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Location-based services & positioning technique using SUPL (Secure User Plane Location)

Aakash Kaushal
Anupriya Malhotra
Hanish Vohra

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Abstract

SUPL is an IP based technological solution developed by Open Mobile Alliance (OMA) to provide Location Based Services (LBS) to mobile devices in a wireless network. SUPL works in User Plane (U-plane) to provide Location Based Services without impacting the control plane elements of the network.

This document describes some of the location positioning methods and positioning protocols used within SUPL system.

1. Introduction

The advent of the Location Based Services has made wireless positioning one of the most important components in the recent years. Numerous applications depend on wireless positioning ranging from device tracking, navigation, advertisement, traffic management and automated billing. Location-aware applications like search, maps and navigation are becoming fundamental to a growing number of consumers. The role of location in digital life is changing as a majority of smartphone owners' use their phones' location-based services for their day to day needs. Generally Location Based Services (LBS) can be classified into Commercial LBS, internal LBS, emergency LBS and lawful Intercept LBS [4].

In order to cater to Location-based services business, more accuracy and availability from positioning technologies is needed. While several proprietary location and positioning protocols have been developed in the market, scalable and cost- effective solutions can only be realized using standardized solutions. A variety of techniques over the Control Plane have been proposed for positioning which include indoor and outdoor positioning methods, to name some GPS, GLONASS, GALILEO are predominately satellite dependent and OTDOA, EOTA, ECID are cellular network based [1].

Control-plane(C-Plane) plays a big changing role for the development of location services across wireless technologies (GSM, UMTS, CDMA, and LTE) [2], hence a new standardized positioning protocol called SUPL has been proposed in order to fulfill the needs of the future location-based services. Secure User Plane Location (SUPL) is an IP based technological solution that was developed to support Location- Based Services (LBS) for wireless communications [6]. SUPL encapsulate the Control Plane positioning protocols, uses data network for location services without impacting the C-Plane thus offloading any changes in service provider's infrastructure. It is a separate network layer that performs many LBS functions that would otherwise be governed within the C- Plane, and is designed to work with existing mobile internet systems.

2. Legacy Protocols

Location-based services are gaining momentum but not all wireless service providers are equipped with location services technology yet due to the high implementation cost i.e. modification of the Control Plane protocols. Therefore, a location aware service is required which should locate a Mobile Station (MS) with a reasonable accuracy and minimum implementation cost by introducing minimum changes to the network or the MS. The limitations of C-Plane in terms of architecture and bearer protocols are necessarily reflected in the C-Plane positioning protocols and limit the feature sets offered. When it comes to introducing new features into the standards, the problems lie in the currently utilized C-Plane positioning standards being bound to the architecture and protocol limitations in the respective RANs.

3. SUPL Fundamentals

SUPL's basic architecture includes two important elements.

a) SUPL enabled terminal (SET) - This is a mobile device such as a cell phone which is configured to support SUPL.
b) SUPL Location platform (SLP) - This is a server responsible for tasks such as providing assistance data to SET, position determination, charging etc.

SET and SLP can be connected through any TCP/IP connection such as GPRS/LTE/Wi-Fi. Depending on the mode of connection between SET and SLP, the SLP has to be updated with the co-ordinates of the GPS satellites or cell tower or Wi-Fi routers.

To calculate the exact position of a device, SUPL makes use of a positioning method and a positioning protocol [6]. The positioning method and positioning protocol may vary from one network to other. Figure-1 shows possible combinations of wireless communications standards and positioning protocols.

	GSM	WCDMA	LTE	CDMA2000
C-PLANE	RRLP	RRC	LLP	TIA-801
U-PLANE	RRLP	RRC	RRLP/LLP	TIA-801

Figure 1: Positioning Protocols

SUPL uses these positioning protocols and positioning methods to enable the communication between SLP and SET. The details of these methods like the type of assistance data or, the need of real time difference between various cells are out of scope of SUPL and are taken care by the underlying protocol or network. Few of the positioning methods are depicted below.

3.1. Positioning Methods

A variety of positioning techniques have been proposed to calculate the location of a mobile node in a wireless network. In this section, we describe a few positioning techniques used to locate a mobile in a cellular network.

3.1.1. Trilateration Method

Trilateration method works by calculating the intersection point of three circles centered by three cell towers as shown in Fig.2. The distance of the mobile device from these cell towers is used as the radius of the three circles. To calculate the distance of the mobile device from the cell towers, signal strength of the cell received by the MS is used. So, the trilateration approach consists of two steps:

a) Convert the signal strength to the distance between towers and cell.
b) Compute the location.

The Mobile devices forward the received signal strength to the cell tower regularly. Therefore, in the GSM network, the signal strength method can be implemented without any major investments.

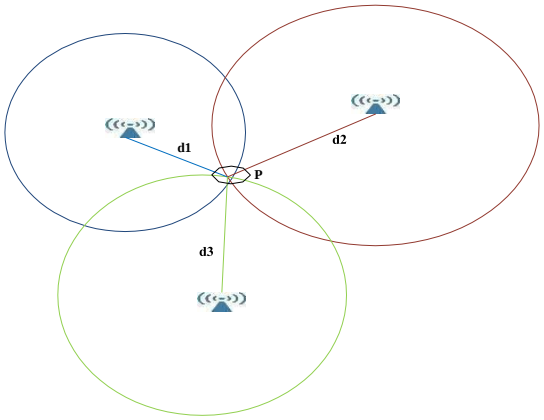

Figure 2: Trilateration Method

3.1.2. Observed Time Difference of Arrival (OTDOA)

OTDOA is a positioning method used in LTE networks. In this technique, mobile device measures the Reference signal time difference (RSTD) between several eNodeBs and reports these time differences to a specific device in the network called ESMLC. ESMLC based on these time differences and the location of eNodeBs calculates the mobile's location.

The Time of Arrival (ToA) of the downlink signal from several eNodeBs is subtracted from the ToA of the downlink signal from a reference eNodeB. This time difference between the reference and neighboring eNodeB is called Reference Signal Time Difference (RSTD). These RSTDs measured over a period of

time from each eNodeB is then used to form various hyperbolas and the point of intersection of these hyperbolas is the desired location of the mobile device. The accuracy of this technique depends highly on the synchronization of different eNodeBs.

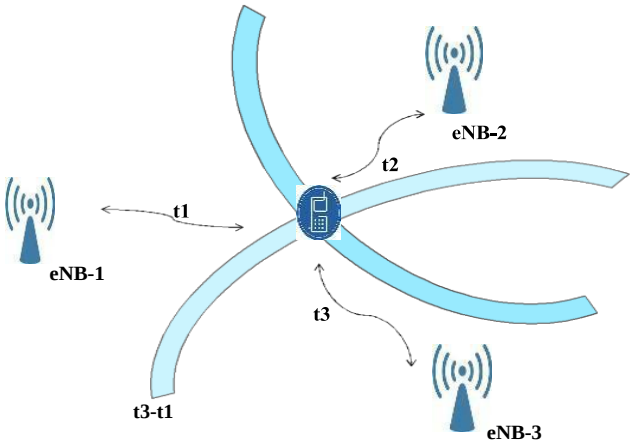

Figure 3: OTDOA in LTE

3.1.3. Location Fingerprints

In the last couple of years, location fingerprinting techniques has become very popular for indoor areas where global positioning system (GPS) does not work well because of weak signaling strength inside a building or urban areas. The fingerprinting technique is relatively simple to deploy compared to the other techniques such as angle-of-arrival (AOA) and time-of- arrival (ToA). The major advantages of this technique are:

a) To use this technique, no special hardware is required at Mobile station (MS) end.
b) This positioning system does not need new infrastructure because it can reuse the already equipped Wireless LAN devices.

This technique is used to improve the accuracy of the indoor positioning system by using pre-measured location related data. It works in two different phases:

i) Offline Training Phase:
In this phase, a mobile device is used to calculate the Received Signal Strength (RSS) values from several wireless LAN access points. A large number of RSS samples are recorded to get the average of RSS reading. These RSS readings are then used to calculate the RSS finger prints.

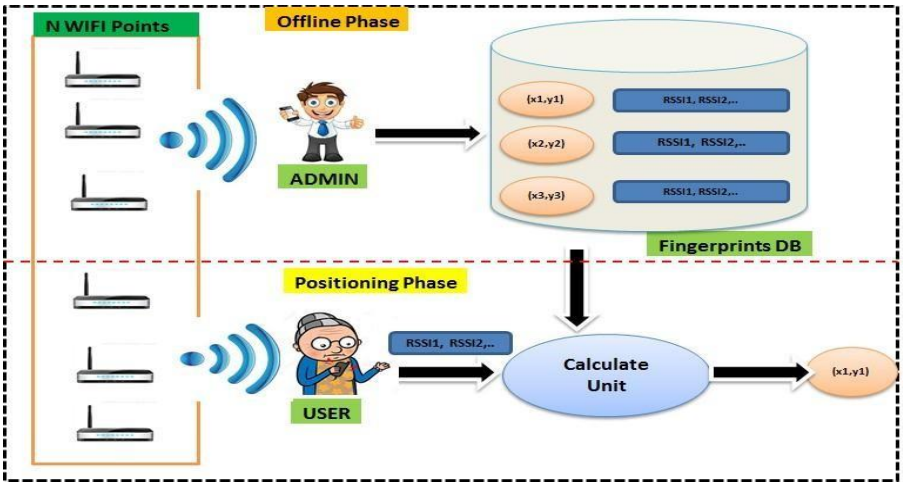

Figure 4: Fingerprinting phase

ii) Positioning Phase:
During this phase, a mobile device measures the RSS values from any unknown position and applies a position estimation algorithm to estimate its current location using the previously created RSS fingerprints.

3.1.4. A-GPS

GPS is the most popular and widely used navigation system but one disadvantage to use GPS alone is that if GPS system is not used for a long time it takes minimum 30 to 50 seconds before it displays the position. This is because of low data rate 50bits/sec of GPS signals. This waiting time can be reduced by using A-GPS (Assisted-GPS) [3]. The main role of A-GPS is to provide assistance data to the GPS receiver via wireless network. Using this data MS equipped with A-GPS can calculate the position more quickly. Basically three types of data that the assistance server may provide to the GPS receiver are:

a) Precise GPS satellite orbit and clock information.
b) Initial position and time estimate.
c) A-GPS-only receivers, satellite selection, range, and range-rate information.

The location may also be estimated at the assistance server using the feedback data received from the A-GPS receiver. Once GPS assistance information has been received at the assistance server, position estimation calculation can be done either at the MS side or network side depending on where A-GPS methods are defined [5].

3.2. SUPL for LTE and Wi-Fi

The below figure shows a detailed architecture of SUPL. This Figure shows the solution of A-GPS based SUPL architecture.

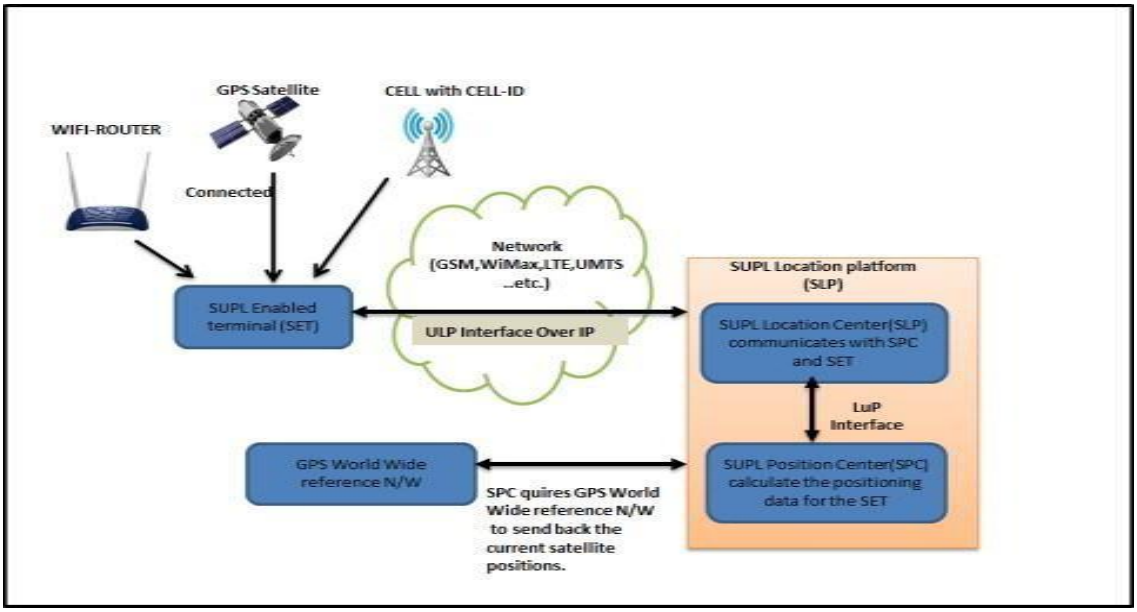

Figure 5: SUPL Architecture

The SLP has to be updated with the coordinates of the GPS satellites so that it can provide the assistance data to the SET. This update is done by the GPS World Wide Reference Network. To start the SUPL procedure, SET has to send its approximate position to the SLP. In this case, it sends the cell-id of the serving cell to the SLP. Based on this cell-id, SLP sends GPS assistance data to SET. SET on receiving the A-GPS data finds the GPS signals which are used to calculate exact location of the SET using a positioning method.

3.2.1. LTE Positioning Protocol

To locate a mobile device in an LTE network, SUPL makes use of the OTDOA positioning method among others and LTE positioning protocol (LPP). LPP is used to enable the communication between E- SMLC and SLP possible. It majorly consists of below 2 steps:

a) Transfer of Assistance Data

To enable the Mobile to measure the RSTD information, E-SMLC in the LTE network transmits the OTDOA assistance data which essentially consists of the below two types of information:

i) Parameters of the reference cell. RSTD of the neighbor cells are calculated relative to this reference cell.
ii) Parameters of the neighbor cells. This consists of a list of neighbor cells and their parameters. The neighbor cell information list is sorted in decreasing order of their priorities. Mobile provides the RSTD information in the same order of the priorities as set by the location server.

b) Transfer of Location Information

Based on the assistance data received by the location server, mobile calculates the RSTD of the up to 24 neighboring cells and provides these location measurement information to the server which uses this data to estimates mobile's exact location.

3.2.2. Wi-Fi based Solution

Global positioning system is very popular in outdoor positioning environment but it is not suitable for indoor positioning because of weak satellite signal strength. The satellite signal is easily blocked inside building. To overcome the GPS drawback for indoor positioning, Wi-Fi solutions has been introduced and this solution has become more popular. The main advantage of this solution is that, already existing Wi-Fi networks can also be used for position estimation. There are many applications of indoor positioning system like inventory tracking, tracking small children, tracking patients in hospitals, location based advertisement (PUSH messages) and guiding blind people. The following solutions are based on Wi-Fi positioning.

a) Trilateration positioning method can be used with WiFi systems to estimate the position of any indoor WiFi object like MS, laptop etc. For e.g. when any WiFi object like and MS connects to a WiFi access point (AP), it receives the signal strength (RSS) from AP and AP's SSID. Based on RSS, MS calculates its distance from the AP. Similarly, if the distance is calculated from three different APs, the approximate position can be calculated using the trilateration method. The problem with this solution is that calculating the distance based on RSS is difficult because received signal strength from the APs may vary (up to 15dbm) continuously over time from the same location.
b) Fingerprints positioning method is another solution to calculate the position of any Wi-Fi object in indoor environment. The advantages of this solution are that more accurate estimations are possible and no extra hardware is required at MS. To use this solution, we need to create offline fingerprint database and maintain it. Each entry in the database is represented as a pair of "Location and received signal strength from Wi-Fi access point". To get better accuracy from this approach, efficient maintenance of an offline fingerprint database is required.

4. Conclusions

SUPL is a standardized technique which is well designed for the future location services business. It uses data network for location services without impacting the C-Plane protocols thus offloading any changes in the service provider's infrastructure. Thus using SUPL for location based services offers multiple advantages to the network operators.

5. References

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