MSF Whitepaper on Location Services in LTE Networks

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Abstract and Executive Summary

Support for Location Services (LCS) in LTE is an important network requirement driven by the following considerations:

- Operators must comply with regulatory requirements for emergency services such as E911 in North America, E112 in Europe and 110 in China, in terms of accuracy as well as speed
- Location Based Services (LBS) are considered by many to be a key driver for future revenue growth from mobile services

Location services for the purpose of regulatory compliance and/or commercial services are already commonly supported in today's deployed 2G and 3G wireless networks. The LCS solution in LTE therefore will be required to:

- Provide a cost-effective solution which will meet the accuracy and volume demand of existing as well as new and growing LBS applications and users
- Provide a smooth transition with continuous location services from the 2G/3G wireless networks to LTE.

This paper discusses the network architecture of such a LCS solution, based on the on-going specification work in 3GPP and OMA.

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1.0 Introduction

Location services (LCS) in a wireless network deals with the capabilities to locate target UEs, triggered by either external or internal requests. It makes available the location information to Location Based Services (LBS) for value-added applications which are accessible to mobile subscribers or to other third parties.

Wireless network and devices are in a unique position to provide LCS due to the inherent geo-location capability of radio signals as well as the user mobility tracking of the system through procedures such as paging and location updates.

Location-based services for regulatory compliance and for navigation applications are already commonly deployed in 2G and 3G wireless networks. With the availability of smart handsets and significant increase in wireless bandwidth brought on by technologies such as LTE, it is expected that the demand for LBS applications will grow rapidly.

2.0 Problem Statement

Drivers for LCS in the LTE network include:

- Complying with local regulation:
    - Ensure compliance with mandates for personal emergency localization
- Developing existing revenue streams:
    - Enhance existing service utility through greater location accuracy
    - Provide greater customer satisfaction of existing LBS
- Creating new revenue streams:
    - Offer new services, differentiate on high accuracy localization

The LTE LCS solution is required to:

- Provide a cost-effective solution which will meet the accuracy and volume demand of existing as well as new and growing LBS applications and users
- Provide a smooth transition with continuous location services from the 2G/3G wireless networks to LTE.

3.0 A Survey of Current Industry Solutions

LCS in the LTE network is a work-in-progress in both the 3GPP and the OMA standard bodies.

- LCS C-Plane based solution is being worked in 3GPP Release 9. The functional and network architecture have been finalized, stage 3 definition is expected to be frozen end of 2009.
- The U-Plane based solution is being worked in the OMA. SUPL 2.0 with enhancement to support emergency services and LTE access is awaiting validation in upcoming test fests.

These two solutions will be described in this section. Many existing 2G and 3G networks have already deployed either a C-plane or a U-plane solution.

While the C-Plane and the U-Plane solutions are distinct in the type of bearers and protocols used to carry and communicate LCS requests and responses, to control and deliver required assistance data and radio measurements, they both utilize and support a similar set of positioning technologies which enable the network to accurately locate a mobile user. The set of positioning methods being specified for LTE in 3GPP will also be described briefly in this section.

3.1 C-Plane LCS Solution

The LCS Control Plane solution was originally introduced in the GSM network to support emergency services. The Serving Mobile Location Center (SMLC) is the key functional component in GSM to support LCS. It manages the overall co-ordination and scheduling of resources required for the location of a mobile. It also calculates the final location and velocity estimate, as well as estimates the achieved accuracy.

The Control Plane solution is later adopted in the UMTS network with the introduction of the Standalone SMLC (SAS) functional component in place of the SMLC in the GSM network.

In GSM and UMTS, both the positioning methods and signaling protocols used have dependency on the air interface technology. While the 3GPP-defined positioning methods for LTE are also dependent on the air interface, the LTE Positioning Protocol (LPP) is designed to be forward looking and to accommodate other positioning technologies in the future.

The location service architecture specified for LTE consists of the evolved SMLC connected to the MME over the new SLs interface. With this architecture, location service continuity is possible during intra-eNB and inter-eNB handovers without MME relocation.

The E-SMLC communicates with the UE for location services and assistance data delivery using the new LPP protocol. It communicates with the eNB for eNB almanac and other assistance data using the LPPa. External or network initiated location service requests are forwarded through the GMLC to the MME via the SLg, which performs the LCS user subscription authorization function.

The following figure illustrates the LCS Control Plane architecture in LTE.

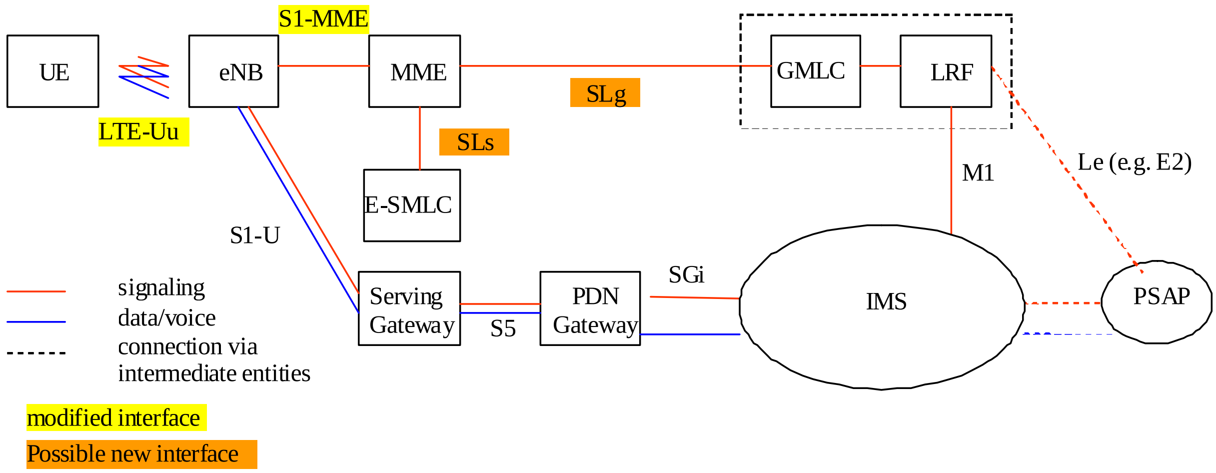


Figure 1: LCS Control Plane architecture with E-SMLC

3.2 U-plane LCS Solution

The U-plane LCS solution is based on user plane technology which is independent of the underlying network type. SUPL is the U-plane location technology developed by OMA (Open Mobile Alliance) for positioning over wireless network based on secure user plane IP tunnels. It is an application layer protocol operating over the interface between the SUPL Location Platform (SLP) and the SUPL Enabled Terminal (SET).

The SLP consists of two functional entities: the SUPL Location Centre (SLC) and the SUPL Positioning Centre (SPC). The SLC is responsible for coordination and administrative functions to provide location services, while the SPC is responsible for the positioning function. These are architecturally analogous to the GMLC and the E-SMLC in the C-Plane solution.

The core strength of SUPL is the utilization, wherever possible, of existing protocols, IP connections, and data-bearing channels. SUPL standards are complementary to and compatible with C-Plane standards. SUPL supports C-Plane protocols developed for the exchange of location data between a mobile device and a wireless network, including RRLP, RRC and TIA-801.

SUPL also supports the MLP (Mobile Location Protocol), RLP (Roaming Location Protocol) and ULP (User Plane Location Protocol). MLP is used in the exchange of Location based Service (LBS) data between elements such as an SLP and a GMLC, or between two SLPs; ULP is used in the exchange of LBS data between an SLP and a SET.

The following figure illustrates the U-plane architecture in OMA.

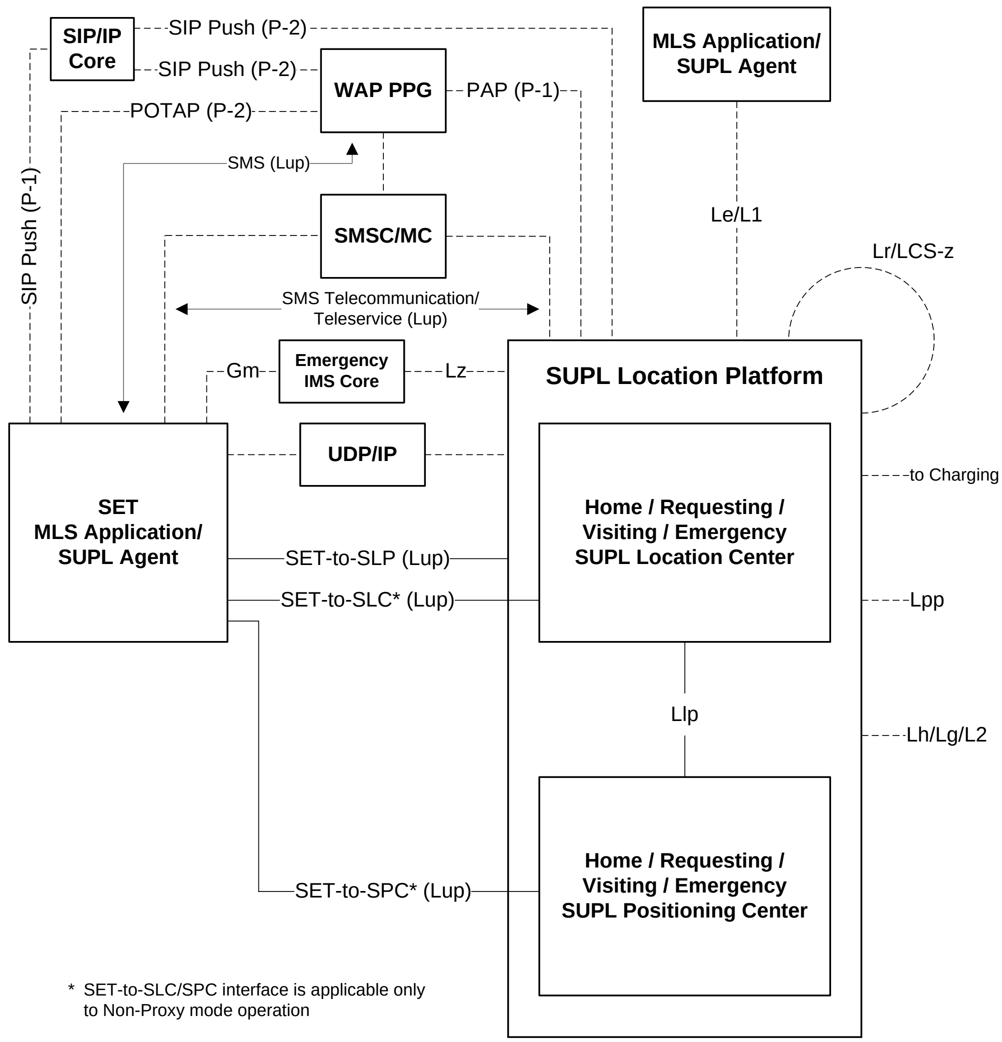


Figure 2: LCS User Plane architecture with SLP

3.3 Positioning Methods

The positioning of UEs is a service provided by the RAN to enable the network to support location services. UE positioning is a technology based on measuring radio signals to determine the geographic position and/or velocity of the UE. For E-UTRAN access, three positioning methods have been specified in 3GPP for R9:

- Network-assisted GNSS methods;
- Downlink positioning;
- Enhanced cell ID method.

Hybrid positioning using multiple methods from the list of positioning methods above is also supported. These positioning methods may be supported in UE-based, UE-assisted/E-SMLC-based, or eNB-assisted versions, as summarized in the table below:

Method	**UE-based**	**UE-assisted, E-SMLC-based**	**eNB-assisted**	**SUPL**
A-GNSS	Yes	Yes	No	Yes (UE-based and UE-assisted
Downlink	Yes [FFS]	Yes	No	Yes (UE-assisted; UE-based FFS)
E-CID	FFS	Yes	Yes	Yes (UE-assisted; eNB-assisted)

Table 1: Summary of Positioning Methods defined in 3GPP R9

3.3.1 Network-assisted GNSS Methods

Global Navigation Satellite System (GNSS) refers to satellite navigation systems that provide autonomous geo-spatial positioning with global or regional coverage, for example: GPS, Galileo, SBAS and others. The different GNSSs can be used separately or in combination to determine the location of a UE.

In the E-UTRAN, the GNSS is designed to work with assistance data provided by the network. Assisted GNSS uses signals broadcast by satellites to determine the positions of UEs equipped with GNSS receivers. Two types of assistance data are provided to improve the positioning speed and accuracy performance:

- Data assisting the measurements: e.g. reference time, visible satellite list, satellite signal Doppler, code phase, Doppler and code phase search windows;
- Data assisting position calculation: e.g. reference time, reference position, satellite ephemeris, clock corrections.

A-GNSS provides excellent accuracy, and as compared with stand-alone GNSS, it can:

- reduce the UE GNSS start-up and acquisition times
- increase the UE GNSS sensitivity
- allow the UE to consume less power on the handset with the GNSS receiver put in Idle mode when it is not needed

The A-GNSS methods can be operated in UE-assisted mode, where the UE performs GNSS measurements and sends them to the E-SMLC to calculate its position; or the UE-based mode, where the UE performs GNSS measurements and calculates its own location.

3.3.2 Downlink positioning

In the downlink positioning method, the UE positioning is estimated based on measurements taken at the UE of downlink radio signals from multiple eNode Bs, along with knowledge of the geographical coordinates of the measured eNode Bs and their relative downlink timing. One such positioning method is the Down-Link Observed Time Difference On Arrival (DL-OTDOA), illustrated in figure below:

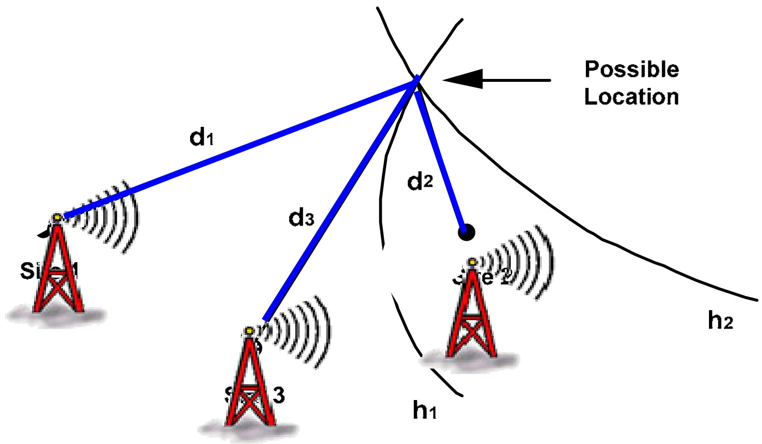


Figure 3: DL-OTDOA method

In the DL-OTDOA method, the UE estimates the difference in the arrival times of signals from separate base stations. Each OTDOA measurement for a pair of downlink transmissions describes a line of constant difference (hyperbola) along which the mobile may be located. The Mobile's position is determined by the intersection of hyperbolas for at least two pairs of base stations. The base stations have to be time synchronized in order to support the required precision in the measurements

IPDL (Idle Period in Down Link) can be used to overcome the hearability problem arising from near-far effect.

DL-OTDOA can operate in UE-based mode or UE-assisted mode. In either mode, it may involve the delivery of eNB related assistance data from the eNB and/or the E-SMLC to the UE to aid in measurement collection and/or location calculation.

3.3.3 Enhanced Cell ID

In the Cell ID (CID) positioning method, the position of an UE is estimated with the knowledge of its serving eNode B and cell. The information about the serving eNode B and cell may be obtained through mobility procedures for mobiles in either active or idle mode, for example, by paging, and tracking area update.

Since the UE can be anywhere in the cell, estimation accuracy depends on the cell size and can be very poor in cells with large coverage area.

Enhanced Cell ID (E CID) positioning refers to techniques which use additional UE and/or E-UTRAN radio resource and other measurements to improve the UE location estimate. UE measurements which can improve the accuracy of the location estimate using the Cell ID method includes E-UTRA carrier Received Signal Strength Indicator (RSSI), Reference Signal Received Power (RSRP) etc. E-UTRAN measurements which can be used in the Cell ID methods include the eNB Round Trip Time (RTT) and the Angle of Arrival (AoA).

4.0 Use Cases

4.1 Location Support for Emergency Services

Perhaps one of the oldest and most evident applications of location based service is the dispatching of rescue in emergency situations. Once alerted, typically the emergency response system needs to locate where the emergency, e.g. an accident or a crime, has taken place; and then to find the closest help available to the victims where again location technology can be useful. For example, in tracking down the closest ambulance or police patrol that can get to the emergency scene the quickest.

Locating speed and positioning accuracy are both critical in an emergency situation. By supporting a combined C-Plane and U-Plane LCS solution, the network will be able to assist in locating the emergency requests from mobile devices which may support only one or the other.

4.2 Location Support for Commercial Services

With the increasing popularity of Smartphones, a mobile user’s ability to access internet services anytime, anywhere is a given. It is the ability to combine the mobile location technology and the available internet services that will open up new ways to enrich consumer services and user experiences. This in turn will open up new revenue opportunities for mobile operators.

There is a broad range of location based applications; some are newly defined, while others are enhancements of existing services. A few examples are:

1. Popular Yellow Page services can be enhanced to “Find the nearest” by combining the traditional service with the location information of the requestor.
2. Navigational assistance is improved with higher positioning accuracy.
3. New social networking services that will provide “friend-finder” presence alerts and facilitate subscribers to connect.
4. “Push” advertisement based on mobile user location to send promotional alerts.
5. Tracking applications such as fleet management and family locator.

4.3 Proposed Interop Event (based on Maturity)

Location Services (LCS) for LTE and the C-plane solution are currently being defined in 3GPP as part of Release 9 content. The Stage 3 definitions are expected to be frozen between end of 2009 and Q1 2010.

Meanwhile SUPL 2.0 specification for the U-plane solution has been almost completed in OMA, and is in maintenance mode for verification, pending test fest activities.

Given the above status in standardization efforts, it is expected that an interoperability event involving Location Services may be feasible towards end of 2010/beginning of 2011 when infrastructure products and supporting devices are expected to become available.

5.0 MSF SWG-Recommended Solution Option(S)

Recognising that there is a reliance on a common set of positioning methods, a unified C-plane and U-plane LCS solution can be cost effectively implemented in the network by deploying an integrated platform to host the positioning function, i.e., the E-SMLC in 3GPP and the SPC in OMA. This combined positioning engine can then feed to either the C-plane and/or the U-plane LCS solution.

This LCS solution architecture provides a number of technical as well as cost advantages:

- An integrated E-SMLC/SPC allows the sharing of OTDOA and ECID assistance data between Control Plane and User Plane, as well as simplifying the delivery and maintenance of eNB almanac data for positioning use.
- An integrated positioning platform lowers the cost of supporting the combined Control Plane and User Plane solution.
- An integrated solution offers a smooth transition from multi-technology networks to an eventual uniform LTE network with continuous Emergency and LBS services. For example, UE with SUPL client can use User Plane solution to get Emergency and LBS services, and UE without SUPL client can use Control Plane to get the same service.
- An integrated LCS solution can be used flexibly to support future LBS applications available in C-plane, U-pane or both.

Optionally, the GMLC and the SLP/SLC can also be optimized by consolidating onto a single platform due to their functional synergy.

The following figure illustrates the integrated LCS solution architecture.

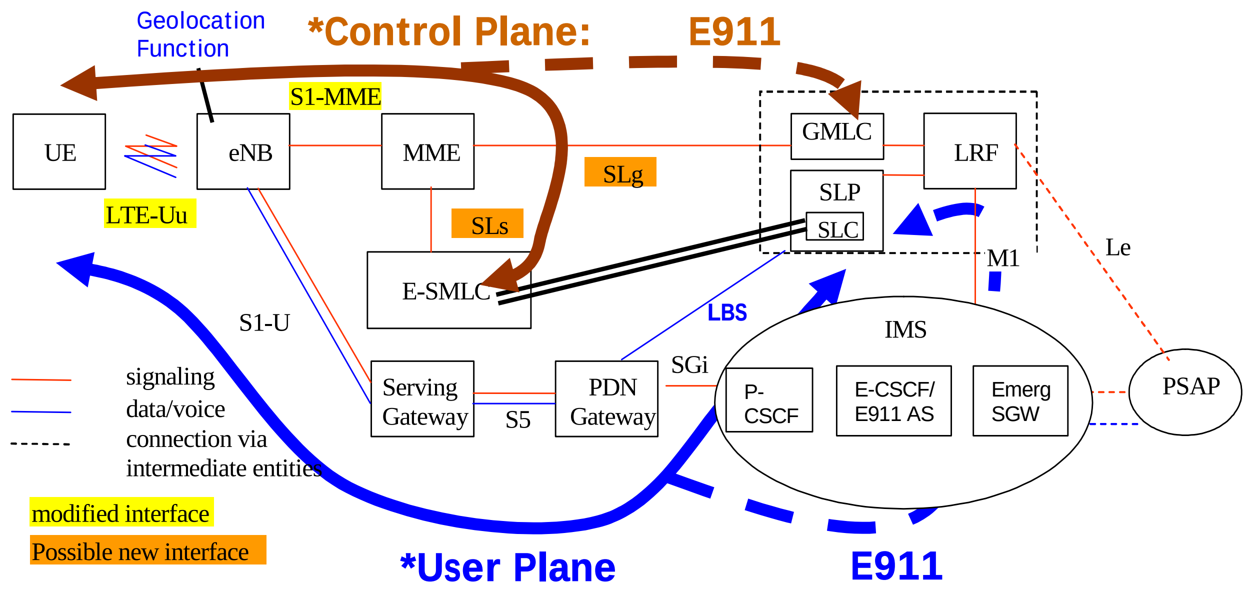


Figure 4: Integrated LCS Solution with E-SMLC/SPC

The MSF SWG recommends the adoption of the integrated C-Plane and U-Plane LCS solution.

5.1 MSF Architecture Based Implementation

Figure 5 below illustrates the additional functional components and interfaces in the MSF baseline architecture in order to support LCS in the LTE network.

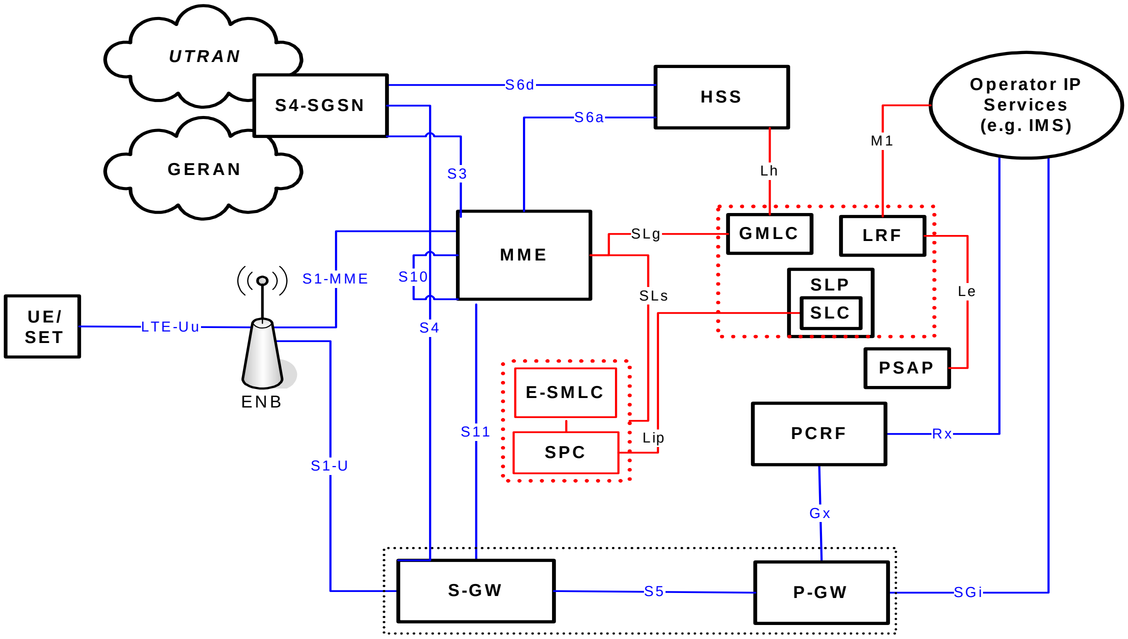


Figure 5: MSF baseline network architecture with LCS components

E-SMLC

The key functional component of the LCS architecture for C-Plane solution is the E-SMLC. It is responsible for the location service function, analogous to an SMLC for GSM or an SAS for WCDMA. It manages the overall coordination and scheduling of resources required for the location of a UE that is attached to the E-UTRAN. It also calculates the final location and estimates the achieved accuracy for non UE-based positioning.

The E-SMLC communicates directly or indirectly with the serving eNodeB and the UE to provide positioning assistance data and measurement instructions, as well as to retrieve positioning measurements. The protocols used by E-SMLC for the communication with UE and the eNodeB are the LPP and LPPa respectively. The E-SMLC also exchanges location information with the core network via the MME.

The E-SMLC interacts with the UE in order to exchange location information applicable to UE-assisted and UE-based positioning methods, and interacts with the E-UTRAN in order to exchange location information applicable to network-assisted and network-based positioning methods.

In the proposed architecture, the E-SMLC can either be hosted in the same platform as the SPC; or if not co-located, can communicate with the SPC over a proprietary interface.

SLP, SLC and SPC

SLP can be a server residing in the network or a network equipment stack. It is responsible for tasks such as authentication to SET and 3rd party LCS client, location request from SET or 3rd party LCS client, roaming and charging. The SLP consists of two functional components: the SLC and the SPC.

The SLC coordinates the operations of SUPL in the network and performs functions of location management, including: Privacy, Initiation, Security, Roaming, Charging, Service management, triggering positioning calculation.

The SPC is responsible for positioning-related functions, including: Security, Assistance Data Delivery, Reference Retrial, and Positioning Calculation.

The SLC and SPC may be integrated into a single system, they can also be separated. For the separated mode, the interface between SLC and SPC is the Internal Location Protocol (ILP) defined by OMA.

SET is a mobile device, such as a cell phone or PDA which has capability of SUPL transactions.

In SUPL, the interface between SET and SLP is Lup which is defined and standardized by OMA; SUPL is the protocol running over Lup. There are two different communication modes between SET and SLP: Proxy Mode and Non-Proxy Mode. For proxy mode, the SPC system will not have direct communication with the SET. In this environment the SLC system will act as a proxy between the SET and the SPC. For non-proxy mode, the SPC system will have direct communication with the SET.

LRF, GMLC
The Location Retrieval Function (LRF) is a functional entity responsible for the retrieval of location information and for providing routing information for a UE which has initiated an IMS emergency session. It handles, where required, interim location information, initial location information and updated location information.

The LRF may be collocated with the GMLC or may be separately located. The retrieved information is provided to the IMS (E-CSCF) via the Ml interface. While not explicitly shown in Figure x, the emergency CSCF is an additional CSCF role introduced by IMS to control the establishment of emergency sessions.

The GMLC is the LCS server already defined for GSM and UMTS networks. It is the first node an external LCS client accesses in a PLMN. The GMLC may request routing information from the HSS via the Lh interface.

After performing registration authorization, it sends positioning requests to the MME and receives final location estimates from the corresponding entity via the SLg interface.

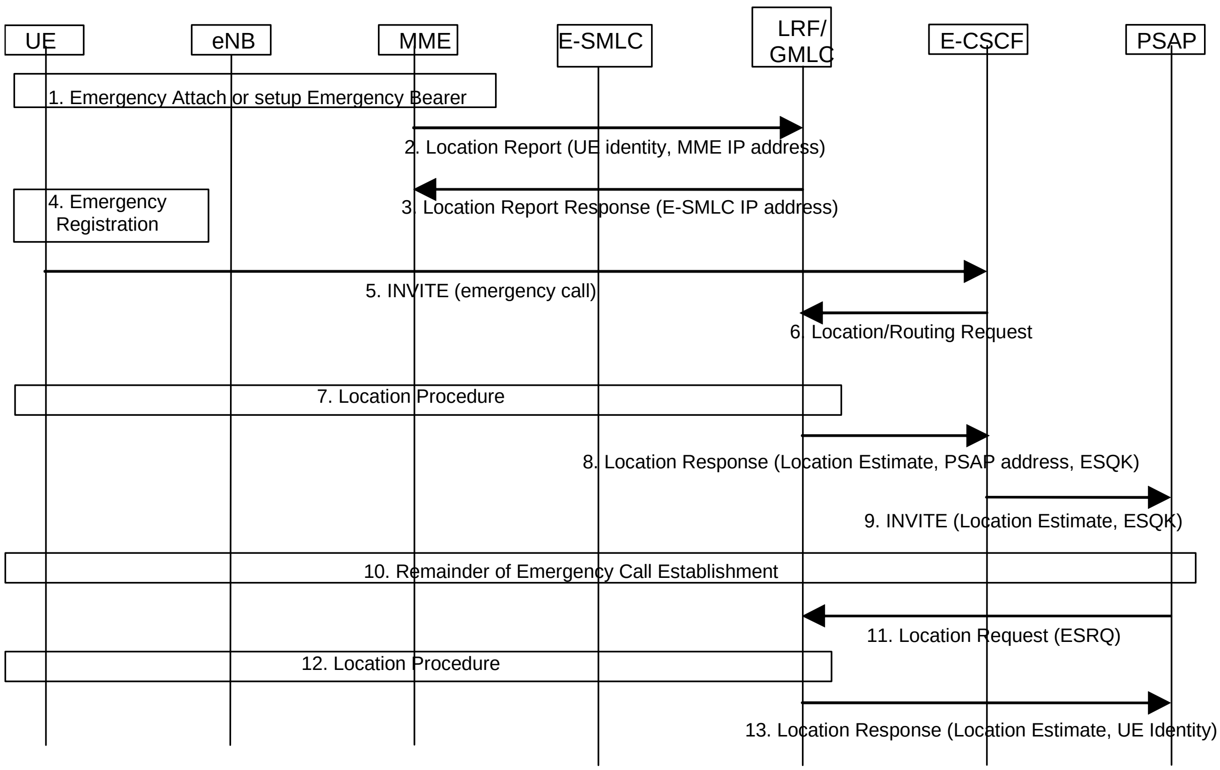
5.1.1 Architecture Gap(s)

The MSF baseline architecture currently does not support LCS in LTE. It is recommended that the LCS capability be supported. The additional network components and interfaces identified in

Figure 5 for the support of LCS in LTE should be incorporated into the physical implementation for the MSF baseline architecture.

5.2 High-Level Call Flows

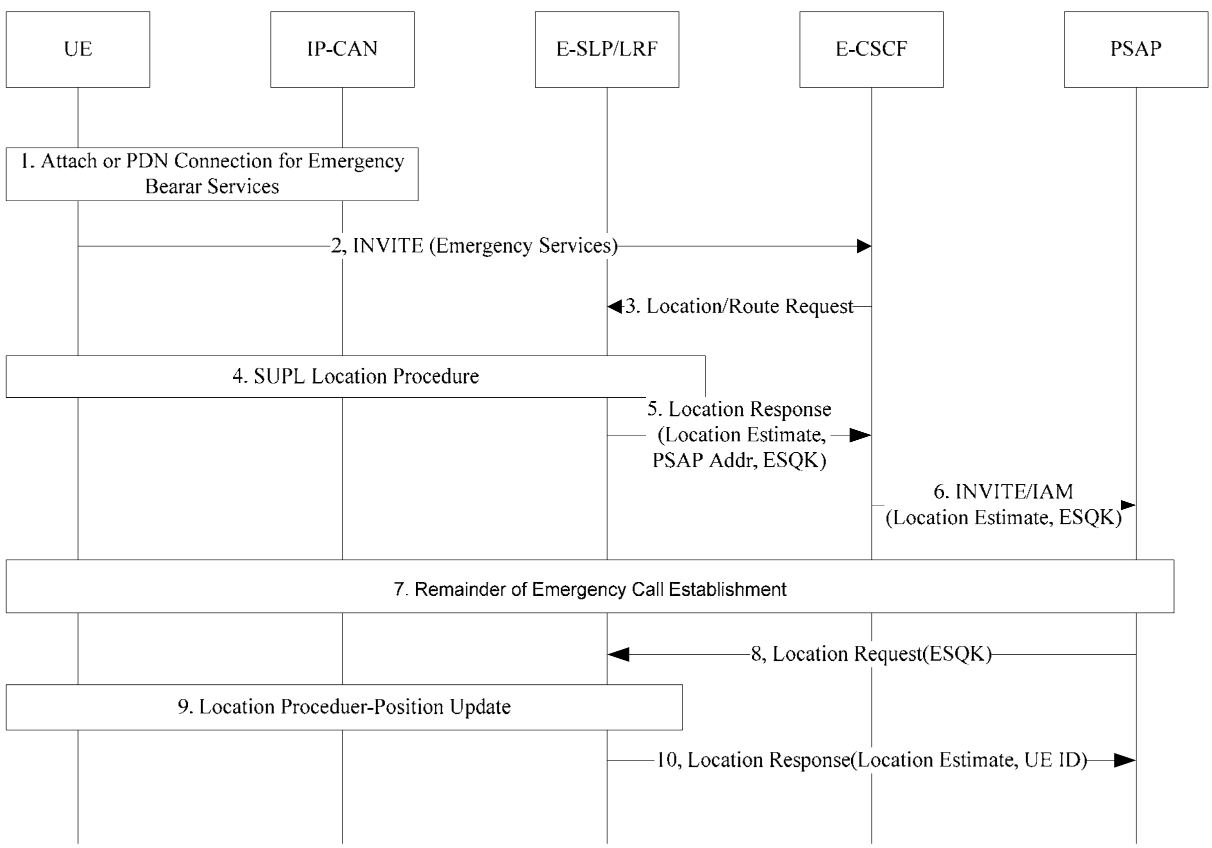
5.2.1 Call Flow for E911 using Control Plane LBS



1. Following an emergency call invocation from the user, the UE will emergency attach to the EPS (i.e., in limited service mode) or if already connected to EPS, request a PDN Connection for emergency bearer services.
2. Once step 1 is complete, the MME sends a location report to a GMLC in the network that is designated to support location of emergency calls. The location report carries the UE identity (e.g. IMSI) and the MME IP address.
3. The GMLC acknowledges the location report.
4. The UE may perform an emergency registration with home IMS.
5. The UE sends an INVITE for the emergency call to the IMS in the network. The INVITE is forwarded to the E-CSCF.
6. The E-CSCF sends a location and/or routing request to an LRF which forwards this to an associated GMLC.
7. The GMLC obtains location information for the UE using a procedure applicable to the architecture.

8. The GMLC returns the location information to the LRF which may use this to obtain PSAP routing information. The LRF then returns the location and/or PSAP routing information to the E-CSCF. Correlation information (e.g. an ESQK) can also be included.
9. The E-CSCF routes the call to the PSAP indicated by the LRF. Any ESQK can also be sent to the PSAP.
10. The remainder of the emergency call establishment occurs.
11. The PSAP sends a request to the LRF (e.g. determined using the ESQK) for the location of the UE. The LRF forwards the request to the associated GMLC.
12. The GMLC obtains location information for the UE using the same procedure and returns to the LRF.
13. The LRF returns the location to the PSAP.

5.2.2 Call Flow for E911 using User Plane LBS



1. Following an emergency call invocation from the user, the UE will launch an emergency attach to the IP-CAN over EPS (i.e., in limited service mode) or if already connected over IP-CAN, request a PDN Connection for emergency bearer services.

2. The UE sends an INVITE for the emergency call to the IMS in the visited network. The INVITE is forwarded to the E-CSCF.

3. The E-CSCF sends a location and/or routing request to an LRF which forwards this to an associated E-SLP over internal or standardized interface.

4. The E-SLP obtains location information for the UE using SUPL.

5. The E-SLP returns the location information to the LRF over internal or standardized interface, and LRF may use this to obtain PSAP routing information. The LRF then returns the location and/or PSAP routing information to the E-CSCF. Correlation information (e.g. an ESQK) can also be included.

6. The E-CSCF routes the call to the PSAP indicated by the LRF. Any ESQK can also be sent to the PSAP.

7. The remainder of the emergency call establishment occurs.

8. The PSAP sends a request to the LRF (e.g. determined using the ESQK) for the location of the UE. If updated location was requested, the LRF forwards the request to the associated E-SLP over internal or standardized interface.

9. The E-SLP obtains location information for the UE using the same procedure and provides this to the LRF.

10. The LRF returns the location to the PSAP.

5.2.3 Protocol and Control Gap(s)

In order to support LCS in LTE, several functional components and their associated interfaces, new to the MSF baseline architecture, are required. They have been highlighted in Section 5.1. The applicable new protocols include:

- From 3GPP: LPP/LPPa, ELP, LCS-AP
- From OMA: MLP, RLP, ULP, ILP

6.0 Summary and Conclusions

LBS application is expected to grow rapidly in the LTE network and has the potential of becoming a significant new source of revenues for wireless network operators. Two solutions are available for LCS implementation: the C-Plane based solution standardized by 3GPP and the U-Plane based solution standardized by OMA. Many existing 2G and 3G wireless networks have deployed either one or the other solution.

In order to provide service continuity in a cost-effective manner for both C-Plane and U-plane users, as well as to capitalize on all potential LBS applications developed for either solution, an architecture integrating both the C-Plane and the U-Plane solution has been described and recommended for inclusion into the MSF baseline architecture.

7.0 Definition

MSF baseline architecture:	Within the scope of this document, the MSF baseline architecture refers to the MSF R4 architecture [11] + the architectural framework for the 3GPP Packet-Switched Access Tile [12] + the architectural Framework for the 3GPP Evolved Packet System (EPS) Access Tile [13].

8.0 Acronyms and Abbreviations

3GPP	Third Generation Partnership Project
AoA	Angle of Arrival
CSCF	Call Service Control Function
E-CSCF	Emergency CSCF
ELP	EPC LCS Protocol
E-SMLC	Evolved Serving Mobile Location Center
E-UTRAN	Evolved Universal Transmission Radio Access Network
ECID	Enhanced Cell ID
GMLC	Gateway Mobile Location Center
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
ILP	Internal Location Protocol
LBS	Location Based Service
LCS	LoCation Service
LPP	LTE Positioning Protocol
LPPa	LTE Positioning Protocol annex
MLP	Mobile Location Protocol
OMA	Open Mobile Alliance
OTDOA	Observed Time Difference Of Arrival
PSAP	Public Safety Answering Point
RAN	Radio Access Network
RLP	Roaming Location Protocol
RRC	Radio Resource Control
RRLP	Radio Resource Link Protocol
RSRP	Received Signal Received Power

RSSI	Received Signal Strength Indicator
RTT	Round Trip Time
SAS	Standalone SMLC
SBAS	Space Based Augmentation Systems
SET	SUPL Enabled Terminal
SMLC	Serving Mobile Location Center
SLC	SUPL Location Center
SLP	SUPL Location Platform
SPC	SUPL Positioning Center
SUPL	Secure User Plane Location
UE	User Equipment
ULP	User Plane Location Protocol

9.0 References

[1] 3GPP TS 22.071: “Location Services (LCS); Service description; Stage 1”

[2] 3GPP TS 23.271: “Functional stage 2 description of Location Services (LCS)”

[3] 3GPP TR 23.891: “Evaluation of LCS Control Plane Solutions for EPS”

[4] 3GPP TS 36.305: “Stage 2 functional specification of User Equipment (UE) positioning in E-UTRAN”

[5] 3GPP TS 44.031: "Location Services (LCS); Mobile Station (MS) - Serving Mobile Location Centre (SMLC) Radio Resource LCS Protocol (RRLP)

[6] 3GPP TS 36.331: "Evolved Universal Terrestrial Radio Access (E-UTRA); "Radio Resource Control (RRC); Protocol specification".

[7] 3GPP TS 23.167: “IP Multimedia Subsystem (IMS) emergency sessions”

[8] 3GPP TR 23.869: “IP Multimedia Subsystem (IMS) Emergency calls over General Packet Radio Service (GPRS) and Evolved Packet Service (EPS)”

[9] OMA-AD-SUPL-V2_0: "Secure User Plane Location Architecture Draft Version 2.0".

[10] OMA-TS-ULP-V2_0: "User Plane Location Protocol Draft Version 2.0".

[11] MSFR4-ARCH-OVERVIEW-FINAL, MSF Release 4 Architecture Overview

[12] msf.2008.160: "Architectural Framework for the 3GPP Packet-Switched Access Tile"

[13] MSF-ARCH-013-FINAL: “Architectural Framework for the 3GPP Evolved Packet System (EPS) Access Tile”