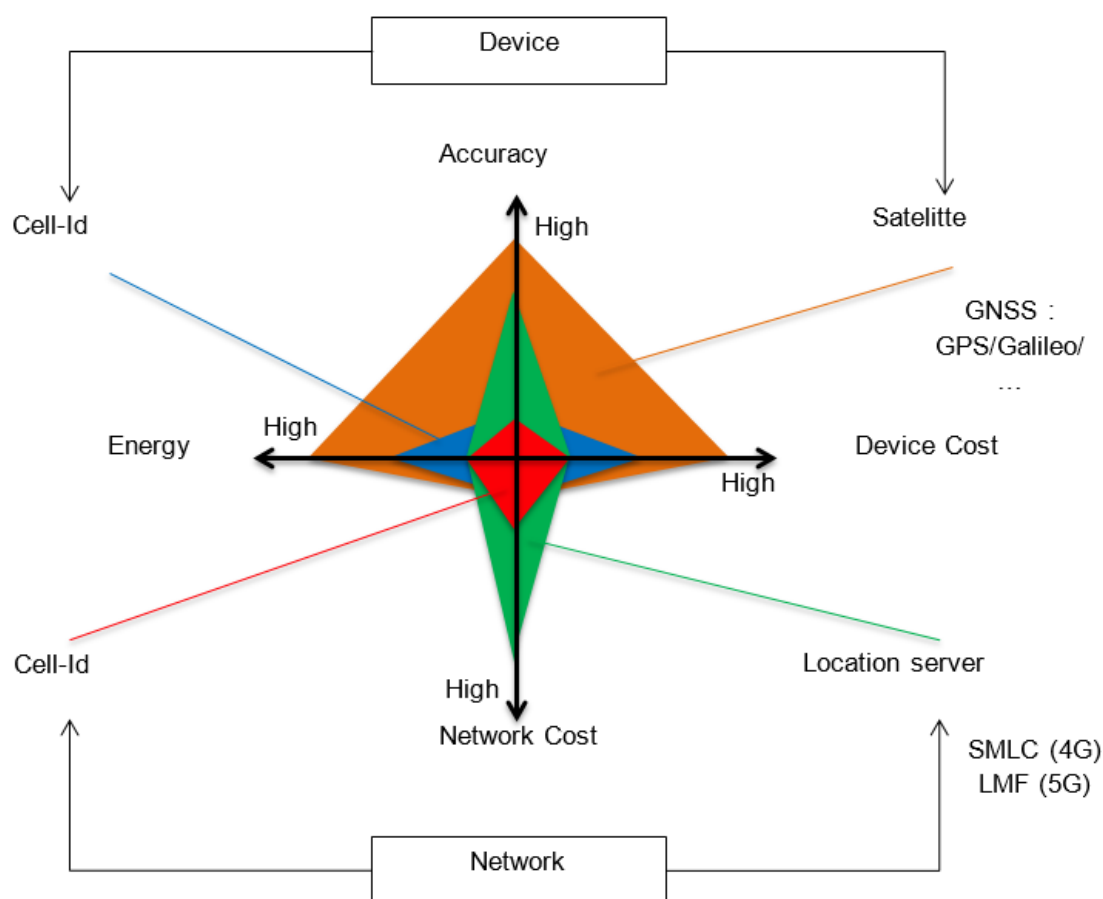
**Figure 1 Location technology**

The second set of location technologies are based on the mobile network which could use:

- the mobile network information like cells to provide location information (Cell-Id) to a location server (and optionally geographical coordinates of the cell)

- a location server Serving Mobile Location Centre (SMLC) or Location Management Function (LMF) able to retrieve geographical coordinates and provide such location to a location server – Gateway Mobile Location Centre (GMLC)

## 2.2   Location requirements

For Long Term Evolution M1 (LTE-M) and Narrow Band Internet of Things (NB-IoT), 4G techniques could be used to retrieve the Cell-Id and the geographical coordinates via the network. Those solutions could be enhanced in the 5G context, but this initial approach will start focusing on 4G solutions.

The network solution using signalling has the following advantages:

- No need for a Global Positioning System (GPS) chipset in the device (GPS or application in the Subscriber Identification Module (SIM).
- Low energy consumption because the location is provided by the network (no data connection or Short Message Service (SMS) is required).
- Location available permanently even if the device is not reachable (last known location by the network).

Based on the network initiative, some updated location requirements could be proposed:

- Rq#1: the device shall consume very low energy (10 years of energy autonomy).
- Rq#2: the device shall minimize data/SMS services while roaming in order to minimize cost to provide the location.
- Rq#3: The network location should be available even if the device is not reachable.

# 3   Use cases

## 3.1   Device journey

Devices are moving around the world, and different conditions could be foreseen during the journey. Device and Network location technologies are a complementary one during the journey.

Geographical conditions

For indoor coverage, the network solution should be the unique way to locate the device, while GNSS and the Network solution could be applicable for outdoor coverage.

Timing conditions

For some applications, it is only requested to have an accurate location at the reception of a package (using GNSS) while during the journey. Only low/medium accuracy is requested when using the network solutions.

## 3.2    Device reachability

In order to save battery, the devices are not always directly reachable (due to Power Save Mode for example). If the device is not reachable, it will be difficult for the network to locate the device.

The figure hereafter describes the relationship between the geographical accuracy, the Power Save Mode period and the speed of the object: a high accuracy needs a lot of energy, while a lower accuracy could save power.
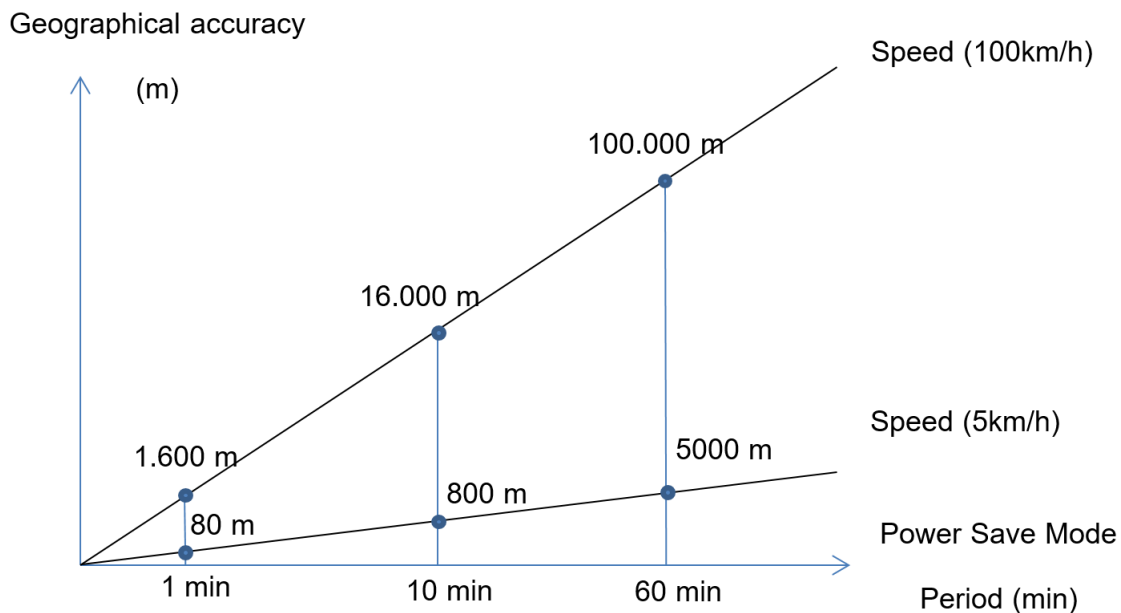


**Figure 2 Geographical accuracy**

As an example, if the average speed of an object is 5 km/h, and if the Power Save Mode (PSM) period is 10 minutes, then the object has potentially moved 800m during this time. This is important to know as it will have an impact on the geographical accuracy requirements.

# 4    Device Location technology

Several technologies are available on the device to enable the object location:

- The device GNSS component will provide the geographical information (latitude, longitude) to a location server
- The device will provide the Cell-id of the mobile network to a location server

## 4.1    Satellite (GNSS)

The most popular one is based on satellite called Global Navigation Satellite System - GNSS (GPS, Galileo, …).

The location of an object could be retrieved by asking the device to turn on the GNSS component, and provide back the geographical information (latitude and longitude). It is based on satellite signal observation and it provides a very high accuracy (5-30m).

It requires a lot of energy and has a high device cost aspect. Additionally, the GNSS solution is not available in indoor conditions (no satellite visibility). Some mobile networks usages are also required to carry such GNSS information to the location servers managing objects.

## 4.2 Cell-Id

Instead of using the satellite signals, the device could also capture the mobile network signals and provide the location information (current Cell-Id and optionally adjacent cells) to a location server.

This solution does not require any GNSS component, but accuracy is low (a little bit better than pure cell-id, due to adjacent cells knowledge).

A major issue is related to the translation of the cell-id into the geographical information (latitude, longitude). An External Database is required, using the Over the Top (OTT) information.

# 5 Network Location technology

## 5.1 Location definition

The location provided by the network could be:

- Cell identity (see Annex A.1)
- Geographical Information (Latitude, Longitude, Uncertainty code) (see Annex A.2)

The cells are identified in a different way according to the network technologies:

- 2/3G: Global System for Mobile communications (GSM) cellGlobalId (CGI)
- 4G: Evolved UMTS Terrestrial Radio Access Network (EUTRAN) e-utranCellGlobalIdentity – (ECGI)
- 5G: New Radio (NR) nrCellGlobalIdentity – (NR-CGI)

If the User Equipment (UE) is unavailable, it is important to note that the network will provide the time elapsed since the last radio contact of the location and the latest known Cell-Id.

## 5.2 2/3/4G location architecture

The picture hereafter (3GPP TS 23.271 [3]) describes the different 2/3/4G network architecture to provide the network location, mainly based on cell-id but also enhanced to the geographical coordinates.
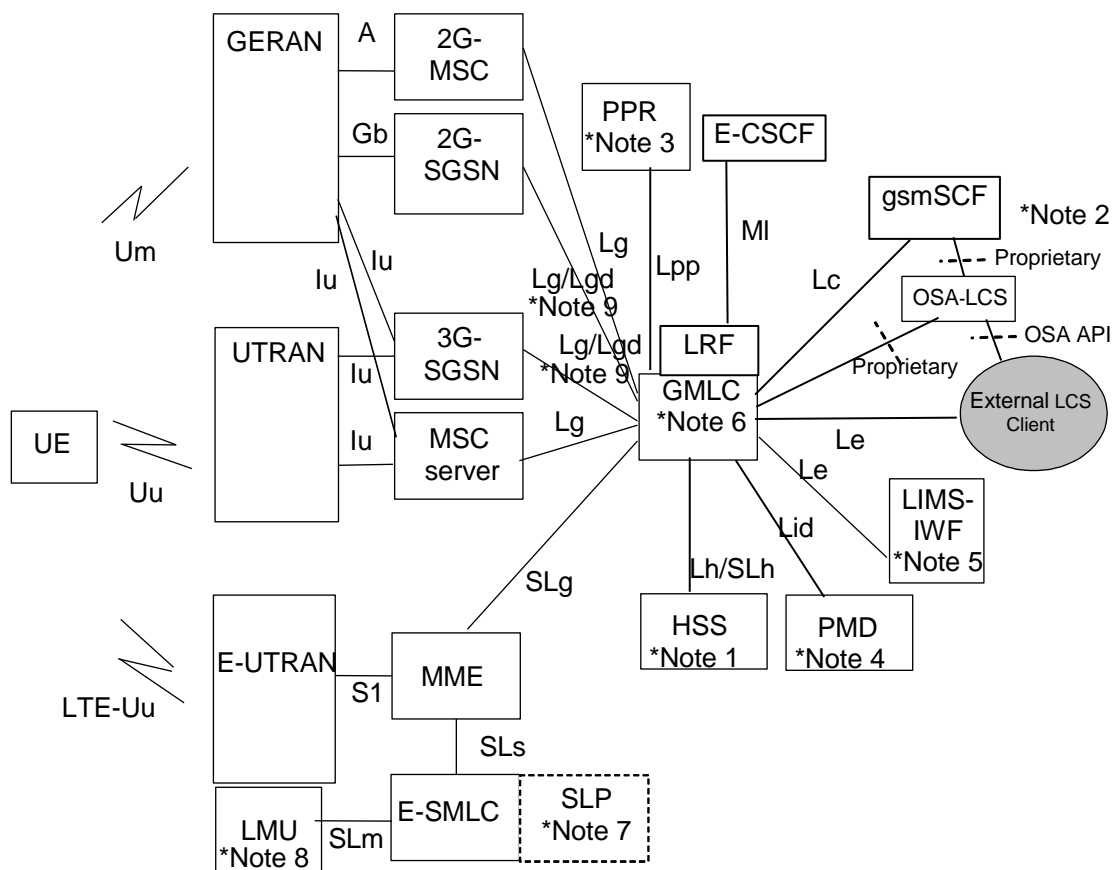
**Figure 3 Location network architecture**

The Gateway Mobile Location Centre (GMLC) is able to interrogate different access nodes located in the visited network by using the adequate interfaces and retrieve:

- The basic cell location provided by the core network Mobile Switching Centre/GPRS Support Node/Mobility management Entity (MSC/SGSN/MME) and optionally the geographical coordinates of the cell.
- The geographical coordinates of the object provided by an advanced location server, the Serving Mobile Location Centre (SMLC)

## 5.3    5G location architecture

The figure hereafter (3GPP TS23.273 [8]) describes the 5G location architecture.

The 5G architecture reuses the GMLC concept and adds a new core network managing the location inside the 5G specific component and retrieve:

- The basic cell location provided by the core network Access and Mobility Management Function (AMF) and optionally the geographical coordinates of the cell
- The geographical coordinates of the object provided by an advanced location server (LMF).
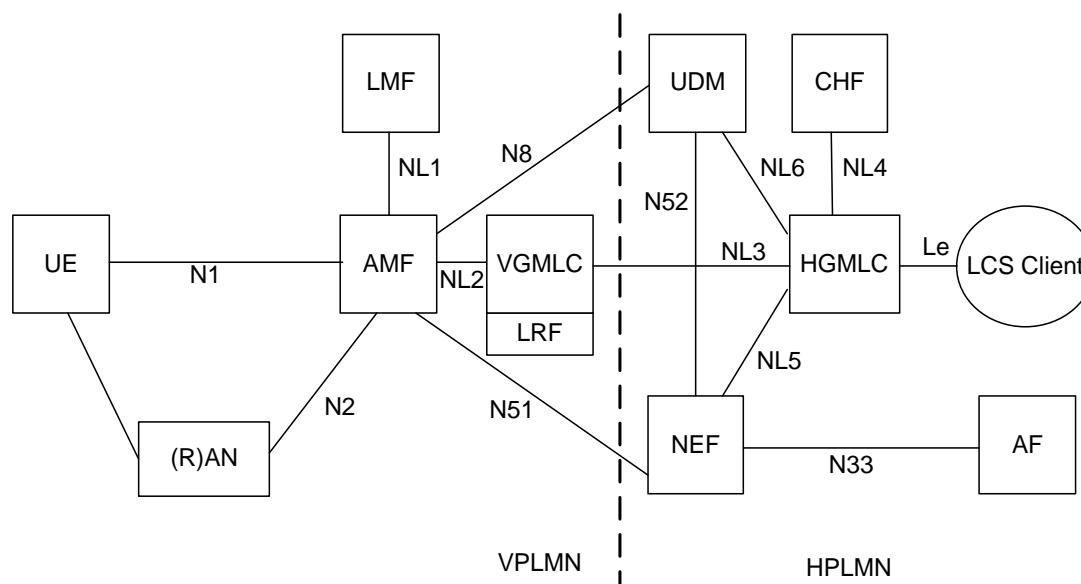
**Figure 4 5G Location network architecture**

## 5.4    Location procedures

3GPP has defined 2 categories of procedure to retrieve the location information.

LCS category is based on specific architecture for location, as defined in 3GPP TS23.271 [3] and 3GPP TS23.273 [8] (Interfaces containing "L").

Other non 3GPP LCS interfaces could also be used to retrieve the location information, reusing existing interfaces designed for mobility or subscriber management.

### 5.4.1    LCS interfaces

The Location Service (LCS) procedures could be used to retrieve the location from the 2/3/4/5G networks (see annex B for more details).

In order to retrieve the object location, Mobile Terminated Location Request (MT-LR) will be used, including potentially privacy checking.

For MT-LR Location Request, when a LCS service request is received at the 5GC GMLC, the target UE may be served by either 5G Core (5GC) or Evolved packet Core (EPC). An EPC/5GC common interface is used between the LCS Client and the 5GC GMLC: this common interface enables the location service request being handled based on whether the target UE is, served by EPC or 5GC. The AF initiates the service request to the 5GC GMLC via the Network Exposure Function (NEF).
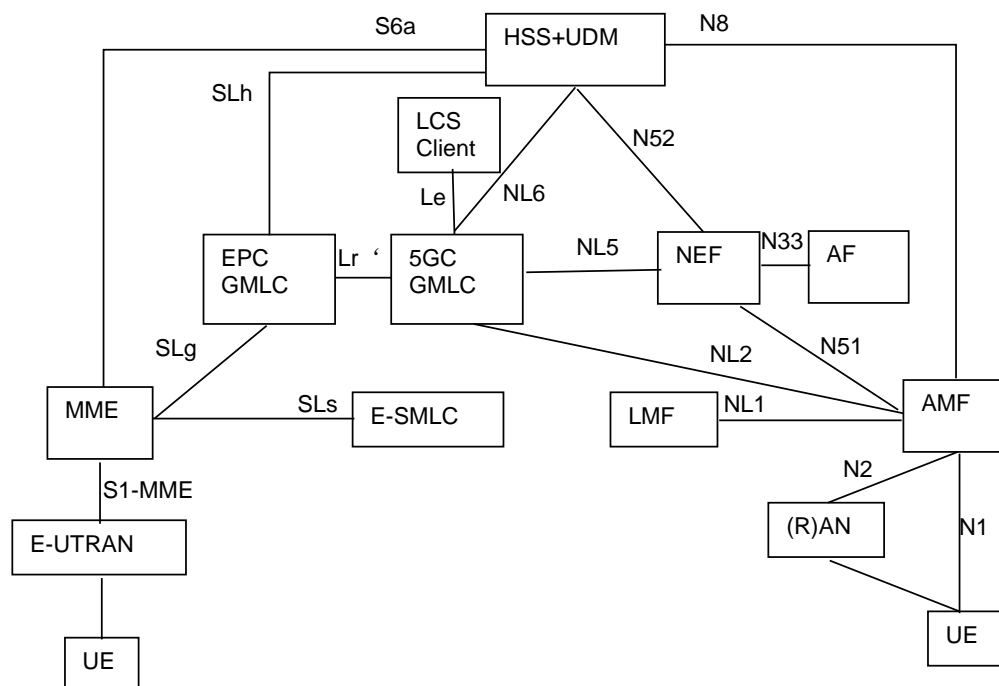
**Figure 5 4/5G Location network architecture**

### 5.4.2    Non LCS interfaces

Non LCS procedures reuse mobility or subscriber management procedures (see annex C for more details).

The following interfaces are designed to retrieve location information from the Application to the Subscriber Database (HLR/HSS/UDM) for the different access networks (CS/PS/EPS/5GS)

- MAP ATI interfaces for HLR
- Diameter Sh for HSS

The following interfaces are designed to retrieve location information from the Subscriber Database (HLR/HSS/UDM) to the Core networks nodes.

- MAP PSI interfaces for the 2/3G networks (MSC/SGSN)
- Diameter S6a/S6d for the PS networks (SGSN/MME)
- HTTPs N8 for 5GS (AMF)

**Figure 6  2/3/4/5G Location network architecture (non LCS)**

## 5.5    Positioning methods

The location architecture enables different positioning methods:

- Basic Cell Id is enabled by the Core network nodes (MSC/SGSN/MME/AMF) and optionally by the geographical coordinates of the cell
- Enhanced positioning methods are enabled by specific location servers (SMLC/LMF): Positioning the UE involves two main steps: signal measurements and the position estimation, also velocity computation based on the measurements could be optional.
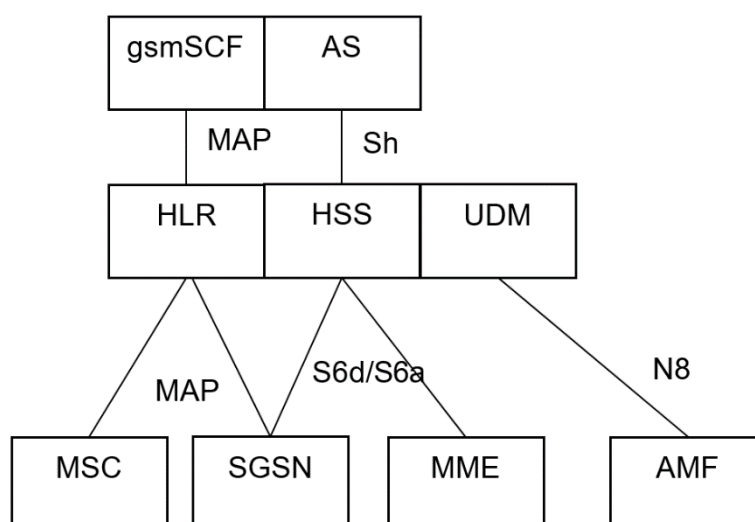
The 4G standard positioning methods (described in 3GPP TS 36.305 [9]) supported are:

- Network-assisted **GNSS** methods;Assisted- Global Navigation Satellite System (A-GNSS): The use of UEs that are equipped with radio receivers capable of receiving GNSS signals
- **Downlink** positioning Downlink Observed Time Difference Of Arrival (O-TDOA): The UE position is estimated based on the measurements of downlink radio signals from multiple Transmission Points taken at the UE, along with the knowledge of the geographical coordinates of the measured Transmission Points and their relative downlink timing.
- **Enhanced** Cell ID method (E-CID): The UE position is estimated with the knowledge of the geographical coordinates of its serving eNodeB. Enhanced Cell ID positioning refers to those techniques which use an additional UE and/or E UTRAN radio resource related measurements, to improve the UE location estimate that is based on Timing Advance (TA) and/or Neighbour Cell (and Rx level) and/or Angle of Arrival (AoA) measurements.
- **Uplink** positioning Uplink-Time Difference Of Arrival (U-TDOA): The UE position is estimated, based on the timing measurements of the uplink radio signals taken at different Location Measurement Unit (LMUs), along with the knowledge of the geographical coordinates of the LMUs. The time required for a signal to be

transmitted by a UE to reach a LMU is proportional to the length of the transmission path between the UE and the LMU.

The table hereafter describes the impacts of different positioning methods:

| Method | UE-based | UE-assisted | eNB- assisted | 3GPP release |
|---|---|---|---|---|
| A-GNSS | Yes<br>Measurements: UE<br>Estimation: UE | Yes<br>Measurements: UE<br>Estimation: LS | No | Rel-9 |
| Downlink (O-TDOA) | No | Yes<br>Measurements: UE<br>Estimation: LS | No | Rel-9 |
| Enhanced Cell-Id (E-CID) | No | Yes<br>Measurements: UE<br>Estimation: LS | Yes<br>Measurements: eNB<br>Estimation: LS | Rel-9 |
| Uplink (U-TDOA) | No | No | Yes<br>Measurements: eNB<br>Estimation: LS | Rel-11 |

Similar positioning methods are also defined for 5G (described in 3GPP TS 38.305 [10]).

Positioning accuracy depends on the different positioning methods and the table hereafter provides an overview of the expected accuracy.

| Positioning methods | Characteristics | Accuracy |
|---|---|---|
| Cell-ID | Use basic Cell ID info from the network | 100m-3km |
| E-CID + TA | Combines Cell ID with Timing Advance | 500m |
| E-CID + AOA | Mobile measures angle of Arrival | 100-200m |
| Downlink (O-TDOA) | Mobile measures downlink Timing Difference | 50-200m |
| Uplink (U-TDOA) | Mobile measures uplink Timing Difference | <50m |
| GPS/Assisted GPS | Use GPS Receivers in Device/Network | 5-30m |

The positioning accuracy depends also a lot on the cellular design: accuracy in rural areas is lower than in urban areas due the cell density (5G cell density in most cases should be higher than in 4G).

# 6   4G network location

## 6.1   Overview

All the 4G options proposed into this document are based on information exchanged with a Diameter signalling protocol, between the home and the visited network. The home network (via the Gateway Location Centre – GMLC) is able to retrieve the Cell-Id by sending a Diameter message to the visited network. The MME of the visited network is answering to this request by providing the Cell-Id and optionally the geographical coordinates.
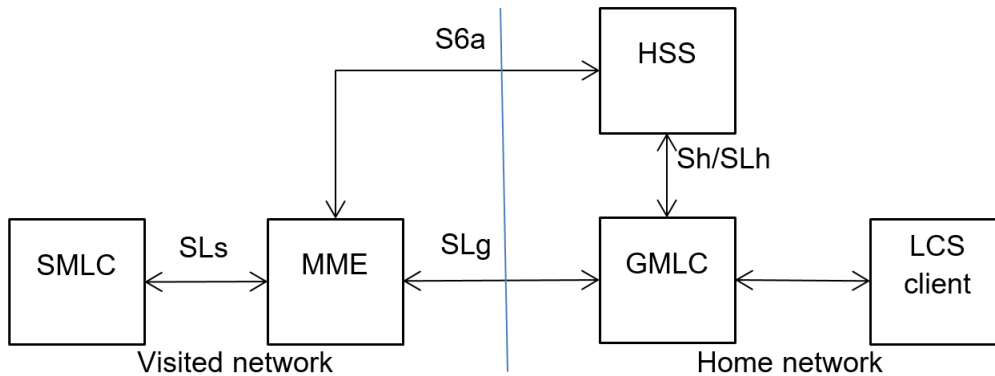
**Figure 7 4G location detailed architecture**

In order to retrieve the location information, 2 different signalling messages could be used see annex C for more detail):

- S6a: Insert-Subscriber-Data-Request/Answer (IDR/IDA)
- SLg: Provide-Location-Request/Answer (PLR/PLA) (LCS architecture)

The 2 signalling interfaces are able to carry the following parameters:

| 4G Location Request | IDR (S6a) | PLR (SLg) | Definition |
|---|---|---|---|
| Flag | IDR-Flags (EPS Location Information Request,  Current Location Request, …) | | TS 29.272 |
| Location Type | | SLg-Location-Type (current, last known, …) | TS 22.071 |

| 4G Location Answer | IDA (S6a) | PLA (SLg) | Definition |
|---|---|---|---|
| Cell-id | E-UTRAN-Cell-Global-Identity | ECGI | TS 29.002 |
| Location X,Y+ Confidence | Geographical-Information | Location-Estimate | TS 23.032 |
| AgeOfLocationInformation | AgeOfLocationInformation | Age-Of-Location-Estimate | TS 29.002 |

## 6.2  4G scenario

Based on those signalling messages, three solutions could be proposed in 4G in order to retrieve the Cell-Id and the associated geographical coordinates. The solution complexity and accuracy could vary depending on the visited network implementation:

- Cell-Id: the visited MME will provide the Cell-Id (ECGI) to the home GMLC
- Cell geographical coordinates: the visited MME will provide the geographical coordinates (latitude, longitude) of the cell to the home GMLC
- Object geographical coordinates: the visited MME (via the SMLC) will provide the geographical coordinates (latitude, longitude) of the object to the home GMLC.

### 6.2.1  4G / Cell-Id

The home network is able just to retrieve the Cell-Id where the object is located, based on the reception of the Provide-Location-Answer or the Insert-Subscriber-Data-Answer Diameter messages provided by the visited network, containing the cell identity.
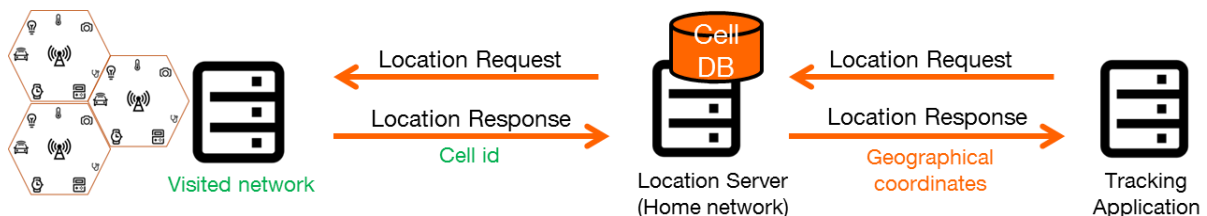


**Figure 8 4G: Cell-Id**

This solution is the simplest one, relying on the existing Insert-Subscriber-Data-Request message or requiring only the opening of the ProvideLocationRequest message of the visited network (MME side).

The major issue is the translation of the Cell-Id into geographical coordinates which could be based on external DB provided by external partners (like OTTs). Those DB accesses are costly and not always provide trusted information.

### 6.2.2  4G / Cell geographical coordinates

The home network is able to retrieve the Cell-Id where the object is located and the estimated geographical coordinates of the cell based on the Provide-Location-Answer or the Insert-Subscriber-Data-Answer Diameter message provided by the visited network.

**Figure 9 4G: Cell geographical coordinate**

The solution is a little bit more complex due to the fact that the visited networks have to configure the MME cell list with the estimated geographical coordinates of the cell.

The major advantage is that they are no more dependency related to Over the Top OTTs external DBs for Cell-Id translation into geographical coordinates.

### 6.2.3    4G / Object geographical coordinate

The home network is able to retrieve the Cell-Id and the estimated geographical coordinates of the object based on the Provide-Location-Answer or the Insert-Subscriber-Data-Answer Diameter message provided by the visited network.
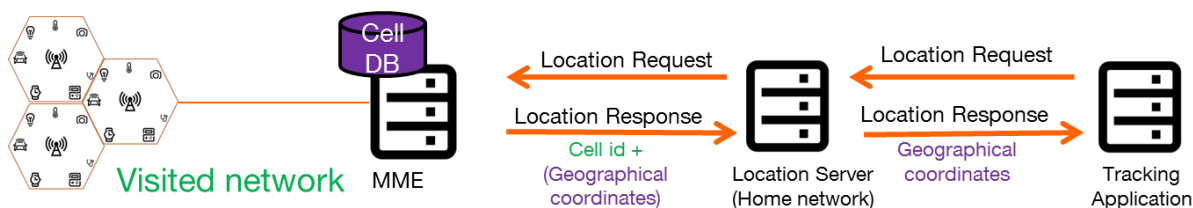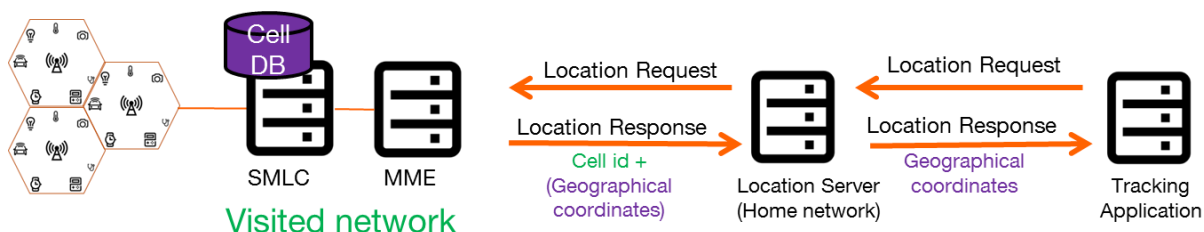


**Figure 10 4G: Object geographical coordinate**

The SMLC (Serving Mobile Location Centre) provided by the visited network is using various technologies to estimate the object location like E-CID (enhanced Cell-Id) or OTDOA (Observed Time Difference of Arrival). The advantage of the SMLC introduction is the accuracy improvement, while there is a significant increase of the solution cost.

# 7   5G networks location

## 7.1   Overview

All the 5G options proposed into this document are based on information exchanged with Hypertext Transfer Protocol Secure (HTTPS) signalling protocol, between the home and the visited network. The home network (via the Gateway Location Centre – GMLC) is able to retrieve the Cell-Id by sending a HTTPs message to the visited network. The AMF of the visited network is answering to this request by providing the Cell-Id and optionally also the geographical coordinates.
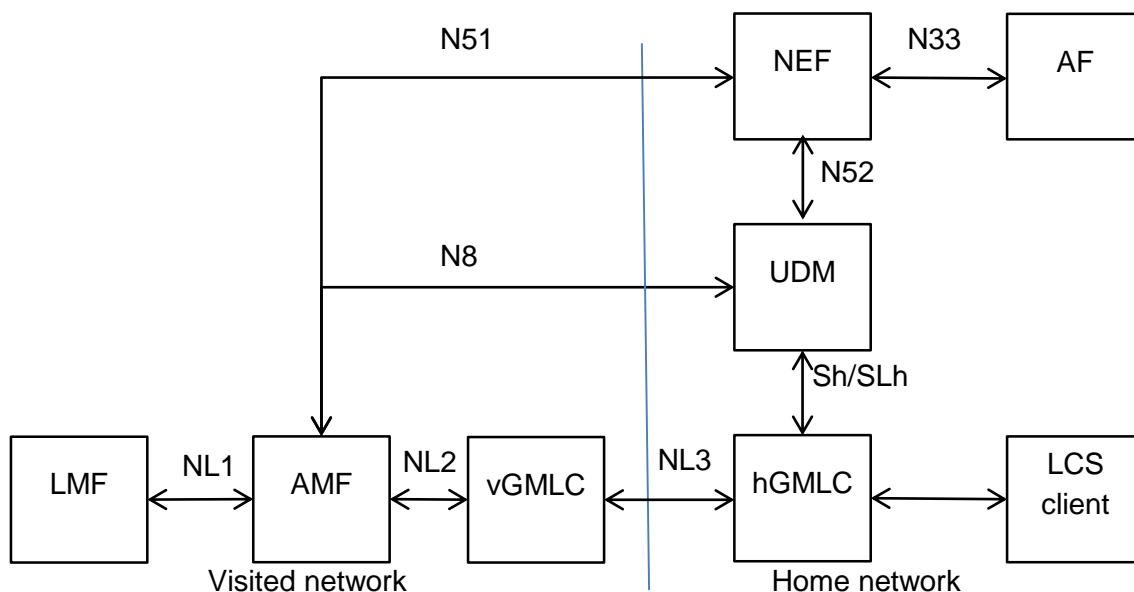
**Figure 11  5G location detailed architecture**

In order to retrieve the location information, 2 different HTTPs signalling messages could be used. See annex C for more detail):

- N8: ProvideLocationInfo
- NL2/3: ProvidePositioningInfo (LCS architecture related to MT-LR procedure)
- N51: EventExposure

The figure hereafter describes the Service Based approach for Location Services
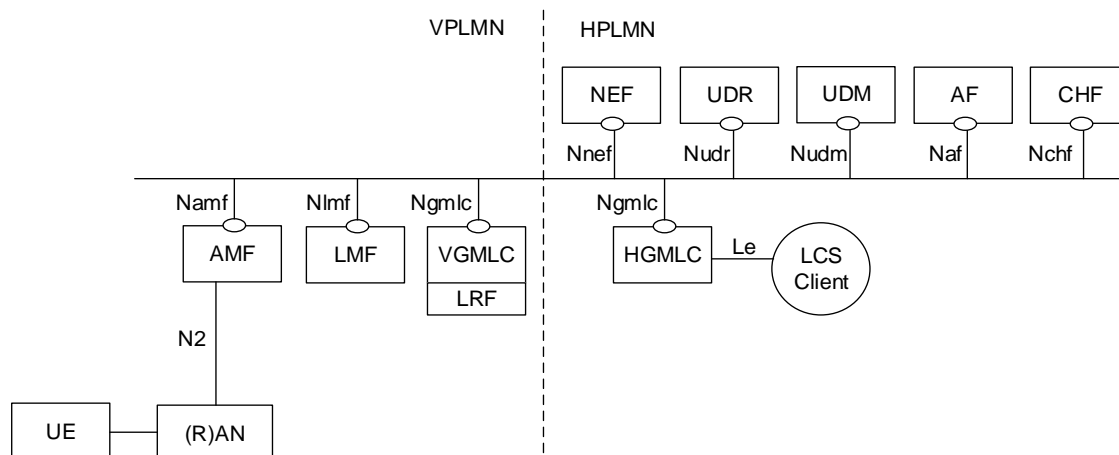


**Figure 12 5G location detailed architecture (service based)**

Namf_Location Service (3GPP TS29.518 [11]) defines the 2 potential methods:

- ProvideLocationInfo (annex D): allows a Network Function (NF) Service Consumer (e.g. Unified Data Management UDM) to request the Network Provided Location Information (NPLI) of a target UE.
- ProvidePositioningInfo (LCS architecture related to MT-LR procedure) (annex C): invoked by the NF Service Consumer (e.g. GMLC) to request the current geodetic

and optionally civic location of the UE. The service operation triggers the AMF to invoke the service towards the LMF.

- Namf_EventExposure Service (3GPP TS29.518 [11], §5.3) defines an additional method:
- Event: Location-Report: NEF subscribes to this event to receive the last known location of a UE or a group of UEs or any UE, and Updated Location of any of these UEs when AMF becomes aware of a location change of any of these UEs with the granularity as requested.

## 7.2   5G scenario

Based on those signalling messages, three solutions could be proposed in 5G (similar to 4G) to retrieve the Cell-Id and the associated geographical coordinates. The solution complexity and accuracy could vary depending on the visited network implementation:

- Cell-Id: the visited AMF will provide the Cell-Id (NR CGI) to the home GMLC.
- Cell geographical coordinate: the visited AMF will provide the geographical coordinates (latitude, longitude) of the cell to the home GMLC.
- Object geographical coordinate: the visited AMF (via the LMF) will provide the geographical coordinates (latitude, longitude) of the object to the home GMLC.

# 8   Conclusions and recommendation

The table hereafter summarizes the impacts of the different options related to 4G and 5G:

|  | Roaming signalling exchanged | Positioning Accuracy | 4G Visited Network Impact | 5G Visited Network Impact | Cell BD: OTT dependency |
|---|---|---|---|---|---|
| Solution 1 | Cell-Id | CID (100m-3km) | Low | Low | Yes |
| Solution 2 | Cell geographical coordinates | CID (100m-3km) | Medium (MME impact) | Medium (AMF impact) | No |
| Solution 3 | Object geographical coordinates | e-CID (500m) OTDOA (50-200m) | High (SMLC introduction) | High (LMF introduction) | No |

This table shows that

- A reduced dependency to the OTTs Cell-Id DBs will be based on the Diameter/http enrichment, provided by the visited network (Solution 2)
- A better accuracy will require a SMLC/LMF investment at the visited network side (solution 3).

**Recommendation**

For Solution 1 (Cell Id), S6a interface is recommended for the initial deployment, based on existing IDR/IDA messages. This will progressively replace the MAP PSI widely deployed for CS location information.

# 9   Further studies

- Use case: Periodical Location versus location on request
- Clear definition of latest known cell id in the core network (impact PSM, battery, …)
- Service Capability Exposure Function (SCEF) impact on location

# Annex A    Location parameters

## A.1    Cell definition

The cells are identified in a different way according to the network technologies:

- 2/3G : GSM cellGlobalId (CGI)
- 4G: EUTRAN e-utranCellGlobalIdentity – (ECGI)
- 5G: nrCellGlobalIdentity – (NR-CGI)

### A.1.1    CGI

Extract 3GPP TS 29.274

The coding of CGI (Cell Global Identifier) is depicted in Figure 8.21.1-1. Only zero or one CGI field shall be present in ULI IE.

| Octets | Bits | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 |
| a | MCC digit 2 | | | | MCC digit 1 | | | |
| a+1 | MNC digit 3 | | | | MCC digit 3 | | | |
| a+2 | MNC digit 2 | | | | MNC digit 1 | | | |
| a+3 to a+4 | Location Area Code (LAC) | | | | | | | |
| a+5 to a+6 | Cell Identity (CI) | | | | | | | |

**Figure 13 CGI field**

The Location Area Code (LAC) consists of 2 octets. Bit 8 of the Octet a+3 is the most significant bit and bit 1 of the Octet a+4 the least significant bit. The coding of the location area code is the responsibility of each administration. Coding using full hexadecimal representation (binary, not ASCII encoding) shall be used.

The Cell Identity (CI) consists of 2 octets. Bit 8 of the Octet a+5 is the most significant bit and bit 1 of the Octet a+6 the least significant bit. The coding of the cell identity is the responsibility of each administration. Coding using full hexadecimal representation (binary, not ASCII encoding) shall be used.

### A.1.2    ECGI

Extract 3GPP TS 29.274

The coding of ECGI (E-UTRAN Cell Global Identifier) is depicted in Figure 8.21.5-1. Only zero or one E-UTRAN cell global identifier (ECGI) field shall be present in the Uplink Information Extraction ULI IE.

| Octets | Bits | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 |
| e | MCC digit 2 | | | | MCC digit 1 | | | |
| e+1 | MNC digit 3 | | | | MCC digit 3 | | | |
| e+2 | MNC digit 2 | | | | MNC digit 1 | | | |
| e+3 | Spare | | | | ECI | | | |
| e+4 to e+6 | ECI (E-UTRAN Cell Identifier) | | | | | | | |

**Figure 14  ECGI field**

The E-UTRAN Cell Identifier (ECI) consists of 28 bits. The ECI field shall start with Bit 4 of the octet e+3, which is the most significant bit. Bit 1 of the Octet e+6 is the least significant bit. The coding of the E-UTRAN cell identifier is the responsibility of each administration. Coding using full hexadecimal representation (binary, not ASCII encoding) shall be used.

### A.1.3    NR CGI

Extract 3GPP TS 38.413

| IE/Group Name | Presence | Range | IE type and reference | Semantics description |
|---|---|---|---|---|
| PLMN Identity | M | | OCTET STRING (SIZE(3)) | Digits 0 to 9 encoded 0000 to 1001, 1111 used as filler digit.<br><br>Two digits per octet:<br>- bits 4 to 1 of octet n encoding digit 2n-1<br>- bits 8 to 5 of octet n encoding digit 2n<br><br>PLMN Identity consists of 3 digits from MCC followed by either:<br>- a filler digit plus 2 digits from MNC (in case of 2 digit MNC) or<br>- 3 digits from MNC (in case of 3 digit MNC). |
| NR Cell Identity | M | | BIT STRING (SIZE(36)) | The leftmost bits of the *NR Cell Identity* IE correspond to the gNB ID |

## A.2    Location Information parameters

### A.2.1    GeographicalInformation

Extract 3GPP TS 29.002

```
GeographicalInformation ::= OCTET STRING (SIZE (8))
--   Refers to geographical Information defined in 3GPP TS 23.032.
--   Only the description of an ellipsoid point with uncertainty circle
--   as specified in 3GPP TS 23.032 is allowed to be used
--   The internal structure according to 3GPP TS 23.032 is as follows:
--   Type of shape (ellipsoid point with uncertainty circle)          1 octet
--   Degrees of Latitude                         3 octets
--   Degrees of Longitude                        3 octets
--   Uncertainty code                            1 octet
```

Uncertainty code: defined in *3GPP TS 23.032*

A method of describing the uncertainty for latitude and longitude has been sought which is both flexible (can cover wide differences in range) and efficient. The proposed solution makes use of a variation on the Binomial expansion. The uncertainty $r$, expressed in metres, is mapped to a number K, with the following formula:

$$r = C\left((1+x)^K - 1\right)$$

with C = 10 and x = 0,1. With $0 \leq K \leq 127$, a suitably useful range between 0 and 1800 kilometres is achieved for the uncertainty, while still being able to code down to values as small as 1 metre. The uncertainty can then be coded on 7 bits, as the binary encoding of K.

| Value of K | Value of uncertainty |
|:---:|:---:|
| 0 | 0 m |
| 1 | 1 m |
| 2 | 2,1 m |
| - | - |
| 20 | 57,3 m |
| - | - |
| 40 | 443 m |
| - | - |
| 60 | 3 km |
| - | - |
| 80 | 20 km |
| - | - |
| 100 | 138 km |
| - | - |
| 120 | 927 km |
| - | - |
| 127 | 1800 km |

**Table 1: Example values for the uncertainty Function**

### A.2.2    GeodeticInformation

Extract 3GPP TS 29.002

```
GeodeticInformation ::= OCTET STRING (SIZE (10))
--   Refers to Calling Geodetic Location defined in Q.763 (1999).
--   Only the description of an ellipsoid point with uncertainty circle
--   as specified in Q.763 (1999) is allowed to be used
--   The internal structure according to Q.763 (1999) is as follows:
--   Screening and presentation indicators    1 octet
--   Type of shape (ellipsoid point with uncertainty circle)         1 octet
--   Degrees of Latitude               3 octets
--   Degrees of Longitude              3 octets
--   Uncertainty code                  1 octet
--   Confidence                        1 octet
```

### A.2.3    AgeOfLocationInformation

Extract 3GPP TS 29.002

```
AgeOfLocationInformation ::= INTEGER (0..32767)
-- the value represents the elapsed time in minutes since the last
-- network contact of the mobile station (i.e. the actuality of the
-- location information).
-- value "0" indicates that the MS is currently in contact with the
--         network
-- value "32767" indicates that the location information is at least
--              32767 minutes old
```

### A.2.4    LocationInformation

Extract 3GPP TS 29.002

```
LocationInformation ::= SEQUENCE {
    ageOfLocationInformation            AgeOfLocationInformation        OPTIONAL,
    geographicalInformation             [0] GeographicalInformation     OPTIONAL,
    vlr-number                          [1] ISDN-AddressString          OPTIONAL,
    locationNumber                      [2] LocationNumber              OPTIONAL,
    cellGlobalIdOrServiceAreaIdOrLAI    [3] CellGlobalIdOrServiceAreaIdOrLAI
    OPTIONAL,
    extensionContainer                  [4] ExtensionContainer          OPTIONAL,
    ... ,
    selectedLSA-Id                      [5] LSAIdentity                 OPTIONAL,
    msc-Number                          [6] ISDN-AddressString          OPTIONAL,
    geodeticInformation                 [7] GeodeticInformation         OPTIONAL,
    currentLocationRetrieved            [8] NULL  OPTIONAL,
    sai-Present                         [9] NULL  OPTIONAL,
    locationInformationEPS              [10] LocationInformationEPS     OPTIONAL,
    userCSGInformation                  [11] UserCSGInformation         OPTIONAL,
    locationInformation5GS              [12] LocationInformation5GS     OPTIONAL }
-- sai-Present indicates that the cellGlobalIdOrServiceAreaIdOrLAI parameter contains
-- a Service Area Identity.
-- currentLocationRetrieved shall be present
-- if the location information were retrieved after a successful paging.
-- if the locationinformationEPS IE is present then the cellGlobalIdOrServiceAreaIdOrLAI
IE,
-- the ageOfLocationInformation IE, the geographicalInformation IE, the
geodeticInformation IE
-- and the currentLocationRetrieved IE (outside the locationInformationEPS IE) shall be
-- absent. As an exception, both the cellGlobalIdOrServiceAreaIdOrLAI IE including an
LAI and
-- the locationinformationEPS IE may be present in a MAP-NOTE-MM-EVENT.
-- UserCSGInformation contains the CSG ID, Access mode, and the CSG Membership
Indication in
-- the case the Access mode is Hybrid Mode.
-- The locationInformationEPS IE should be absent if locationInformationEPS-Supported
was not
-- received in the RequestedInfo IE.
-- The locationInformation5GS IE should be absent if UE did not access via 5GS and IM-
SSF.
```

### A.2.5    LocationInformationGPRS

Extract 3GPP TS 29.002

```
LocationInformationGPRS ::= SEQUENCE {
    cellGlobalIdOrServiceAreaIdOrLAI    [0] CellGlobalIdOrServiceAreaIdOrLAI OPTIONAL,
    routeingAreaIdentity                [1] RAIdentity                  OPTIONAL,
    geographicalInformation             [2] GeographicalInformation     OPTIONAL,
    sgsn-Number                         [3] ISDN-AddressString          OPTIONAL,
    selectedLSAIdentity                 [4] LSAIdentity                 OPTIONAL,
    extensionContainer                  [5] ExtensionContainer          OPTIONAL,
    ...,
    sai-Present                         [6] NULL  OPTIONAL,
    geodeticInformation                 [7] GeodeticInformation         OPTIONAL,
    currentLocationRetrieved            [8] NULL  OPTIONAL,
    ageOfLocationInformation            [9] AgeOfLocationInformation    OPTIONAL,
    userCSGInformation                  [10] UserCSGInformation         OPTIONAL }
-- sai-Present indicates that the cellGlobalIdOrServiceAreaIdOrLAI parameter contains
-- a Service Area Identity.
-- currentLocationRetrieved shall be present if the location information
-- was retrieved after successful paging.
-- UserCSGInformation contains the CSG ID, Access mode, and the CSG Membership
Indication in
-- the case the Access mode is Hybrid Mode.
```

### A.2.6    LocationInformationEPS

Extract 3GPP TS 29.002

```
LocationInformationEPS ::= SEQUENCE {
    e-utranCellGlobalIdentity          [0] E-UTRAN-CGI                 OPTIONAL,
    trackingAreaIdentity               [1] TA-Id OPTIONAL,
    extensionContainer                 [2] ExtensionContainer          OPTIONAL,
    geographicalInformation            [3] GeographicalInformation     OPTIONAL,
    geodeticInformation                [4] GeodeticInformation         OPTIONAL,
    currentLocationRetrieved           [5] NULL                        OPTIONAL,
    ageOfLocationInformation           [6] AgeOfLocationInformation    OPTIONAL,
    ...,
    mme-Name [7] DiameterIdentity        OPTIONAL }
-- currentLocationRetrieved shall be present if the location information
-- was retrieved after successful paging.
```

### A.2.7    LocationInformation5GS

Extract 3GPP TS 29.002

```
LocationInformation5GS ::= SEQUENCE {
    nrCellGlobalIdentity               [0] NR-CGI                      OPTIONAL,
    e-utranCellGlobalIdentity          [1] E-UTRAN-CGI                 OPTIONAL,
    geographicalInformation            [2] GeographicalInformation     OPTIONAL,
    geodeticInformation                [3] GeodeticInformation         OPTIONAL,
    amf-address                        [4] FQDN                        OPTIONAL,
    trackingAreaIdentity               [5] TA-Id                       OPTIONAL,
    currentLocationRetrieved           [6] NULL                        OPTIONAL,
    ageOfLocationInformation           [7] AgeOfLocationInformation    OPTIONAL,
    vplmnId   [8] PLMN-Id                OPTIONAL,
    localtimeZone                      [9] TimeZone                    OPTIONAL,
    rat-Type [10] Used-RAT-Type          OPTIONAL,
    extensionContainer                 [11] ExtensionContainer         OPTIONAL,
    ...}
-- currentLocationRetrieved shall be present if the location information
-- was retrieved after successful paging.
```
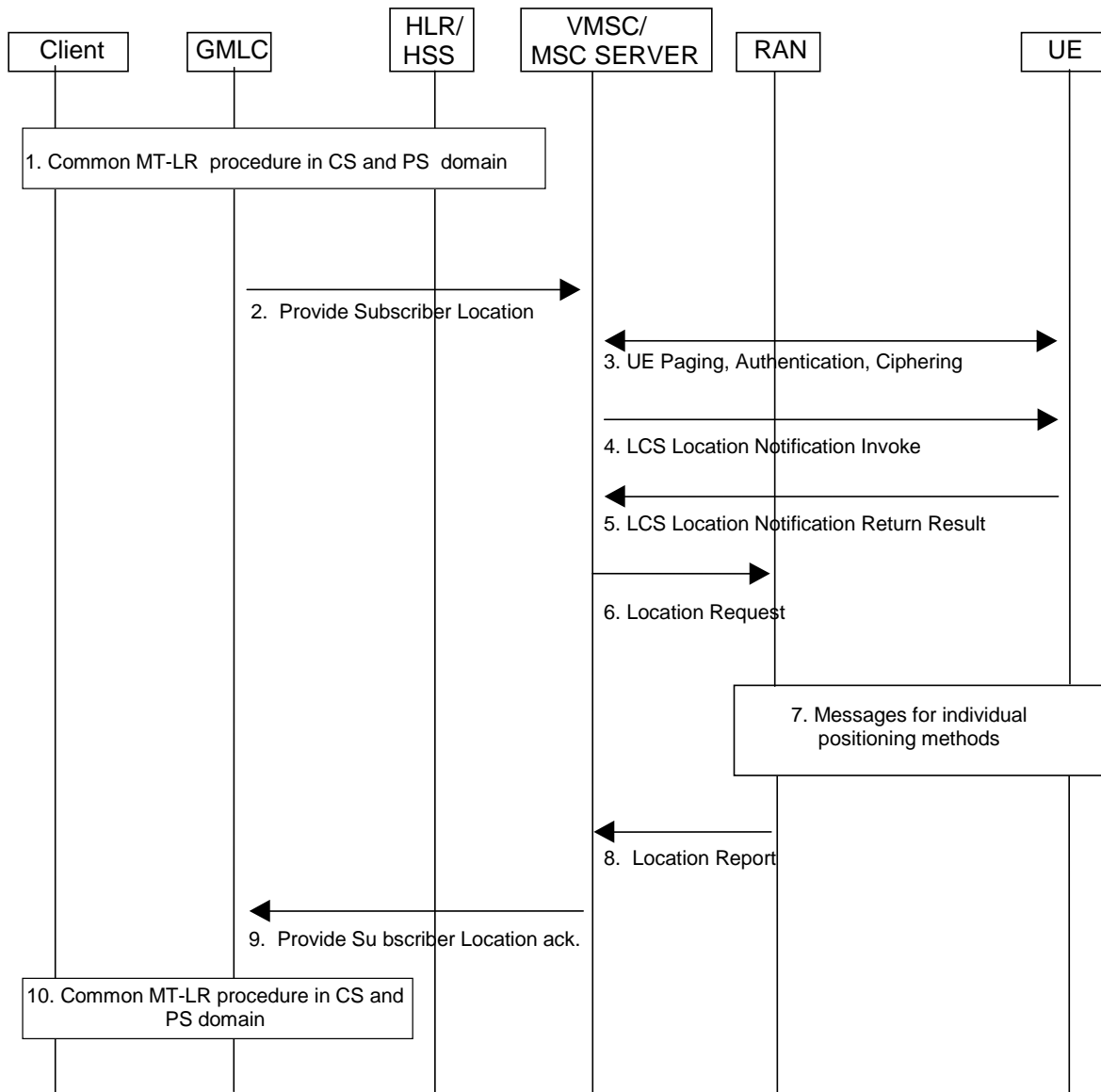
# Annex B   Location procedure (3GPP LCS)

This annex describes the location procedure which are related to LCS as defined in 3GPP TS23.271 [3] and 3GPP TS23.273 [8].
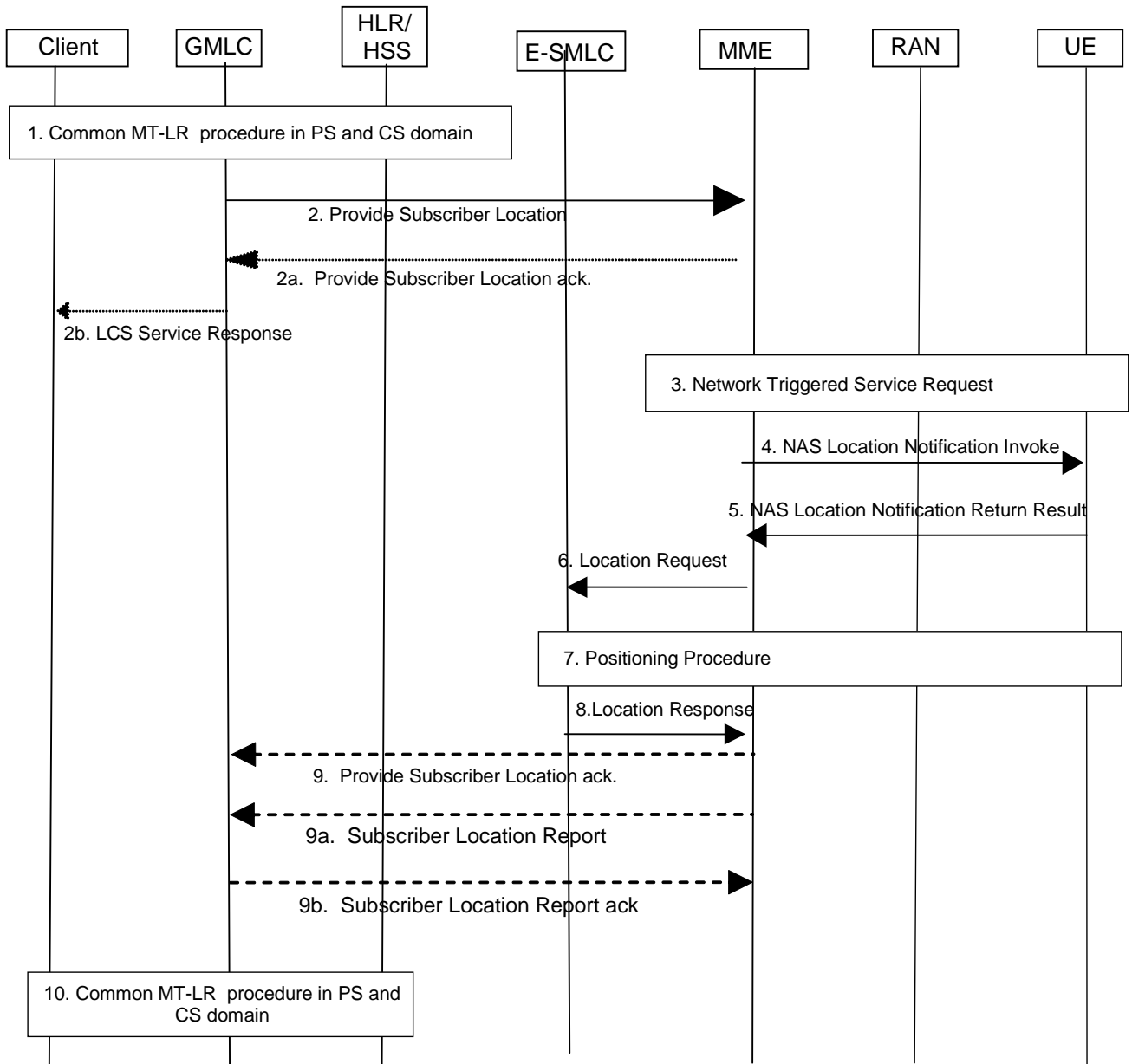
## B.1   Circuit Switch (CS) MT-LR procedure (2/3G)

The figure hereafter describes the 2G/3G MT-LR procedure (3GPP TS23.271 [3]).

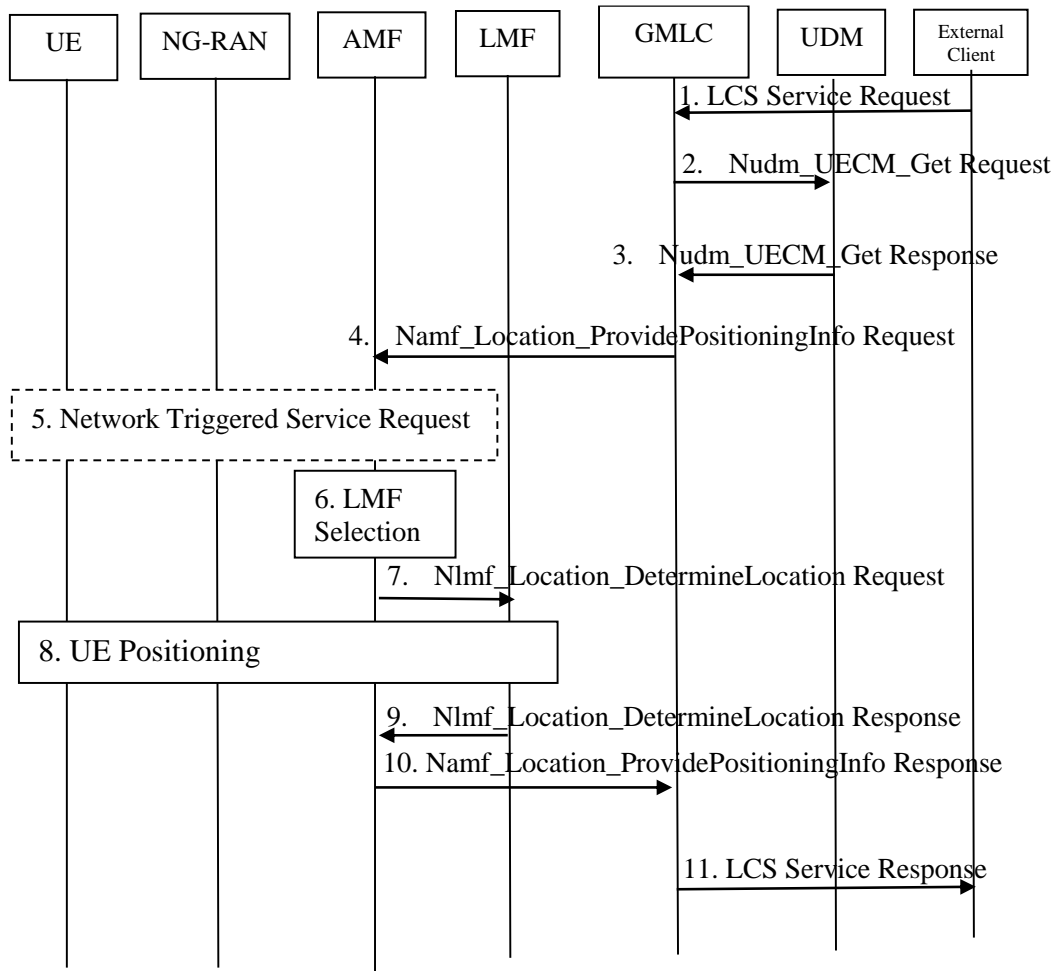## B.2    Evolved packet Core (EPC) MT-LR procedure (4G)

The figure hereafter describes the 4G MT-LR procedure (3GPP TS23.271 [3]).

## B.3   5GC MT-LR procedure (5G)

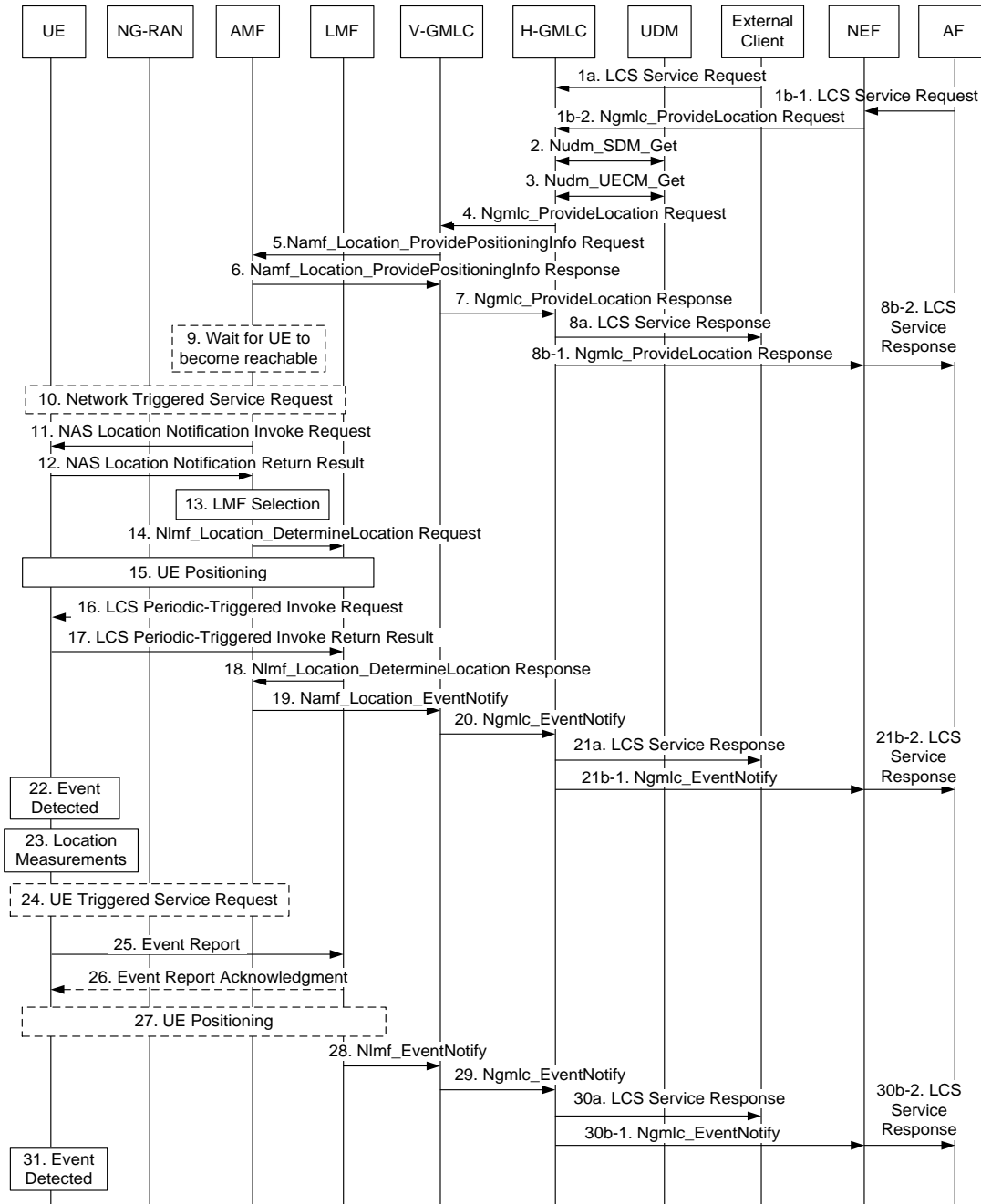The figure hereafter describes the 5G MT-LR procedure (3GPP TS23.273 [8]).

This procedure enables the immediate location retrieval, not waiting for the UE availability (if UE is not available, the AMF will answer to the GMLC with the last known EU location (Cell-Id and Age).

## B.4    Deferred 5GC MT-LR procedure (5G)

The figure hereafter describes the Deferred 5GC-MT-LR Procedure for Periodic, Triggered and UE Available Location Events (3GPP TS23.273 [8]).

This procedure enables the location retrieval, waiting for UE availability.
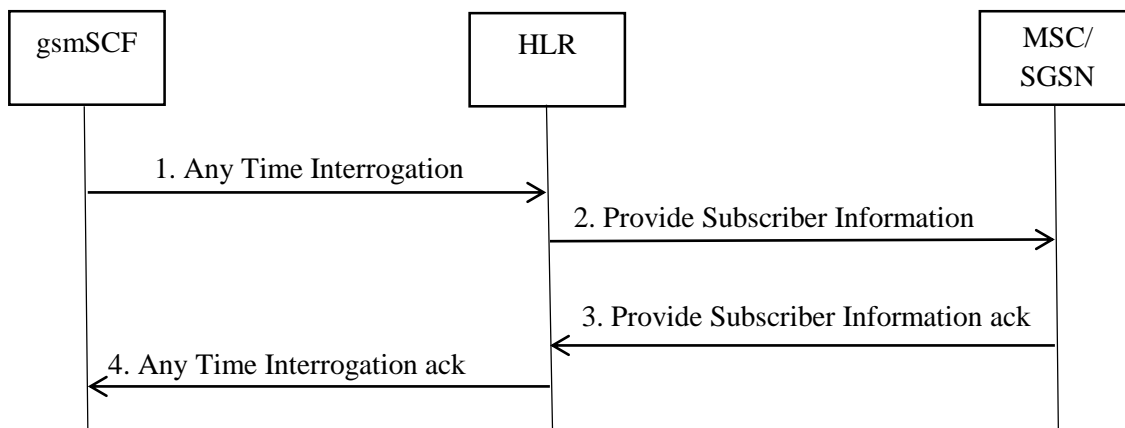
# Annex C   Location procedure (non 3GPP LCS)

This annex describes the location procedure which are not related to 3GPP LCS.

## C.1   Circuit Switch (CS) location procedure (2/3G)

The figure hereafter describes the 2G/3G location procedure based on MAP interface (3GPP TS29.002 [1]).



## C.2   Evolved packet Core (EPC) location procedure (4G)

The figure hereafter describes the 4G location procedure based on Sh (3GPP TS 29.328 [13]) and S6a interface.
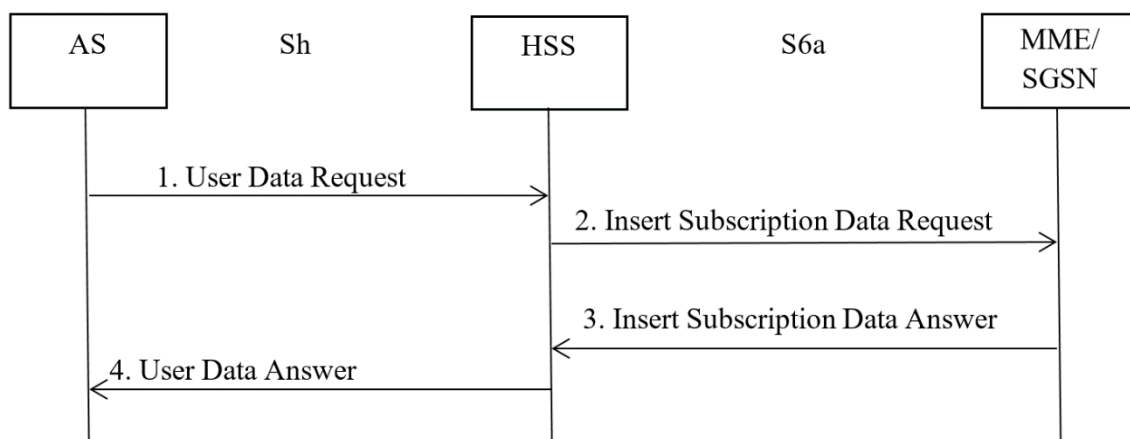


Notes:

Sh interface is able to support Location Information for CS, PS, EPS and 5GS.

HSS is also able to retrieve MSC/SGSN location information based on MAP-PROVIDE-SUBSCRIBER-INFO as described in previous section

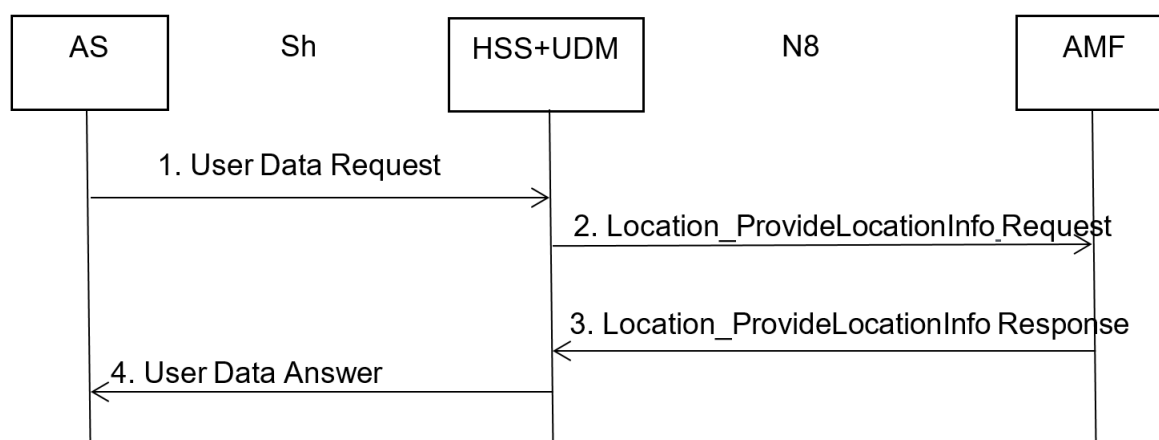## C.3    5GC location procedure (5G)

The figure hereafter describes the 5G location procedure based on Sh (3GPP TS 29.328 [13]) and N8 interface.



# Annex D    Location interfaces

## D.1    4G - S6a / S6d

### D.1.1    Insert-Subscriber-Data-Request (IDR) Command

The Insert-Subscriber-Data-Request (IDR) command, indicated by the Command-Code field set to 319 and the 'R' bit set in the Command Flags field, is sent from HSS) to MME or SGSN.

Message Format when used over the S6a or S6d application (extract 29.272):

*[ Route-Record] The following parameters are related to location information retrieval.

IDR-Flags:

- EPS Location Information Request, this bit, when set, shall indicate to the MME or the SGSN that the HSS requests the MME or SGSN for location information
- Current Location Request: This bit when set shall indicate to the MME or the SGSN that the HSS requests the MME or SGSN to provide the most current location information by paging the UE if the UE is in idle mode. This bit is used only in combination with the " Evolved Packet System (EPS) Location Information Request" bit.

### D.1.2    Insert-Subscriber-Data-Answer (IDA) Command

The Insert-Subscriber-Data-Answer (IDA) command, indicated by the Command-Code field set to 319 and the 'R' bit cleared in the Command Flags field, is sent from MME or SGSN to HSS.

Message Format when used over the S6a or S6d application (extract 29.272).

The following parameters are related to location information retrieval.

This Information Element shall contain the EPS-Location Information. It shall be present if the EPS location information was requested within IDR

- [EPS-Location-Information] : MME or SGSN-Location-Information

Where MME-Location-Information contains the following location information :

- [E-UTRAN-Cell-Global-Identity]
- [Tracking-Area-Identity]
- [Geographical-Information]: The Geographical-Information AVP is of type OctetString and shall contain the geographical Information of the user. For details and octet encoding, see 3GPP TS 29.002
- [Geodetic-Information]: The Geodetic-Information AVP is of type OctetString and shall contain the Geodetic Location of the user. For details and octet encoding, see 3GPP TS 29.002
- [Current-Location-Retrieved]
- [Age-Of-Location-Information]: The Age-Of-Location-Information AVP is of type Unsigned32 and shall contain the elapsed time in minutes since the last network contact of the user equipment. For details, see 3GPP TS 29.002.

## D.2    4G - SLg interface

### D.2.1    Provide-Location-Request (PLR) Command

The Provide-Location-Request (PLR) command, indicated by the Command-Code field set to 8388620 and the 'R' bit set in the Command Flags field, is sent by the GMLC in order to request subscriber location to the MME or SGSN.

Message Format (Extract 29.172)

The following parameters are related to location information retrieval.

{ SLg-Location-Type }

[ User-Name ]

[ MSISDN]

[ IMEI ]

{ LCS-EPS-Client-Name }

{ LCS-Client-Type }

[ LCS-Requestor-Name ]

 [ LCS-Priority ]

[ LCS-QoS ]

[ Velocity-Requested ]

[LCS-Supported-GAD-Shapes ]

[ LCS-Service-Type-ID ]

[ LCS-Codeword ]

[ LCS-Privacy-Check-Non-Session ]

[ LCS-Privacy-Check-Session ]

[Service-Selection ]

[ Deferred-Location-Type ]

[ PLR-Flags ]

## D.2.2    Provide-Location-Answer (PLA) Command

The Provide-Location-Answer (PLA) command, indicated by the Command-Code field set to 8388620 and the 'R' bit cleared in the Command Flags field, is sent by the MME or SGSN to the GMLC in response to the Provide-Location-Request command.

Message Format (Extract 29.172)

The following parameters are related to location information retrieval.

[ Location-Estimate ]

[ Accuracy-Fulfilment-Indicator ]

[ Age-Of-Location-Estimate]

[ Velocity-Estimate ]

[ EUTRAN-Positioning-Data]

[ ECGI ]

[ GERAN-Positioning-Info ]

[ Cell-Global-Identity ]

[ UTRAN-Positioning-Info ]

[ Service-Area-Identity ]

[ Serving-Node ]

[ PLA-Flags ]

[ ESMLC-Cell-Info ]

[ Civic-Address ]

[ Barometric-Pressure ]

| Location-Estimate | 1242 | 3GPP TS 32.299 [10] | OctetString | |

The Location-Estimate AVP (AVP code 1242) is of type OctetString and contains an estimated location of an MS in universal coordinates and the accuracy of the estimation. Refers to the geographical area description in TS 23.032 [227] for the internal structure and encoding of this AVP.

## D.3     4G – Sh interface

### D.3.1     User-Data-Request (UDR) Command

The User-Data-Request (UDR) command, indicated by the Command-Code field set to 306 and the 'R' bit set in the Command Flags field, is sent by a Diameter client to a Diameter server in order to request user data.

Message Format (extract from 29.329 [14]

The following parameters are related to location information retrieval.

- The Requested-Domain = CS/PS
- The Requested-Nodes = MME/SGSN/AMF
- The Current-Location indicates whether an active location retrieval has to be initiated or not
- The Serving-Node-Indication: If present it indicates that the sender does not require any location information other than the Serving Node Addresses/Identities requested (e.g. MME name, VLR number). Other location information (e.g. Global Cell ID, Tracking Area ID) may be absent.

### D.3.2     User-Data-Answer (UDA) Command

The User-Data-Answer (UDA) command, indicated by the Command-Code field set to 306 and the 'R' bit cleared in the Command Flags field, is sent by a server in response to the User-Data-Request command.

Message Format (extract from 29.329 [14]

The following parameters are related to location information retrieval.

User-Data contains Location Information for different networks as described in Annex C

| CSLocationInformation | PSLocationInformation | EPSLocationInformation | TWANLocationInformation | 5GSLocationInformation |
|---|---|---|---|---|
| CellGlobalId | CellGlobalId | E-UTRANCellGlobalId | TWAN-SSID | NRCellGlobalId |
| ServiceAreaId | ServiceAreaId | TrackingAreaId | TWAN-BSSID | E-UTRANCellGlobalId |
| LocationAreaId | LocationAreaId | GeographicalInformation | TWAN-PLMNID | TrackingAreaId |
| LocationNumber | RoutingAreaId | GeodeticInformation | CivicAddress | GeographicalInformation |
| GeodeticInformation | GeodeticInformation | AgeOfLocationInformation | TWANOperatorName | AMFAddress |
| GeographicalInformation | GeographicalInformation | CurrentlocationRetrieved | LocalTimeZone | SMSFAddress |
| AgeOfLocationInformation | AgeOfLocationInformation | MMEName | LogicalAccessID | CurrentlocationRetrieved |
| VLRNumber | CurrentLocationRetrieved | UserCSGInformation | | AgeOfLocationInformation |
| CurrentLocationRetrieved | SGSNNumber | VisitedPLMNID | | VisitedPLMNID |
| MSCNumber | UserCSGInformation | LocalTimeZone | | LocalTimeZone |
| UserCSGInformation | VisitedPLMNID | RATtype | | RATtype |
| E-UTRANCellGlobalId | LocalTimeZone | | | |
| TrackingAreaId | RATtype | | | |
| LocalTimeZone | | | | |

## D.4   5G – Namf_ Location_ProvideLocationInfo service operation

Extract from 3GPP 23.502

| Service Name | Service Operations | Operation Semantic | Known Consumer(s) |
|---|---|---|---|
| Namf_Location | ProvideLocationInfo | Request/Response | UDM |

**Service operation name:** Namf_Location_ProvideLocationInfo

**Description:** Provides Network Provided Location Information (NPLI) of a target UE to the consumer NF.

**Input, Required:** UE Identification SUPI. **(*)**

**Input, Optional:** 5GS Location Information Request, Current Location Request, (RAT) type Requested, Local Time Zone Request. **(*)**

**Output, Required:** Success/Failure indication.

**Output, Optional:** 5GS Location Information (Cell Identity, Tracking Area Identity, Geographical/Geodetic Information, Current Location Retrieved, Age of Location Information, Current RAT Type), Local Time Zone, Failure Cause. In the case of non-3GPP access: a UE local IP) address (used to reach the N3IWF/TNGF) and optionally UDP) or TCP) source port number (if (NAT) is detected).**(*)**

**(*)** As this is a copy of the 3GPP specs; Abbreviations are as follows:

SUPI: Subscription Permanent Identifier

RAT: Radio Access Technology

IP: Internet Protocol

UDP: User Datagram Protocol

TCP: Transmission Control Protocol

NAT: Network Address Translation

## D.5    5G - Namf_ Location_ProvidePositioningInfo service operation

Extract from 3GPP 23.502

| Service Name | Service Operations | Operation Semantic | Known Consumer(s) |
|---|---|---|---|
| Namf_Location | ProvidePositioningInfo | Request/Response | GMLC |

**Service operation name:** Namf_Location_ProvidePositioningInfo

**Description:** Provides UE positioning information to the consumer NF.

**Input, Required:** UE Identification (SUPI or Permanent Equipment Identity (PEI), Client Type.

**Input, Optional:** Location QoS, Supported GAD shapes, UE Privacy Requirements, External Client Identification, Deferred location type, Deferred location parameters, Notification Target address, Notification Correlation ID.

**Output, Required:** Success/Failure indication

**Output, Optional:** Geodetic Location, Civic Location, Position Methods Used, Failure Cause.

# Annex E    Document Management

## E.1    Document History

| Version | Date | Brief Description of Change | Approval Authority | Editor / Company |
|---------|------|---------------------------|--------------------|--------------------|
| 1.0 | 08/04/2020 | Initial version | NG | Marc Balon, Orange |
| 1.1 | 03/05/2021 | Updates 4G and 5G architecture (CR1002) | NG | Marc Balon, Orange |

## E.2    Other Information

| Type | Description |
|------|-------------|
| Document Owner | Marc Balon |
| Editor / Company | Orange |

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Your comments or suggestions & questions are always welcome.