LTE Location Based Services Technology Introduction

White paper

LTE Location Based Services (LBS) involve the process of determining where a device is located. Global Navigation Satellite System (GNSS) based solutions are highly accurate and the technology of choice for absolute position accuracy, providing the device has a good line-of-sight, but this is not always the case. A device can be in a highly dense urban environment with reduced satellite visibility or indoors with very low signal levels.
These limitations of GNSS systems have meant that LTE cellular based alternatives have been developed within 3GPP Release 9 and onwards. They are described in this white paper.

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1 Introduction

Location Based Services (LBS) is already well established, using the location of the mobile device for both emergency services (E911,) and infotainment (map services, directions to a chosen location, local advertising/information and "find a friend"). So far, this is just the beginning for LBS; the increasing sophistication of the smart phone, high-speed data rates with LTE, and consumer demand for 'always-on' interaction mean that LBS applications are going to expand massively over the coming years.

What all location based services have in common is finding where the mobile device is actually located. LTE Release 9 provides support for the following location technologies:

Satellite Based Positioning:

Autonomous and Assisted Global Navigation Satellite Systems (A-GNSS) such as GPS and GLONASS

Mobile Radio Cellular Positioning:

Observed Time Difference of Arrival (OTDOA) and enhanced Cell ID (eCID)

Hybrid Methods:

Hybrid-GNSS or GNSS + Mobile Radio Cellular Positioning like OTDOA

Control Plane (C-Plane) and User Plane (U-Plane) session handling:

LPP, SUPL 2.0

Mobile phone users expect the same Quality of Service whether they are stationary, on the move, in a city, or on the countryside. Location Based Services are no exception and must deliver the same user experience with a fast 'Time to First Fix' (TTFF) performance and reliable location accuracy. The location is not the only changing factor; device connectivity can also vary as the user roams around the network between LTE, 3G, and 2G. With the evolution in cellular technologies from 2G towards 4G, the approach to providing location based services has developed from simple satellite based positioning to complex trilateration methods and hybrid solutions

This application note describes the positioning methods available for LTE in detail.

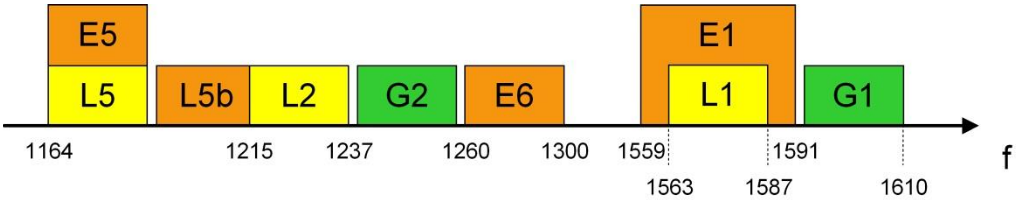
2 Global Navigation Satellite Systems

Positioning defines the process of determining the positioning and/or velocity of a device using radio signals.

Location Based Services, short LBS, are a significant element in today's service portfolio offered via a network operator's cellular network. It starts with simple things like answering the question "Where am I?" which is very often combined with determining points of interests, such as closest restaurants, shopping possibilities or finding a route from one point to another. Further social networks like facebook, Google Plus and others allow that status updates can be linked with the current position of the user.

Beside the commercial usage, there are also safety aspects for positioning. As an example more than half of all emergency calls in the European Union (EU) are made using a mobile device. In almost 60% of all cases, the caller cannot provide its current position accurately. Therefore the EU has issued a directive in 2003, where network operators are required to provide emergency services with whatever information is available about the location where the emergency call was made from. In the United States of Americas this is mandatory since a long time with the FCC's Enhanced 911 mandate making the location of a cell phone available to emergency call dispatchers [1]. With this mandate the FCC has defined accuracy requirements for the different methods position estimation can be based on for county and country level, i.e. 67% of all emergency calls made on the county level need to be in a range of 50 m or less. These are quite high accuracy requirements that need to be fulfilled and guaranteed no matter what the underlying position estimation technology is or in which environment the position will be estimated in. The challenges for accurate position estimation are influence by the environment - urban areas, city centre, outdoor or indoor and the mobility of the user. Based on these two categories, a different technological approach might be more applicable and effective.

Determining a device's position is traditionally based on satellite-based position estimation using Global Navigation Satellite Systems (GNSS), like the Global Positioning System, short GPS. There are more systems in use and or currently established, such as Russia's GLONASS, the European GALLILEO and the Chinese COMPASS. Other countries are also planning satellite constellations such as India. Figure 1 provides an overview of GPS, GLONASS and GALILEO along with the frequencies they are using.



GALLILEO		GPS		GLONASS	
Signal	$f_{Carrier}$ [MHz]	Signal	$f_{Carrier}$ [MHz]	Signal	$f_{Carrier}$ [MHz]
E1	1575,420	L1C/A	1575,420	G1	1602±k*0.5625
E6	1278,750	L1C	1575,420	G2	1246±k*0.5625
E5	1191,795	L2C	1227,600	k = -7 … 13	
E5a	1176,450	L5	1176,450		
E5b	1207,140				

Figure 1: Frequencies being used by GPS, GALLILEO and GLONASS

Today the majority of all modern mobile devices such as smart phones and tablets have an integrated GNSS receiver. To estimate a 3D position properly the receiver needs to have an unobstructed line of sight to at least four satellites. This is one of the drawbacks of only using GNSS. For example, in city centers or in cities with narrow alleys, the line of sight reception of the low power radio signals coming from the satellites is not guaranteed. In fact, in many situations, including being indoors, it is impossible to get sufficient line of sight. Figure 2 shows an example of availability of satellite signals in a city center.

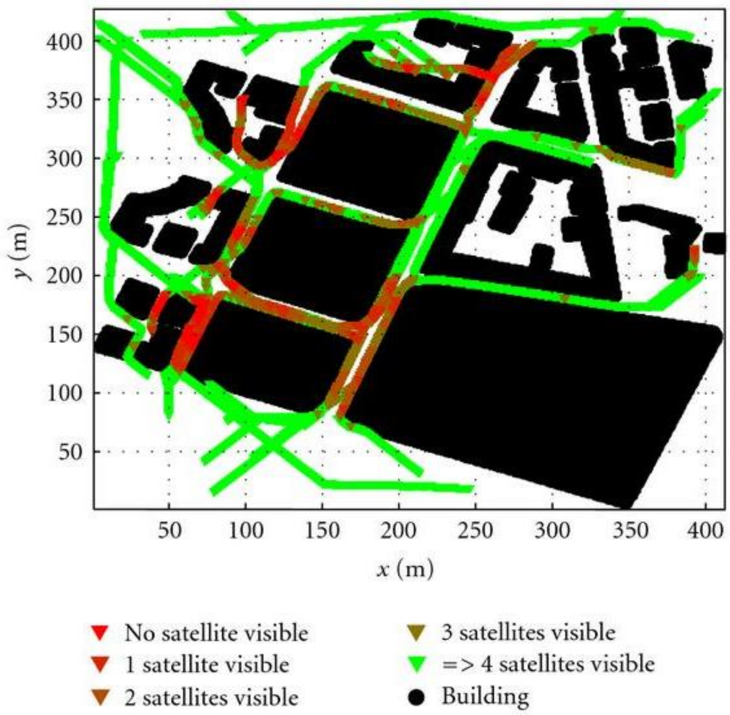


Figure 2: Number of visible GPS satellites in a city centre [4]

2.1 Assisted – Global Navigation Satellite Systems

To overcome the line-of-sight and low signal level drawbacks of autonomous GNSS the cellular network assists the GNSS receiver by providing assistance data for the visible satellites. Assistance data typically includes the Almanac and/or Ephemeris data which is normally received via the satellite navigation message. This assistance data improves the performance for start-up and acquisition times – TTFF, sensitivity, and power consumption. The general network topology for A-GNSS can be seen in Figure 3.

Figure 3: A-GNSS uses data from both the satellites and the cellular network

In an Assisted GNSS system, the contents of the navigation message are supplied to the receiver by the cellular network. This enables the receiver to know which satellites are in view and what their most likely Doppler shift is. This information allows the search region to be restricted and the TTFF can be reduced down to a few seconds as opposed to an autonomous cold start TTFF of many minutes. An overview of the GPS Navigation Message can be seen in Figure 4.

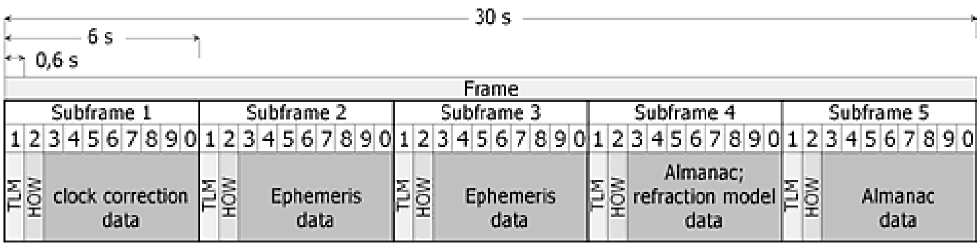


Figure 4: GPS Navigation Message Frame = 1,500 bits = 5 Sub-frames with 300 bits each (50 Hz)

The GPS navigation message is broadcasted by each satellite and is transmitted with a relatively low data rate of 50 bits/sec. This navigation message contains information about the location of the satellites, satellite health, time, clock correction etc. and must be available to the receiver before attempting to determine its location.

An overview of the navigation message contents for GPS is as follows:

Sub-frames 1-3: Satellite-specific, repetition every 30 seconds

Subframe 1 = GPS date (week number), clock correction, satellite status & health

Subframe 2 & 3 = Ephemeris: Very accurate information for the transmitting satellite (time + correction info), enables calculation of satellite position and receiver position, data valid for <4 hours

Sub-frames 4-5: Satellite-generic, repetition after 12.5 min

Almanac: Track data of every satellite, determines which satellites to search for, and includes their location and PRN, data valid up to ~180 days

Each subframe = 1/25 of total almanac

25 whole frames for complete almanac (15,000 bits) = 12.5 minutes

Each subframe contains GPS time (HOW) Handover Word

There are 2 basic methods for positioning calculation for A-GNSS, both approaches involve the mobile device measuring the GNSS signals:

Mobile Assisted

The device measures the visible satellites and sends GNSS measurement data (code phase, Doppler, signal strength) to the network, which calculates the position.

Mobile Based

The device performs the same satellite measurements as Mobile Assisted but also calculates its position before sending the calculated location back to the network. This requires additional processing and position determination algorithms to be supported in the device.

For Mobile Based a location calculation must be performed within the device using an iterative algorithm due to the multiple unknowns. For example, the azimuth and elevation of the satellites on which ionospheric and troposheric corrections depend cannot be known until the position of the device is known – which is what the device is trying to determine. Additionally the time of flight is unknown until the receiver position is known and the satellite position at transmission time cannot be determined until the time of flight is known…

The sensitivity of the position determination algorithm is such that approximate initial values for unknown parameters will be sufficient to calculate a better approximation to the parameters. For A-GNSS solutions, initial starting values can be derived from known cellular network information like the base station (eNB in LTE) serving cell location. Further iterations of the algorithm then provide better approximations, until the required accuracy of sub 1 meter is achieved. Typically approximately four iterations will converge with a location of suitable accuracy.

This location calculation places additional complexity on the device resulting in additional processing to be performed and therefore increased power consumption.

2.2 Why A-GNSS is not always enough

As statistics prove that almost 50% of all connections are made from inside, indoors remains a challenging environment. Often there is still an acceptable coverage by mobile radio signals, to receive the A-GNSS information, however this does not help if the satellites cannot be detected due to no reception of GNSS signals inside a building.

In such a critical scenario, position estimation using mobile radio signals is the way forward. Such methods are not new and have already been available for Global System of Mobile Communication (GSM) position estimation based on mobile radio signals. The following table Figure 5 compares position estimation based on (A-) GNSS, such as GPS with position estimation based on mobile radio systems.

(A-)GNSS	Mobile Radio Systems
Low bandwidth (typical 1 – 2 MHz)	High bandwidth (up to 20 MHz in LTE)
Very weak received signals	Comparatively strong received signals
Similar received power levels from all satellites	One strong signal from the serving base station, strong interference situation
Long synchronization procedures	Short synchronization procedures
Signal a-priori know due to low data rates	Complete signal not a-priori known to support high-data rates, only certain pilots
Very accurate synchronization of the satellites by atomic clocks	Synchronization of the base station not a-priori guaranteed
Line of sight (LOS) access as normal case, not suitable for urban / indoor areas	Non-line of sight (NLOS) access as normal case, suitable for urban / indoor areas
3-dimensional positioning	2-dimensional positioning

Figure 5: Comparison GNSS and Mobile Radio Systems

However with LTE, as the mobile broadband technology of choice for the majority of network operators worldwide, additional methods have been standardized and existing ones enhanced. The following sections will provide a detailed overview on positioning methods defined for LTE within 3GPP Release 9 based on mobile radio signals, beside traditional (A-)GNSS. A-GNSS is supported in LTE, where the required transfer of assistance data and information is handled by LPP (Location Positioning Protocol) as defined in [2].

3 General aspects of LTE positioning

Generally an execution of a positioning method, independent if based on satellite or mobile radio signals, consist of three steps:

1. Providing initial assistance and information for position estimation.
2. Execution of certain measurements and reporting of measurement results.
3. Position estimation based on measurement results.

The supported positioning methods in LTE rely on the high-level network architecture shown in Figure 6. As one of the design goals for LTE was to decentralize everything, the network architecture has been defined in that way, that it is generally independent from the underlying network. There are three main elements involved in the process, the Location Service Client (LCS), the LCS Server (LS) and the LCS Target. A client, means the requesting service, is in the majority of the cases installed or available on the LCS target. This service obtains the location information by sending a request to the server. The location server is a physical or logical entity that collects measurements and other location information from the device and base station and assists the device with measurements and estimating its position. The server basically processes the request from the client and provides the client with the requested information and optionally with velocity information.

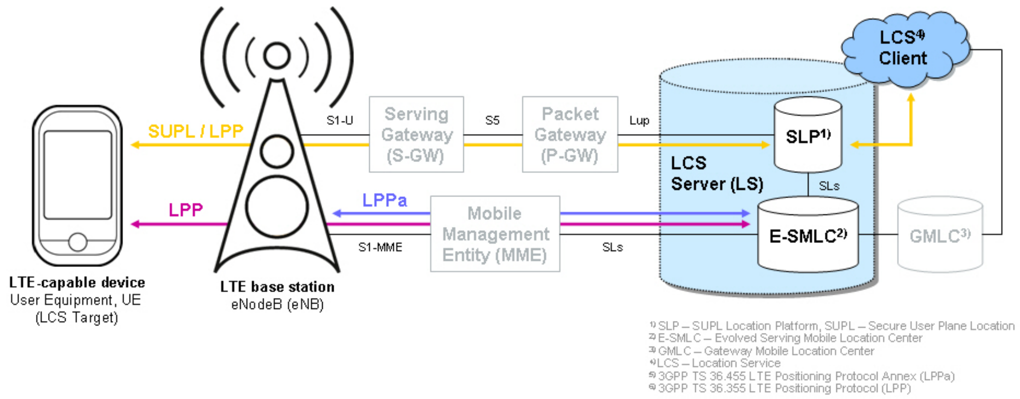


Figure 6: E-UTRA positioning network architecture

There are two different possibilities for how the device (client) can communicate with the location server. There is the option to do this over the user plane (U-Plane), using a standard data connection, or over the control plane (C-Plane). In the control plane the E-SMLC (Evolved Serving Mobile Location Center) is of relevance as location server, where for the user plane this is handled by the SUPL Location Platform. SUPL stands for Secure User Plane Location and is a general-purpose positioning protocol defined by the Open Mobile Alliance (OMA). Both E-SMLC and SLP are just logical entities and can be located in one physical server.

C-Plane

LBS session is established and assistance data message exchange is performed over the 'control' channels. Control plane signalling is supported for positioning due to being a more reliable and robust connection, to overcome possible network congestion in an emergency scenario. LTE Positioning Protocol (LPP) [2] is the protocol used for C-Plane LBS sessions.

U-Plane

The data link is used as the bearer for handling the LBS session and for transport of the assistance data messages. U-Plane is the default approach used for infotainment (map services, directions to a chosen location, local advertising/information and "find a friend") applications due to the large amount of data transfer. This volume of data is not typically carried over cellular control channels.

Two protocols are used for the overall information exchange: the LTE Positioning Protocol (LPP) and the LTE Positioning Protocol Annex (LPPa) [2], [3]. The latter one is used for the communication between the Location Server and the eNode B, the LTE base station. The base station in case of OTDOA is in charge for proper configuration of the radio signals that are used by the terminal for positioning measurements, the so called positioning reference signals (PRS). It further provides information back to the E-SMLC, enables the device to do inter-frequency measurements if required and – based on the E-SMLC request – takes measurement itself and sends the results back to the server.

The differentiation between supported positioning methods is based on two facts. First, who or what is the "measurement entity", which could be only device or base station. Second, who or what is the "position estimation entity". To classify the measurements, the term "assisted" is used. For position calculation or estimation the term "based" is used. With that knowledge, position methods supported in LTE can be further categorized. The following table provides an overview on supported positioning methods in LTE and which category they belong to.

Method	UE-based	UE-assisted	eNB-assisted	3GPP Release
A-GNSS	**Yes** Measurement: UE Estimation: UE	**Yes** Measurement: UE Estimation: LS	No	Rel-9
Downlink (OTDOA)	No	**Yes** Measurement: UE Estimation: LS	No	Rel-9
Enhanced Cell ID	No	**Yes** Measurement: UE Estimation: LS	**Yes** Measurement: eNB Estimation: LS	Rel-9
Uplink (UTDOA)	No	No	**Yes** Measurement: eNB Estimation: LS	Rel-11
RF Pattern Matching	?	?	?	Rel-11

Figure 7: Supported positioning methods in LTE

As Figure 7: Supported positioning methods in LTE shows, there are in total four positioning methods in LTE that are based on mobile radio signals: OTDOA, Enhanced Cell ID, UTDOA and RF pattern matching. The two later ones are currently being standardized by 3GPP and will become part of 3GPP Release 11. These will be not further discussed in this document. OTDOA and Enhanced Cell ID are explained in following sections.

4 LTE Positioning Protocols

The communication protocol used between the device and the LCS varies depending on the wireless communication standard in use and potentially the bearer (C-Plane or U-Plane) being used to transport the assistance data. LTE introduced LPP (Location Positioning Protocol) [2] for the overall information exchange during an LBS session between the UE and the LCS.

U-Plane can theoretically use any location protocol due to the bearer agnostic design applied when defining SUPL. Figure 8 shows typical network deployed combinations.

	GSM	WCDMA	LTE	CDMA
C-Plane	RRLP	RRC	LPP	TIA-801
U-Plane	RRLP	RRLP	RRLP / LPP	TIA-801

Figure 8: Typical deployed protocol vs. bearer combinations

4.1 LPP – Location Positioning Protocol

Location Positioning Protocol (LPP) is a point-to-point protocol that allows multiple connections to different devices. LPP can be used in both: user plane and control plane for LTE. The exchanged LPP messages and information can be divided into four categories:

1. UE positioning capability information transfer to the E-SMLC.
2. Positioning assistance data delivery from the E-SMLC to the UE.
3. Location information transfer.
4. Session management – Error handling and abort functions

LPP provides support for GNSS based positioning, network based positioning and hybrid – a combination of both GNSS and network based positioning.

LPP is a relatively simple protocol with support for reliable in sequence transmission of data. LPP includes support for acknowledged mode information exchange but does not support the reordering of messages due to the use of ‘stop-and-wait’ transmissions to ensure that messages arrive in the correct order of transmission. When LPP is used over U-Plane via SUPL, the acknowledgment information is omitted and replaced by TCP/IP protocol.

LLP over C-Plane provides support for three distinct location requests:

MO-LR – Mobile Originated Location Request

The mobile device / UE initiates the location determination session

MT-LR – Mobile Terminated Location Request

The network (LCS) initiates the location determination session, which can be rejected by the user via the use of privacy settings on the device.

NI-LR – Network Induced Location Request

The network (LCS) initiates the location determination session, typically used for Emergency Services. NI-LR differs from MT-LR since privacy settings have no effect on NI-LR.

4.2 SUPL – Secure User Plane

SUPL is an encrypted IP technology that was developed to support Location-Based Services (LBS) for wireless communications. SUPL is bearer agnostic and can be applied to multiple wireless standards including LTE where SUPL 2.0 is commonly used for U-Plane LBS sessions. Figure 9 provides an overview of the network entities involved in both U-Plane and C-Plane LBS. The U-Plane message exchange takes place in connected stated over the IP data link of the mobile communication standard.

SUPL 2.0, the latest version from OMA, does not define messages for the transport of assistance data. Instead it defines a set of protocols for transporting existing messages as defined by the wireless standards: GSM (RRLP), WCDMA (RRC), CDMA (TIA-801) and LTE (LPP). This provides greater flexibility for operator LTE LBS deployment. For instance this allows the rollout of LTE LBS using existing RRLP protocols (instead of LPP) over SUPL 2.0, thus reducing the required changes in the device and network.

Secure User Plane Location (SUPL)

Secure: Encrypted IP connection = SSL (TLS1.0 or 1.1) with pre-shared certificates

User **P**lane: IP communication via SUPL Enabled Terminal (SET) and the SUPL Location Platform (SLP)

Location: position calculation, A-GNSS

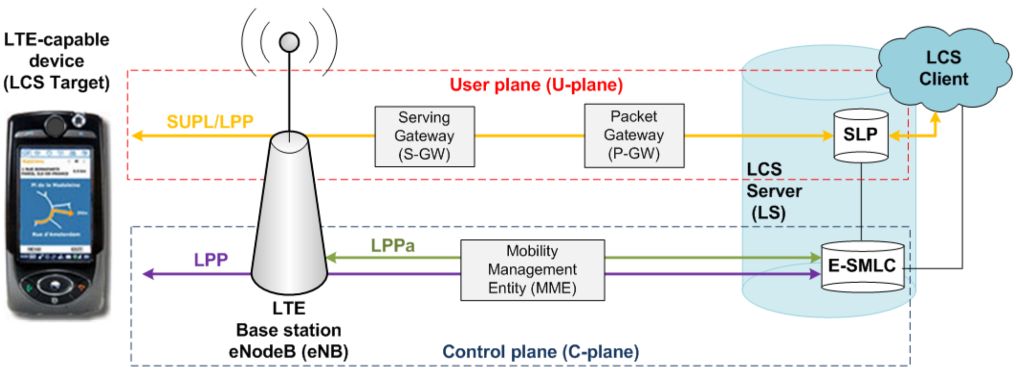


Figure 9: E-UTRA positioning network architecture

SUPL provides support for two kinds of sessions: Network Initiated (NI) when the network wants to determine the device location and SET Initiated (SI) – SUPL Enabled Terminal Initiated for when the device wants to determine its location. To be able to establish a NI session with a SET a trigger must be sent to the SET informing it to move to connected state and to contact a specific IP address and port.

NI – Network Initiated

The network requires the device position. Requires a trigger to start such as:

MT-SMS: could be via NAS or over IMS

WAP-Push

UDP Push

SIP Push

The trigger is used to inform the device of the IP and port for the SUPL session and to trigger the device to initiate the connection.

SI – SET Initiated

The device requires its position for a particular service – Turn-by-turn navigation applications or Find My Nearest apps.

SUPL 2.0 includes multiple enhancements over SUPL 1.0 notably support for Hybrid location positioning techniques, support for major GNSS technologies, area event triggering and emergency call handling for E911.

4.2.1 Areas Event Triggering

SUPL 2.0 introduces support for geographical area event triggers which enables reporting from the SET when it is outside a specific area, entering, within, or leaving a particular area. These triggers are mutual negotiated between the SET and the LCS. The addition of these geographic events opens up new location based services such as targeted advertising or ‘Passbook’ based applications for airport boarding pass notifications.

An overview of area event trigger can be seen in Figure 10. The messages used by SUPL 2.0 to deliver this feature rich service can be classified into the following message categories:

Trigger messages – used to exchange SET area event capabilities and to configure/start and stop the triggering

SUPL TRIGGERED START/RESPONSE/STOP

Reporting – used by the SET to report back to the SLP if the area event requirements are met

SUPL REPORT

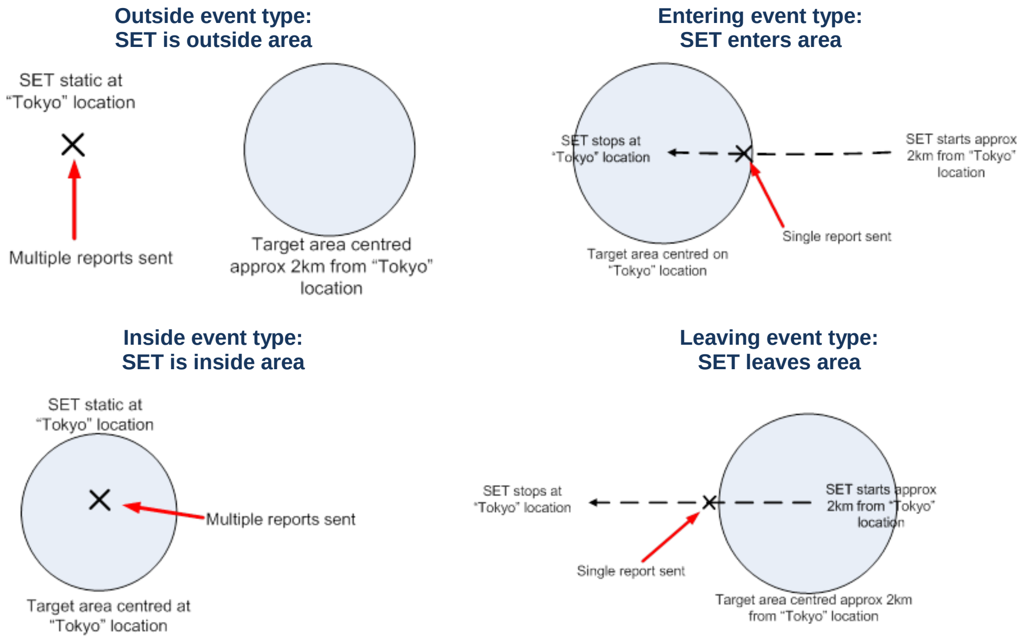


Figure 10: SUPL 2.0 Area Event Triggering

4.2.2 Emergency Call Handling - E911

Additions to SUPL 2.0 for emergency call handling include the prioritization of emergency SUPL sessions over non-emergency sessions. This is a very important addition to SUPL due to the network migration from circuit switched voices services to all IP IMS based VoLTE calls this represents a significant shift in wireless communications. In LTE VoLTE enabled networks the E911 – Emergency Voice Calls could take place over the IP packet data domain therefore priority must be assigned to the emergency SUPL session.

SUPL 2.0 provides support for the following:

- Any non-emergency SUPL session is immediately aborted when an Emergency SUPL session starts
- During an emergency SUPL session, any non-emergency SUPL_Init is discarded
- If there are multiple Emergency SUPL_init messages arriving, then:
  - UE first processes the SUPL_init messages that refer to a E-SLP that is on a whitelist, that is stored in the UE
  - UE then processes the other SUPL_init messages.
- If there are more than one Emergency SUPL Inits, with FQDNs that are on the whitelist, the UE responds according to: "first come first serve".

5 OTDOA – Observed Time Difference of Arrival

OTDOA is the positioning solution of choice when GNSS signals cannot be used due to a lack of a clear line of sight. OTDOA uses neighbor cells (eNB's) to derive an observed time difference of arrival relative to the serving cell. Current solutions are based on both Inter-Band and Intra-Band eNB measurements. With future network deployments of LTE Advanced Carrier Aggregation (LTE-A CA), OTDOA can be further extended to measurements of LTE-A Component Carriers (CC's).

5.1 Reference Signal Time Difference (RSTD) measurement

This position estimation is based on measuring the Time Different Of Arrival (TDOA) of special reference signals, embedded into the overall downlink signal, received from different eNB's. Each of the TDOA measurements describes a hyperbola, where the two focus points (F1, F2) are the two measured eNB's. The measurement needs to be taken at least for three pairs of base station. The position of the device is the intersection of the three hyperbolas for the three measured base stations (A-B, A-C, B-C; see Figure 11).

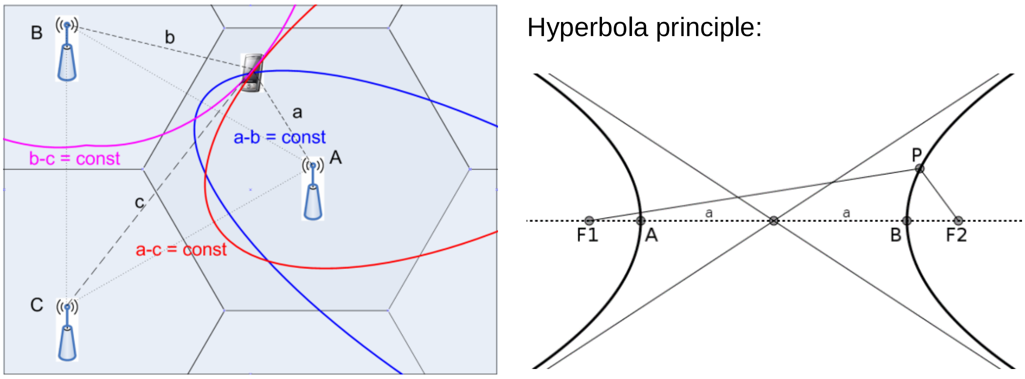


Figure 11: TDOA measurement based on hyperbolas

The measurement taken between a pair of eNB's is defined as Reference Signal Time Difference (RSTD) [5]. The measurement is defined as the relative timing difference between a subframe received from the neighboring cell j and corresponding subframe from the serving cell i. These measurements are taken on the Positioning Reference Signals, the results are reported back to the location server, where the calculation of the position happens. In the case of Hybrid Mode these RSTD measurements can be combined with GNSS measurement to calculate the position of the device.

5.2 Positioning Reference Signals (PRS)

With 3GPP Release 9 Positioning Reference Signals (PRS) have been introduced for antenna port 6 as the Release 8 cell-specific reference signals are not sufficient for positioning.

What is an antenna port?

An antenna port is defined such that the channel over which a symbol on the antenna port is conveyed can be inferred from the channel over which another symbol on the same antenna port is conveyed. The device (UE) shall demodulate a received signal – which is transmitted over a certain antenna port – based on the channel estimation performed on the reference signals belonging to this (same) antenna port. The way the "logical" antenna ports are mapped to the "physical" TX antennas lies completely in the responsibility of the base station. There's no need for the base station to tell the UE.

The simple reason is that the required high probability of detection could not be guaranteed. A neighbor cell with its synchronization signals (Primary-/ Secondary Synchronization Signals) and reference signals is seen as detectable, when the Signal-to-Interference-and-Noise Ratio (SINR) is at least -6 dB. Simulations during standardization have shown, that this can be only guaranteed for 70% of all cases for the 3rd best-detected cell, means 2nd best neighboring cell. This is not enough and has been assumed an interference-free environment, which cannot be ensured in a real-world scenario. However, PRS have still some similarities with cell-specific reference signals as defined in 3GPP Release 8. It is a pseudo-random QPSK sequence that is being mapped in diagonal patterns with shifts in frequency and time to avoid collision with cell-specific reference signals and an overlap with the control channels (PDCCH).

PRS are defined by bandwidth (N_{RB}^{PRS}), offset (Δ_{PRS}), duration (N_{PRS} = number of consecutive subframes) and periodicity (T_{PRS}). It's worth noting, that PRS bandwidth is always smaller than the actual system bandwidth (N_{RB}^{DL}). PRS are always mapped around the carrier frequency, the unused DC subcarrier in the downlink [Figure 12]. In a subframe where PRS are configured, typically no PDSCH is transmitted.

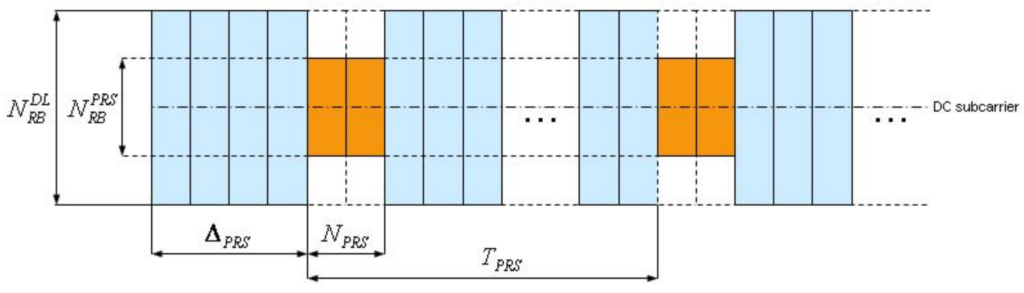


Figure 12: PRS configuration

PRS can be muted on certain occasions to further reduce inter-cell interference. All this information, means PRS configuration and PRS muting is provided via the LPP protocol from the Location Server.

6 eCID – Enhanced Cell ID

OTDOA is the method of choice for urban and indoor areas, where (A-)GNSS will not provide its best or no performance at all. Another method for position estimation in LTE is Enhanced Cell ID (E-CID), based on Cell of Origin (COO). With COO the position of the device is estimated using the knowledge of the geographical coordinates of its serving base station, in terms of LTE the eNB. The knowledge of the serving cell can be obtained executing a tracking area update or by paging. The position accuracy is in that case linked to the cell size, as the location server is only aware that the device is served by this base station. This method would of course not fulfill the accuracy requirements defined by the FCC. Therefore Enhanced Cell ID has been defined with LTE, mainly for devices where no GNSS receiver has been integrated. On top of using the knowledge of the geographical coordinates of the serving base station, the position of the device is estimated more accurately by performing measurements on radio signals. E-CID can be executed in three ways, using different types of measurements:

1. E-CID with estimating the distance from 1 base station.
2. E-CID with measuring the distance from 3 base station.
3. E-CID by measuring the Angle-of-Arrival (AoA) from at least 2 base station, better 3.

In the first two cases the possible measurements can be: Reference Signal Received Power (RSRP), a standard quality measurement for Release 8 terminals; or TDOA and the measurement of the Timing Advance (TADV) or Round Trip Time (RTT). In the first case the position accuracy would be just a circle. Method number 2 and 3 provide a position accuracy of a point, while measuring more sources. For case 1 and 2, the measurements are taken by the device, and are therefore UE-assisted. For case number 3 the measurements are taken by the base station and are therefore eNB-assisted (Figure 13).

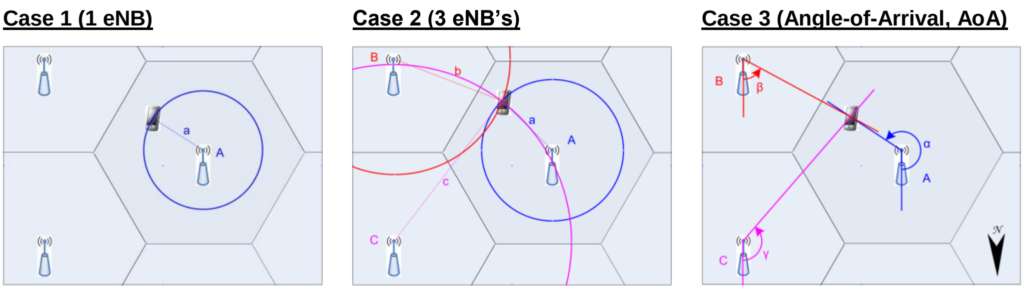


Figure 13: Enhanced Cell ID (E-CID) methods

The following sections will take a look on TDAV measurement and measurement of the Angle-of-Arrival (AoA).

6.1 Timing Advance (TDAV), Round Trip Time (RTT)

With 3GPP Release 9 the timing advance measurement has been enhanced, so that there are now a Type 1 and a Type 2 measurement. The Type 2 measurement relies on the timing advance estimated from receiving a PRACH preamble during the random access procedure. Type 1 is defined as the sum of the receive-transmit timing difference at the eNB (positive or negative value) and the receive-transmit timing difference at the terminal (always a positive value). The base station measures first its own timing difference and reports to the device to correct its uplink timing per Timing Advance (TA) command, a MAC feature. The UE measures and reports its receive-transmit timing difference as well. Both timing differences allow the calculation of the Timing Advance Type 1, corresponding to the Round Trip Time (RTT). The RTT is reported to the location server, where the distance d to the base station is calculated using $d = c * RTT/2$, where c is the speed of light (Figure 14).

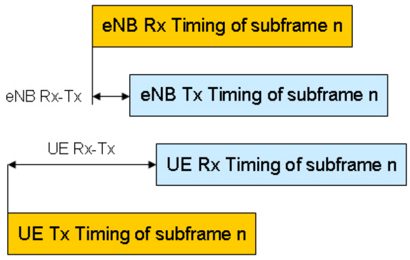


Figure 14: eNB and UE receive-transmit timing difference

6.2 Angle-of-Arrival (AoA) measurement

RTT and TA can be used for distance estimation, however they do not provide any information on direction. This can only be obtained from an Angle-of-Arrival (AoA) measurements. AoA is defined as the estimated angle of a UE with respect to a reference direction which is geographical North, positive in a counter-clockwise direction, as seen from an eNB. This is shown in the Figure 15.

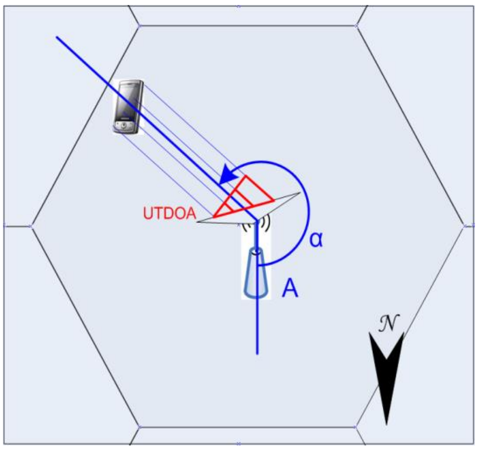


Figure 15: Angle-of-Arrival (AoA) measurement

The eNB can usually estimate this angle on any part of the uplink transmission, however typically Sounding Reference Signals are used for this purpose. But the Demodulation Reference Signals (DM-RS) also provide sufficient coverage. In addition, the antenna array configuration has a key impact to the AoA measurements. Basically the larger the array, the higher the accuracy. With a linear array of equally spaced antenna elements, the received signal at any adjacent elements is phase-rotated by a fixed amount THETA. And the value for THETA is a function of the AoA, as well as the antenna element spacing and carrier frequency

7 Literature

[1] http://www.fcc.gov/document/wireless-e911-location-accuracy-requirements-1

[2] TS 36.355 Evolved Universal Terrestrial Radio Access (E-UTRA); LTE Positioning Protocol (LPP); Release 9

[3] TS 36.455 Evolved Universal Terrestrial Radio Access (E-UTRA); LTE Positioning Protocol A (LPPa); Release 9

[4] “Hybrid Data Fusion and Tracking for Positioning with GNSS and 3GPP-LTE”; http://www.hindawi.com/journals/ijno/2010/812945/

[5] TS 36.214 Evolved Universal Terrestrial Radio Access (E-UTRA); Physical Layer measurements; Release 9

8 Additional Information

Please send your comments and suggestions regarding this white paper to

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