A-GPS Performance in Urban Areas

José Manuel López López, Fernando López Aguilar,
and Juan Javier Cabanas Abascal

Telefónica I+D,
Emilio Vargas 6, 28029 Madrid, Spain
{josemll,fla,jjca}@tid.es

Abstract. This paper presents a study of the performance of A-GPS based on OMA SUPL (Secure User Plane Location) in urban areas. Field tests are conducted to compare A-GPS versus conventional GPS using commercial cell phones. Test scenarios include urban indoor and urban outdoor areas. Performance is measured in terms of TTFF (Time To First Fix) location delay and location accuracy. Results for a dedicated handheld GPS receiver are also provided as a reference.

Keywords: A-GPS, SUPL, TTFF, location accuracy.

1 Introduction

An emergency situation requires a rapid coordination of all the emergency staff in order to provide a rapid response within the crisis scenario. Legacy systems allow to carry the emergency call and to obtain the basic information to manage the emergency based on the voice communication between the caller and the callee. This information is subjective and always depends on the interpretation of the callee. One piece of this information, and maybe one of the most important, is the location of the call. If the emergency call is made over a fixed network, this location can be obtained from the address of the fixed line. The problem arises for an emergency call over a mobile network, in which case the only information that can be obtained comes from the serving cell. Out of the cell identifier the cell coverage can be derived, resulting an uncertainty area ranging in size from dozens of meters to some kilometers.

The introduction of IMS (IP Multimedia Subsystem) brings the opportunity of sending location coordinates embedded in the call, which is crucial for precise assistance in emergency calls. GPS-enabled phones provide location, but they typically take too long in fixing a position in cold start, the so-called TTFF (Time To First Fix) delay. In order to solve this issue Assisted GPS (A-GPS) has been developed to convey assistance information to the terminal. A-GPS allows for faster TTFF, reducing the delay for emergency calls to start, thus saving precious time.

A-GPS was first implemented over control-plane protocols. This solution needed changes in the operator's network because signalling was not prepared to carry the kind of assistance data that A-GPS needs. Apart from that, an increasing number of

J. Rodriguez, R. Tafazolli, C. Verikoukis (Eds.): MOBIMEDIA 2010, LNICST 77, pp. 413–422, 2012.

A-GPS capable users could exhaust the system capacity because of the A-GPS control-plane traffic.

Later on, OMA (Open Mobile Alliance) specified SUPL (Secure User Plane Location) as a solution where a standard user plane data bearer such as IP suffices with no further changes in the network. SUPL assumes that the mobile network, or other access network, is capable of establishing a data bearer connection between terminal and location server. A basic philosophy of SUPL is to use existing standards whenever it is possible, so SUPL architecture is designed to be extensible, allowing for future positioning technologies as long as they share the same basics. The first release, SUPL 1.0, provides full functionality for A-GPS. SUPL 2.0 introduces the A-GNSS (Assisted Global Navigation Satellite System) concept to support additional technologies, for instance A-GANSS (Assisted Galileo and Additional Navigation Satellite Systems).

This paper assesses the performance of SUPL-based A-GPS versus conventional GPS using GPS-enabled cell phones in Madrid (Spain). Results are also compared to those for a dedicated GPS receiver.

This paper is divided as follows: Sections 2 presents an overview of the SUPL architecture with all the elements involved in the location process. Section 3 describes SUPL Protocol description in which we can see the exchanged messages between the SUPL Enabled Terminal (SET) and SUPL Location Platform (SLP). Section 4 defines the filed trial to collect data and continue showing the results of them. Finally, Section 5 gives us the conclusion of this work.

2 Overview of SUPL

The SUPL architecture (see [1] for details), is based on these entities (Fig. 1):

- SUPL Enabled Terminal (SET): a mobile equipment (phone, smartphone or PDA) able to communicate with the SLP through a SUPL Agent. In the scope of this study, the SET has an embedded GPS receiver for precise location.
- SUPL Location Platform (SLP): a server whose purpose is to manage location requests and provide assistance information to the SET. In A-GPS, the SLP retrieves GPS data from a Global Reference GPS Receiver. In turn, it relies on a WWRN (World Wide Reference Network).
- World Wide Reference Network (WWRN): tracks GPS satellites and delivers assistance data to any subscriber or operator around the world.

SUPL 2.0 requirements are specified in [2]. Data bearer independence is one of the major overall system requirements. It is stated that the SUPL architecture and specifications must be compatible with all underlying network technologies. Air interface standards (GSM, WCDMA/TD-SCDMA, LTE, CDMA, HRPD, UMB, WLAN, WiMAX) and transport media (packet data services, SMS, etc) must be supported. SUPL shall not impose any requirements on the underlying data bearer service, so it must not be necessary to modify the underlying network technology.

Regarding interoperability with other standards, SUPL architecture shall allow coexisting with available location related standards specified by 3GPP2, 3GPP and IEEE, i.e., without impacting their operation and performance in any way.

As for location technology, SUPL is required to support not only A-GPS, but also a range of other positioning methods: Cell ID (in fact, it will be a backup positioning method when others fail), Enhanced Cell ID, autonomous GNSS (e.g. standalone GPS), and E-OTD/O-TDOA (Enhanced-Observed Time Difference/Observed Time Difference of Arrival) if such measurements are available in the network.

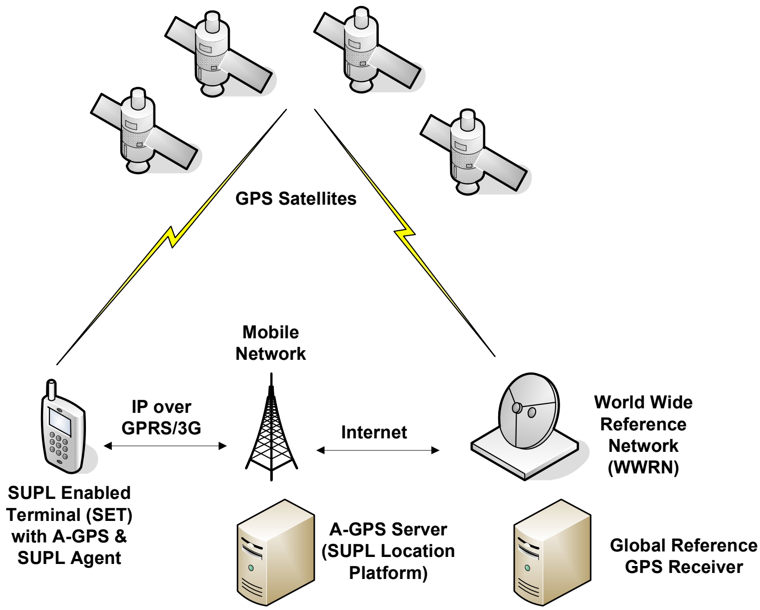

Fig. 1. Overall SUPL-enabled A-GPS architecture

3 SUPL Protocol Description

The message transaction that occurs when the SET initiates communication with the SLP in order to obtain assistance for its own location can be seen in Fig. 2. This scenario is also known as SET-initiated SUPL (see [3]). This transaction is realized over a Secure Socket Layer (SSL), which allows that the information is used only by the SET and the person who requests for it.

First, the SET sends a SUPL START message to the SLP. This message carries the Location Id (including the information of the cell in which the device is connected to), the positioning capabilities of the terminal and the Session Id. In addition, as is specified in SUPL 2.0, the terminal's estimated position could be added to this message.

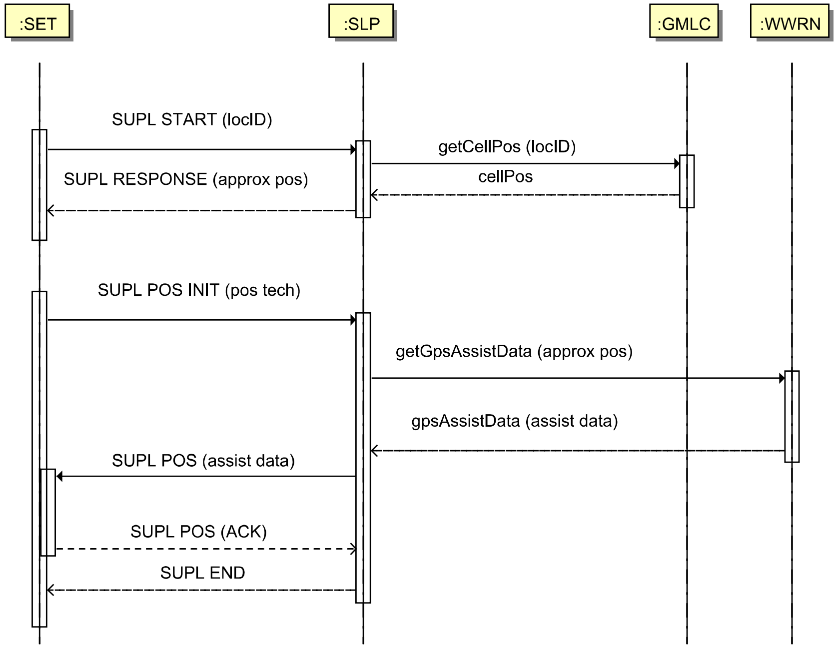

Fig. 2. Messages exchanged for SET-initiated SUPL-enabled A-GPS

The SLP responds with a SUPL RESPONSE message containing the SLP Session Id, which is included in all the remaining messages, as well as the mobile terminal Session Id. This message also includes the positioning method used (chosen from the capabilities of the terminal). Compared to SUPL 1.0, SUPL 2.0 adds one more element to the message; in this case the mobile device receives an approximated initial position based on the cell information provided in the previous message. This data is retrieved from a GMLC (Gateway Mobile Location Center).

Next, the terminal sends a SUPL POSINIT message with the requested assistance data (i.e. almanac, ephemeris, acquisition assistance for the area, reference time, ionospheric models and so on).

The following two messages in the conversation are SUPL POS. The first one is sent by the SLP returning the assistance data required. The second one is sent by the SET as an acknowledgment of the first SUPL POS. This block can be repeated several times depending on the amount of assistance information the SLP needs to send.

Finally, the SLP sends a SUPL END to finish the communication with the SET. Once the communication between the SLP and the SET is finished, the terminal is ready to profit from the received navigational data by locking on the most suitable satellites and calculate its position. This position could be embedded in an IMS emergency call or used for a regular location-based service.

Without this navigational data, the terminal would have to search the whole satellite constellation looking for the strongest signals (though some selection criteria allow to narrow the search), and then download the navigational data before being able to calculate its position. A-GPS speeds up the whole process, improving performance as described in the following section.

4 Field-Test Results

A set of field tests were carried out to assess A-GPS performance. Each test measures TTFF (Time To First Fix) and accuracy of a GPS method in different scenarios. TTFF is the time it takes a GPS receiver to calculate its position after a cold start. Accuracy is an estimate of the error the receiver makes when calculating its position. Field tests were conducted using several GPS-based location methods:

- A-GPS with SUPL server A
- A-GPS with SUPL server B
- Built-in GPS
- Handheld GPS

The first two methods use A-GPS enabled cell phones based on SUPL, but differing in the commercial SUPL server, for the sake of generality and to avoid biased results due to the use of only one SUPL server. The servers come from two well-known network providers and offer similar standard assistance, i.e., no special tuning was done for the tests. Technical details about terminals and servers cannot be revealed due to non-disclosure agreements signed with equipment providers. As was explained in this paper, in SUPL the server takes a guess of the location of the terminal to get a useful list of the satellites covering the real position of the terminal and acquisition assistance data. Then, the terminal uses this list to narrow the search of GPS satellites and speed up position calculation. The SUPL server takes the reference location out of the Cell Identifier that the terminal uses to access the network, retrieving the coordinates of the base station from a cellular database.

Built-in GPS relies on the embedded GPS receiver of the cell phones, with no assistance from an external server. Handheld GPS uses a dedicated, multi-channel GPS receiver, instead of the receivers integrated in cell phones described so far. This autonomous receiver does not use assistance information either.

Field tests were conducted in urban indoor and urban outdoor scenarios. In the urban indoor scenario, the terminals were placed inside buildings, such as the one in Fig. 3, on different floors and near the windows. Due to the weak GPS signal level indoors, only A-GPS methods worked in this scenario. In the urban outdoor scenario, the terminals were taken to public squares and places of the neighborhood in Fig. 4 (obtained with Google Maps) with a wide view of the sky. In this case, the whole set of GPS methods described above was tested.

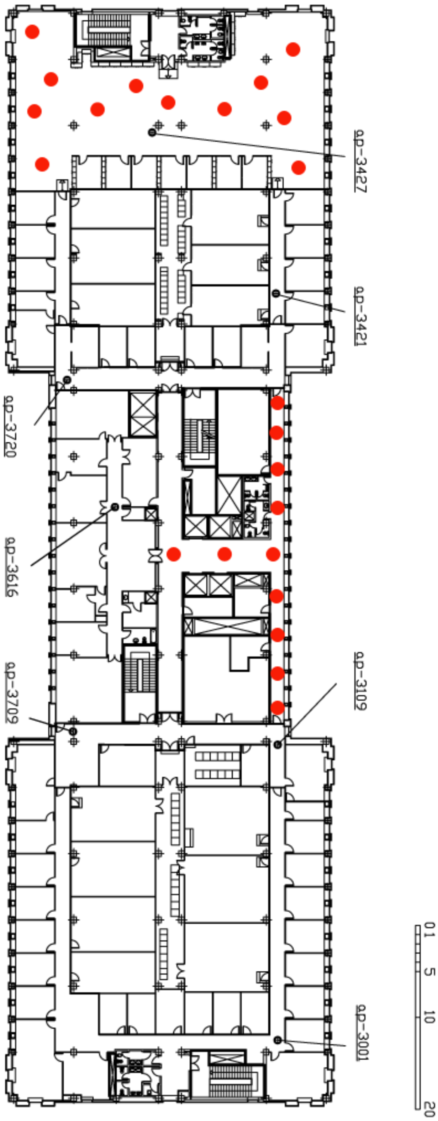

Fig. 3. Sample measurements (dot markers) in urban indoor scenario

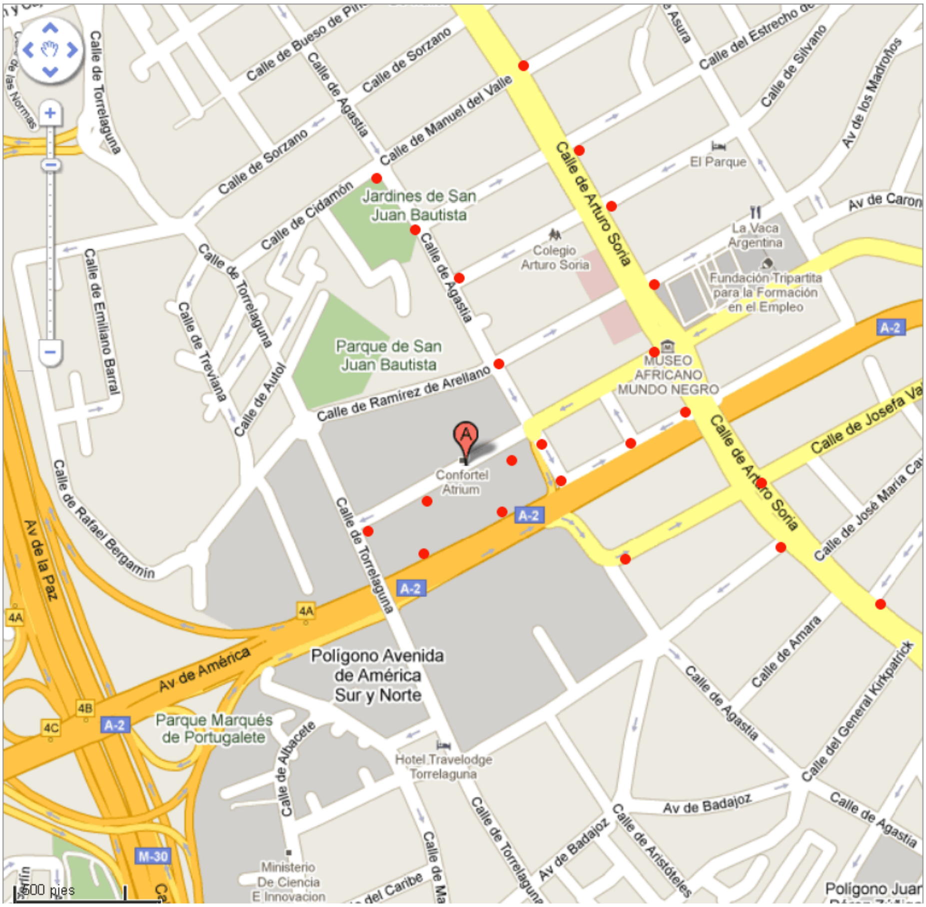

Fig. 4. Sample measurements (dot markers) in urban outdoor scenario

The A-GPS and built-in GPS tests used several state of the art, off-the-shelf GPS-enabled cell phones. Data connections to retrieve assistance data ran on 3G/3.5G, depending on coverage. The handheld GPS test used a 12-channel dedicated receiver. In all cases, the terminals were cold-started, to force the receivers to calculate their position from scratch without using previous orbital data or other aid to acquisition. A MIDlet application was developed in J2ME to run on the cell phones and collect TTFF (measuring the time elapsed since position is requested and position is calculated) and accuracy (as provided by the receiver) measures using the Location API [10].

Performance results are shown in Table 1, which shows the metrics in terms of average TTFF and average accuracy for each field test out of more than one hundred realizations. Lower scores mean better performance. Fig. 5 and Fig. 6 show the same results graphically. Reductions in both metrics due to A-GPS are highlighted in Table 2.

Table 1. Performance results

GPS method	Urban indoor		Urban outdoor	
	TTFF (s)	Accuracy (m)	TTFF (s)	Accuracy (m)
A-GPS/Server A	46.00	67.53	16.46	18.30
A-GPS/Server B	35.60	58.60	14.16	17.33
Built-in GPS	n/a	n/a	94.57	58.68
Handheld GPS	n/a	n/a	32.4	5.4

Table 2. Improvements due to A-GPS

Comparison	Urban outdoor	
	TTFF (%)	Accuracy (%)
A-GPS/Server A over built-in GPS	82.59	68.80
A-GPS/Server B over built-in GPS	85.02	70.46

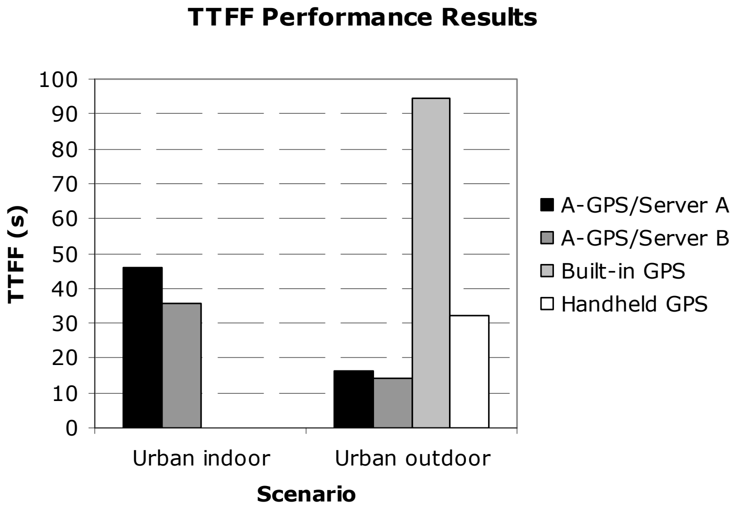

Fig. 5. TTFF performance results

A-GPS surpassed built-in GPS in both urban indoor and urban outdoor scenarios. Built-in GPS did not work indoors, while outdoors A-GPS improved TTFF and accuracy by 80% and 70% respectively. Compared to handheld GPS outdoors, A-GPS reduced TTFF by 50%, but handheld GPS was three times as accurate. These results were expected because A-GPS provides ad-hoc navigational data to the terminal, which helps to quickly lock on the satellites covering the terminal's location area, instead of scanning the whole constellation and downloading navigational data as in conventional GPS. Results were alike for the two SUPL servers used in A-GPS tests.

The type of scenario had a huge impact in performance. Built-in and handheld GPS did not work indoors, while A-GPS methods scored more than 50% better in the urban outdoor scenario. This is due to the fact that satellite signals are weakened indoors, reducing the number of satellites in view and the quality of reception, paying a toll in TTFF and accuracy performance metrics.

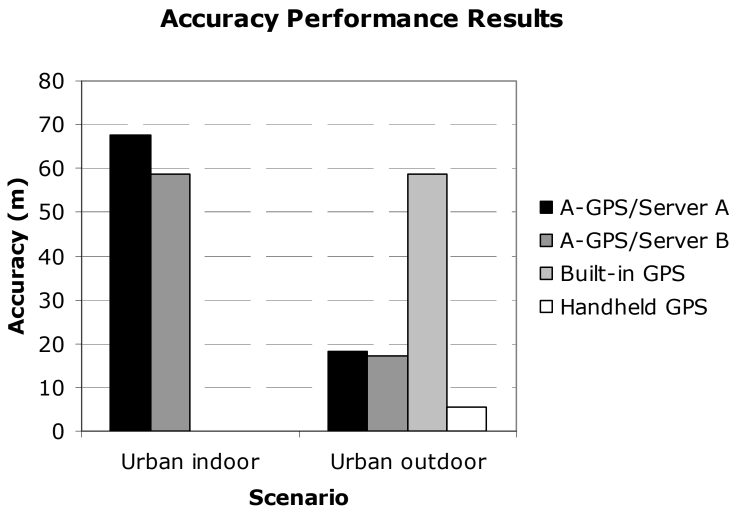

Fig. 6. Accuracy performance results

5 Conclusions

This paper presents the results for A-GPS in urban areas. Field tests were conducted comparing A-GPS with conventional GPS (built-in and handheld dedicated) for urban indoor and urban outdoor scenarios. Commercial cell phones were used for A-GPS and built-in GPS tests, while a dedicated receiver was used for handheld GPS. TTFF location delay and location accuracy were measured to assess performance.

Previous work in literature studied SUPL A-GPS performance [6]. To our knowledge, this is the first study dealing with several SUPL servers both in urban indoor and urban outdoor scenarios in Spain. We also compare the results with a dedicated handheld GPS.

Performance results show that A-GPS clearly surpassed built-in GPS in both urban indoor and urban outdoor scenarios, matching the performance of the dedicated handheld receiver outdoors in TTFF, but the dedicated receiver was still more accurate. This is due to the more powerful, multichannel chipset installed in the dedicated receiver. The choice of SUPL server led to similar results with no significant differences in performance. Summarizing, A-GPS improves built-in GPS in terms of sensitivity, broadening the use of GPS to indoor environments and reducing battery drain. All these advantages extend GPS availability for precise location, which is paramount in emergency situations.

Acknowledgments. This study was supported by the European project PEACE (IP-Based Emergency Applications and Services for Next Generation Networks), ICT-SEC-2007.1.7-225654.

References

1. OMA: Secure User Plane Location Architecture, OMA-AD-SUPL-V2_0 (2009)
2. OMA: Secure User Plane Location Requirements, OMA-RD-SUPL-V2_0 (2009)
3. Open Mobile Alliance: User Plane Location Protocol, OMA-TS-ULP-V2_0 (2009)
4. 3GPP: Location Services (LCS); Mobile Station (MS) – Serving Mobile Location Centre (SMLC) Radio Resource LCS Protocol (RRLP), Release 9, 3GPP TS 44.031 V9.2.0 (2010)
5. French, G.T., Barth, M.: Understanding the GPS: An Introduction to the Global Positioning System. Baker GeoResearch (1997)
6. Bayrak, Ö., Göze, T., Barut, M., Oguz Sunay, M.: Analysis of SUPL A-GPS (Secure User Plane Location) in Indoor Areas. In: SIBIRCON 2008, pp. 469–473. IEEE Region 8 (2008)
7. Lachapelle, G.: GNSS Indoor Location Technologies. In: GNSS 2004/The 2004 International Symposium on GNSS/GPS (2004)
8. Singh, S.: Comparison of Assisted GPS (AGPS) Performance using Simulator and Field Tests. In: Proceedings of ION GNSS (2006)
9. Karunanayake, M.D., Cannon, M.E., Lachapelle, G.: Evaluation of Assisted GPS in Weak Signal Environments Using a Hardware Simulator. In: Proceedings of ION GNSS (2004)
10. JSR-179: Location API for J2ME, http://jcp.org/en/jsr/detail?id=179