A Low Cost Positioning and Visualization System using Smartphones for Emergency Ambulance Service

Alexandre Bellini Carlos E. Cirilo Vinícius R. T. Ferraz Josué G. Araujo
Juliana L. Duque Luana P. Annibal Rafael S. Durelli Cesar Marcondes

Computer Science Department
Federal University of São Carlos (UFSCar)
Rod. Washington Luís, Km 235, Caixa Postal 676
13565-905 São Carlos-SP, Brazil

Email: {alexandre_bellini, carlos_cirilo, vinicius_ferraz, josue_araujo}@dc.ufscar.br, {juliana_duque, luana_annibal, rafael_durelli, marcondes}@dc.ufscar.br

ABSTRACT
An ambulance is the type of emergency vehicle that, in order, to accomplish its mission of transporting patients in critical condition to hospitals, they must run as fast as they can through a city streets' maze. Hence, it is necessary a real-time system that could obtain anytime ambulance location. Moreover, it should advice on the best routes based on speed and time for achieve the target, given that the survival of the patients depends on the efficiency of this service. In a city like Sao Paulo in Brazil, for example, during the night, there may be hundreds or even thousands of ambulances running in the city, thus knowing the precise location of these vehicles is quite important. Despite these needs, the process of acquire and identifying the position of every ambulance can be costly if it is based on a GPS on every ambulance and a dedicated communication system. Therefore, we address these challenges in this paper with a low-cost solution based on the Android® Smartphone platform. Thus, we developed: (1) a low-cost integrated GSM antenna probing module that perform continuous wireless "war-driving" and triangulation to estimate the ambulance position accurately, (2) another module to send encrypted messages through SMS service containing the position information to a central (3) a visualization module allowing real-time analysis of ambulances mobility on the city map.

Categories and Subject Descriptors
C.2.4 [**Distributed Systems**]: Client/server, Distributed applications.

General Terms
Experimentation, Algorithms, Performance.

Keywords
Positioning, location, GSM, LBS, circle triangulation.

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1. INTRODUCTION
The recent development of location-based systems, especially in the e-health domain, has led to a technology need to improve location in a more precise and more widespread manner [1]. Many location technologies currently available have some deficiencies such as low coverage or work only in a specific environment under certain restrictions. Nowadays, the most used location technology is the *GPS (Global Positioning System)*. Although GPS is accurate and very effective outdoors under a good line of sight of the sky, it usually does not work well indoors, such as inside buildings or in places where there are many obstacles that block the sky visage, such as buildings in large cities and urban conglomerates [1][2]. Because of these limitations, many systems require a different technology that meets coverage and accuracy need of its applications demand. Systems that perform location using infrared, ultrasound, CDMA and Bluetooth can work well inside buildings, through obstacles and tunnels, however, these technologies whenever operated outdoors become prohibitive in terms of cost, or they are not technically feasible due to interference caused by infrared sun rays [1].

The widespread adoption of mobile devices enabled for the use of IEEE 802.11 *access points* (Wi-Fi APs) and the rapid availability of these Wi-Fi APs in a city, it turned the location based on this technology attractive. Unfortunately, because of its high energy consumption, these devices are not frequently used for purposes of location, unless there is an available power source nearby that can be used intermittently at times when the device is operating [1]. Furthermore, the coverage area of most access points is small, ranging between 10 to 100 meters in diameter [3]. As a result, devices equipped with Wi-Fi cannot be used effectively as a platform for location-based applications that rely on network connectivity, continuous coverage or proactive interactions, such as these applications that perform monitoring and tracking of ambulances [1].

Cellular mobile phones, on the other hand, are devices that people carry; they are reachable most of the time and have network connectivity almost uninterrupted, especially in densely populated urban areas. Moreover, they generally have low power consumption under ubiquitous broadband and connectivity regimes. It is believed that all these features make these mobile phones, especially those devices that operate on the *Global System for Mobile Communications (GSM)* standard, an excellent platform for the development and deployment of location-based applications. One can argue some specific advantages of performing location on these devices compared with Wi-Fi location [1] [4]:

- The mobile phones operate on a **licensed band** and thus they suffer less interference from others electronics such as wireless phones, microwave ovens and Bluetooth devices compared to ISM band;
- The mobile phones use a managed network, which ensures no interference from neighboring *access points* that are tuned to the same channel;
- The development of cellular network is stable and planned compared to the ad hoc deployment of the Wi-Fi APs; and
- The coverage of cellular network is larger than that of Wi-Fi networks.

2. Background

This session presents the main technologies and concepts used in the development presented in this paper.

2.1 Principles of GSM Cellular Networks

The GSM is the most widespread standard for mobile phone in the world, available in 220 countries and regions. Moreover, it has 1050 network operators [1] [9].

The term "*cellular*" comes from the fact that a given geographic area is divided into several areas of coverage, known as **cells**. Each cell has a GSM base station, typically equipped with directional antennas that define sectors of the cell coverage. The base station can transmit signals to as well as can receive signals from mobile devices within its cell [3] [5].

Although the base station can be positioned in the center of the cell, nowadays many systems distribute base-station in the intersection point of three cells. In consequence, a single base station with directional antennas can meet the three cells simultaneously [3].

At the present time, the cell reachability of a cellular network ranges from 100 meters in urban area up to tens of kilometers in the rural zone. The GSM was designed to have a cell radius up to 35 km and, consequently, that is the maximum distance between the base station and the mobile device [1][5].

For each base station is assigned a certain number of channels for data transmission and reception, called **cell allocation** (CA) [5]. Usually, there are several simultaneous calls in a given cell. Those calls need to share the portion of the radio spectrum allocated to cellular service provider. An approach to share the radio spectrum is the combination of frequency-division multiplexing (FDM) and time-division multiplexing (TDM), where the channel is divided into several sub-bands of frequency within which time is divided into frames and compartments [3].

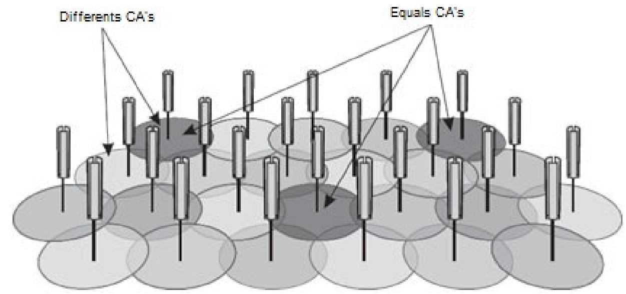

Figure 1. Cell Allocation [5]

An important feature of cellular network based on FDM is that the same CA (or part thereof) can be used by several base stations simultaneously, since they are separated by a huge gap between them, known as **channel reuse distance**. Thus, to avoid the interference among the cells, it is ensured by design that the neighboring base stations have different CA's channels. As illustrated in Figure 1, the cells of the same shading use equal CAs, because they are separated from each other by at least one channel reuse distance. It is possible to see that channel reuse distance is the key concept to make possible serve millions of subscribers with a small number of available channels [5].

In addition, as it can also be visualized in the Figure 1, there are no rigid boundaries between the cell and its neighboring cells. In contrast, they can overlap each other to a greater or lesser degree. This means that a given region will be covered by several base stations simultaneously. In an urban area, a mobile device usually could hear simultaneously a set of at least 10 base stations around it, and, then, select from this set, the one with the strongest signal and the best quality for transmission [5]. The cells' overlapping is an important feature that is essential to advanced positioning methods based on triangulation.

If a network is likely to become overloaded in a given region, the operators can increase their capacity by simply increase the base station density. On the other hand, in order to provide CAs for these new base stations, the intensity of existing signals is reduced, which decrease, as a result, the channel reuse distance. Hence, the same channels can be positioned at a smaller distance, and the capacity of the network in that region is improved. This method is preferentially applied in urban areas with a high concentration of users [5].

2.2 Location-Based Services

Location-Based Services (LBSs) are information technology services for providing the information that has been created, compiled, selected or filtered taking into account the current location of the users or the moving objects. The GSM *Association*, a consortium of 600 operators of GSM network, defines the LBSs simply as services that use the target location to add value to the service, where the target is the "entity" to be located (no necessarily the service user). Examples of that addition of value in a service are presented by GSM *Association* as the filtering of the information (as example, select the closest interest point); the display of the target location on a map; or the automatic activation of the service when the target enters or leaves a predefined location [5].

The attractiveness of the LBS's results comes from the fact that its users do not need to enter the location information manually. Instead, they are automatically located and tracked by a positioning technology. Once the location information is captured, it needs to be processed in various ways, including its translation into a format of a appropriate spatial reference system, its correlation with other information of location or geographic content, maps generation, calculate navigation instructions, and so on. Usually, these tasks are not performed in a single device, but are made by many actors involved in the operation of the LBS [5].

There is also a strict distinction between LBS and **location services**. The latter is intended only to the location of the target (people and objects) and makes the resulting location data available to external actors. A location service does not involve the processing of location data in order to filter or select the location-dependent information or perform other high-level actions (such as LBS do); it is only responsible for the generation and delivery of the location data. However, with this function, these services contribute essentially to the LBS's operations and can be considered as an important sub-service of the LBS. Without a location service, a LBS's user would have to provide location data manually, which could be a cumbersome procedure, especially when doing it in motion and using a mobile device with a limited interface. Thus, the LBS and location services, in general, operate in conjunction [5].

The acceptance or success of any LBS is essentially related to the availability of appropriate standards, which determine the protocols and the application programming interfaces (API) to support cooperation among the actors involved in its operation during the implementation of LBS. Without the existence of standards, these actors would have to communicate using proprietary protocols and technologies, which would prevent competition, open service markets and the success of LBS in general. Standards ensure a seamless interconnection between equipment and software from different sources, and thus allow the use of services that are technically independent of a particular provider. For instance, the success of GSM was significantly determined by the possibilities of global roaming among different networks, which would not be possible without the existence of international standards and its dissemination and adoption by hundreds of mobile operators around the world [5].

2.3 Location

Physical location or simply **location** are terms used to identify the location of a real-world object in a given space, which can be broken into three categories, which are relevant to the creation and use of LBS:

- **Descriptive Location:** relates to natural geographic objects such as territories, mountains and lakes, or artificial geographic objects, i.e., those constructed by man, such as borders, cities, countries, roads, buildings and rooms within a building. These structures are referenced by description, like names, identifiers or numbers.
- **Spatial locations:** mathematically, a spatial location represents a single point in Euclidean space, also called **position**. The position is commonly expressed by means of coordinates bi and three-dimensional. The concept of spatial location also provides the basis for the survey and mapping of descriptive locations.
- **Network locations:** refers to the topology of a telecommunications network comprising multiple *subnets* uniquely identified and interconnected by a hierarchical topology.

The LBS may be based on all these three categories of location. The targets of LBS are located through the positioning, for which there are different methods. Some of them deliver a spatial location, as GPS, while others provide a network location, for example, the identifier (*Cell-Id*), or a combination of both. Once the location of a target was obtained, it needs to be further refined to become usable by the LBS [5].

Therefore, an important function of the LBS is the mapping among the different categories of location. If the positioning delivery a network location or a spatial location, that location must be mapped to a descriptive location to be interpreted by the LBS's user. On the other hand, a descriptive location should be transformed into a spatial location, for example, in a format that one can perform the calculation of distances, in order to relate it to other locations. In general, the mapping is performed with the aid of spatial databases and Geographic Information Systems (GIS) [5].

2.4 Positioning

Positioning is a process by which one obtains a spatial position of a given target, and can be implemented through various methods, which differ in terms of parameters such as quality, processing load, among others [5].

The central function of any process of positioning is the measurement of one or more observable items, i.e. angles, ranges, range differences, or speed. One observable item usually reflects the relative spatial relationship among the target and one or more **fixed points** of well-known coordinates on the surrounding environment. They are often measured using the physical foundations of radio signals, infrared and ultrasound. These signals, when used for measurements of position, are also called **pilot signals** [5].

After determining the required observable items, the position of the target can be achieved taking into account the results of measurements and the coordinates of the fixed points. This determination is generally based on particular method and depends on the type of observable items used.

A target is not able to deliver its position by itself. Therefore, a distributed infrastructure that implements the positioning is required. Each target to be located must be equipped with a terminal, which is the device that one wants to calculate the position. Moreover, base stations are required for most positioning methods, both to perform measurements and to help the terminal to do so. In general, the base stations are fixed points of well-known coordinates mentioned above with which the spatial relationship of a terminal is measured. The network, in turn, may require additional components, for example, geographic databases, servers and control units to coordinate the positioning and to process and distribute the results of the measurement and position data [5].

Furthermore, the position needs to be coordinated and controlled by protocols among the components of the infrastructure. The types of protocols, as well as its complexity and appearance, disagree significantly in several networks and systems. Generally, they are applied among a central control unit and the base stations, and also among base-stations and the terminal. They are used to transfer the coordinates of the base-station and measurement instructions for the terminal (called support data), to transfer measurement data to the network, or to exchange position data calculated, which are also called fixed position [5].

2.5 Positioning Method

Among the existing methods of positioning, in the development of this work we used the **circular trilateration** method, which is a subcategory of **lateration method** [5].

In the lateration method either the range or the range difference between the target and a number of at least three base stations are considered as observable items. Both are used to form a system of *n* nonlinear equations to calculate the target position, where *n* denotes the number of base-stations. For $n = 3$, the lateration is also known as triangular lateration.

If the positioning is based on range, the fixed position can be calculated by means of a circular lateration, determining the intersection of the circles formed by the radii of the target in relation to nearby base stations.

The range and range difference of a target in relation to an base station are obtained by measurements. Regardless of which method is used to measure these observable items, the measurements are always subject to errors and hence the resulting values are often called **pseudo-ranges**, differing from the true range according to a certain error potential [5].

As a prerequisite, the method of circular triangulation requires that the ranges r_i between the target and a number of base-stations $i=1,..., n$, are known in advance. Determining the ranges is not part of the method, but is necessary to enable the application of the method.

To determine the ranges, one can take into consideration the signals intensity received by the terminal from the nearby base-stations. If the terminal is receiving more than a signal from surrounding base-stations, and some of these come with greater intensity than others, it means that the terminal is closer to the base-stations whose signal received is stronger than those in which the signals perceived by the terminal are weaker [6].

Using the *Seidel model* [6] for signals propagation in wireless networks (900 Mhz, close to GSM), it is possible to quantify the ranges. According to the model, the expected signal strength (*ss*) at distance *d* is given by:

$$ss = ss_0 - 10.n.\log_{10}(d/d_0)$$

In the formula, ss_0 is the signal strength that would be observed by the terminal in the free space at a distance d_0 from the transmitter base station. The value of the constant *n* is based on the characteristics of radio waves and the physical environment (density of obstacles, etc.), with *n* ranging typically between 2 and 5. In Wi-Fi for instance, the access points often do not return a signal greater than -32 dBm at a distance of 1 meter [6]. In analogy to this type of network, we use $d_0 = 1$ and $ss_0 = -32$ dBm. Once the positioning is operated in a city where we do not assume anything about the characteristics of radio signals from existing GSM antennas, we chose *n* to a low value of 2.5. Applying these values in the equation, we can estimate the distance between the terminal and base station as follows:

$$ss = -32 - 10.2,5.\log_{10}(d/1)$$
$$d = 10^{(-32-ss)/25}$$

Once *d* represents the estimated distance between the terminal and the transmitter base-station, if we obtain *d* for each base station *i* of the neighborhood, then we would obtain r_i necessary ranges for the operation of circular triangulation method.

Knowing the range between a terminal and a single base-station limits the target position to a circle around the base station, with the range given by the circle radius, as shown in Figure 2 (a). If we add the range of another base station, then the target position can be reduced to the two points in which both circles intersect (Figure 2 (b)). The range of a third base station leads, finally, to an unambiguous target position (Figure 2 (c)).

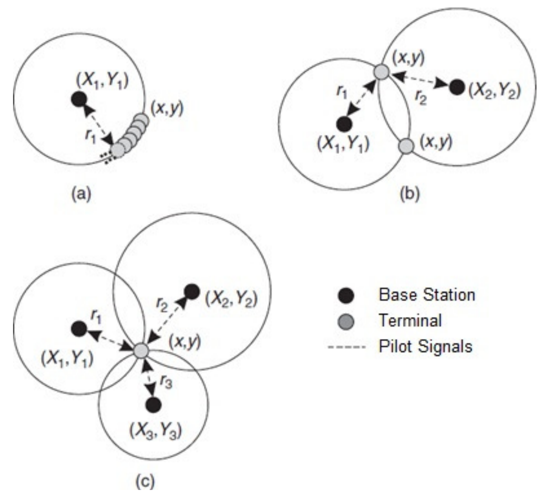

Figure 2. Circular triangulation [5]

The calculation of target position is based on the *Pythagorean Theorem*. If *(Xi, Yi)* are the well-known coordinates of the *i-th* base station in the Cartesian coordinate system, and if *(x, y)* are the unknown coordinates of the target to be calculated, then range r_i between the *i-th* base station and the target can be expressed by the following equation.

$$r_i^2 = (X_i - x)^2 + (Y_i - y)^2$$

As we want to obtain an accurate position, we use the distances from the target to the closest three base stations as parameter, which we denote by D1, D2 and D3, from the closest to the farthest. Thus, we have:

$$D_1^2 = (X_1 - x)^2 + (Y_1 - y)^2$$
$$D_2^2 = (X_2 - x)^2 + (Y_2 - y)^2$$
$$D_3^2 = (X_3 - x)^2 + (Y_3 - y)^2$$

Solving the system of linear equations above, we can then estimate the geographical position of the target. If the coordinates of the base-stations are given by latitude and longitude, or if the target position must be expressed in latitude and longitude, the ellipsoidal coordinates must be transferred to Cartesian coordinates and vice versa, in order to apply the equation.

3. Architecture and Operation

In this work, we focused on the development of affordable LBS for the *on-line* viewing of ambulances mobility on a city perimeter. This LBS is composed of three different applications operated in a distributed infrastructure, as illustrated in Figure 3.

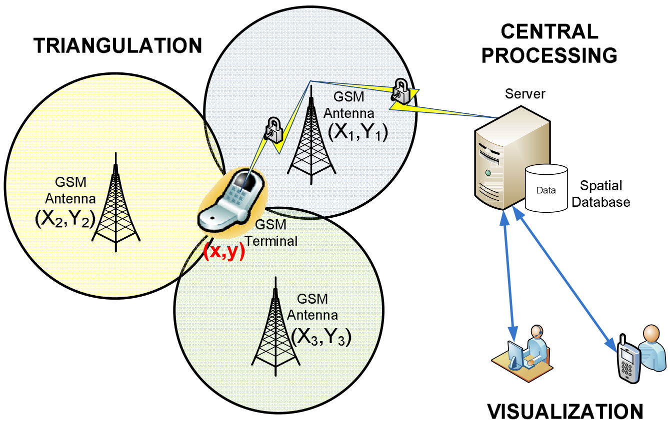

Figure 3. LBS Architecture

The **triangulation** of the base-stations, which runs on the GSM terminal fixed in the ambulance, gets the pilot signals from base stations of its surroundings. Then it selects the three closest base stations, comparing the distances obtained through *Seidel's model*.

After that, the estimated fixed position of the ambulance in Cartesian coordinates is calculated through the resolution of the equation system of the circular triangulation method, which has the three smallest distances as parameters, along with the geographical coordinates of the base stations previously stored in the nonvolatile memory of the terminal.

If the values of the newly calculated *x* and *y* differ from the latest values obtained, indicating that the ambulance remained in motion, a message containing the fixed position and the identification of the issuer terminal is generated. Then this message is encrypted and finally transmitted to the application server of the central processing through an *HTTP socket*. This whole process is repeated every 10 seconds indefinitely.

The application of triangulation was coded in Java and run on *Android* [7] [8], an operating system based on Linux aimed at mobile devices developed by *Google*. It allows the running of Java applications without the need of a *Java Virtual Machine* (JVM) since it has a virtual machine itself. Also, most of the API's used in the *Java Platform Standard Edition* (J2SE) are compatible with *Android*.

As soon as the server receives the message containing the position information, the server application of the **central processing**, written in Java, performs its decryption and extracts the data contained in it. With the help of API *Geotools* 2.5, the fixed position extracted from the message is converted into an ellipsoidal coordinate (latitude and longitude) system and, finally, stored in a spatial database.

The database were implemented using the *DBMS PostgreSQL 8.3.3* and its spatial extension *PostGIS 1.3.6*. The queries are performed by a PHP script that receives asynchronous requests from a Web application and returns a KML, which is a XML-based structure to represent geospatial data, its attributes, annotations and visualization parameters.

At the Web application, there is a *mashup* of Google Maps API, which uses AJAX and is maintained by Google. It allows friendly search and **visualization** of road maps, remote sensing images and discrete objects like the ambulances from our spatial database. The Web application gives a real-time visualization of the ambulances locations. At intervals of 10 seconds, it retrieves a new KML from the Processing Central, parses it and then plots this information on the map.

Focusing in the interoperability and reuse, all tools and document formats that were chosen to store, retrieve, process and visualize data of ambulances locations are based on open standards like those specified by *Open Geospatial Consortium (OGC)*.

3.1 Simulation

Aiming to experiment the solution described in this work, a simulation environment was built as a software component, implemented in Java. Its goal is to generate signal intensities issued by base-stations that would be captured at the moving ambulance's terminal for positioning calculation. Therefore, a hypothetical (but feasible) urban region was delimited. It contains 9 GSM base-stations, identified with numbers from 0 to 8, distributed through a geographical area of 1600 per 1600 meters, as illustrated at Figure 4. Each base-station has a maximum range with approximately 1131 meters of radius. This arrangement ensures that every point of the simulation area is covered by the signal from at least 3 base-stations, an essential condition for applying the circular lateration method.

The hypothetical region was subdivided in a *grid* of 32 per 32 microcells, each one corresponding a 50 per 50 meters block of the region, as also can be seen at Figure 4. This *grid* was defined as a three-dimensional array, that we will call *matrix*, where *matrix[x][y][n]* stores a signal intensity from the nth base-station received by the terminal at the microcell with corresponding *(x,y)* position, with *x* and *y* varying from 0 to 31, and n varying from 0 to 8. For instance, position *matrix[9][30][7]* stores the signal intensity from the 7th base-station captured at the microcell located at (9,30).

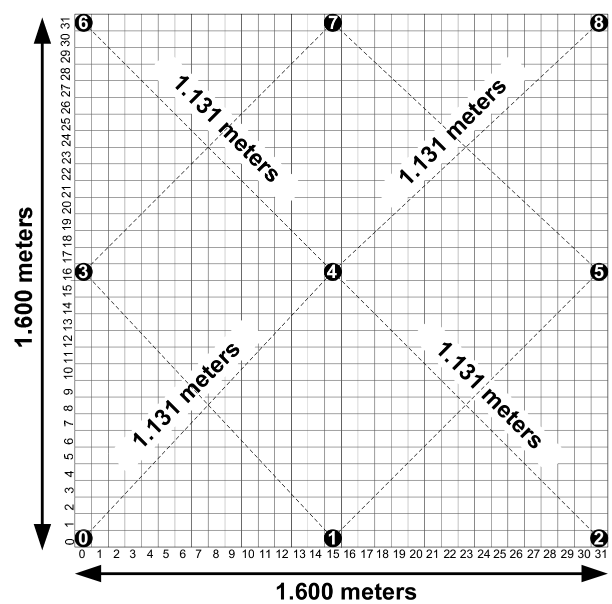

Figure 4. Hypothetical region

In order to determine feasible extensions for each microcell, the mean size of a city block from São Carlos (Brazil), which is approximately 100 meters, was taken as a parameter. Furthermore, possible speeds that ambulances could have in urban roads were considered. Thus, if the ambulance moves at 30 km/h, every 10 seconds[1] it travels about 83.33 meters, i.e. a little more than a half a city block. Thereby, if the microcells are put on each half of the city blocks, in this case every 50 meters, a less discrepant view of the ambulance's location can be shown on every refresh of the map. Supposing that an ambulance moves on urban roads at a speed of 60 km/h, every 10 seconds its displacement would be approximately of 166.67 meters, i.e. almost two blocks. Therefore, the variation of its position would be of 2 blocks every refresh, allowing a clear view of its route on the map.

The *matrix* contents were made with the use of *Seidel* model. Once the coordinates of base-stations are known, it is possible to calculate its distance regarding each *matrix* field, then use the result as parameter to Seidel model and finally obtain the signal intensity of each base-station. Considering that this process always returns exact values of signal intensities, an intentional random noise fraction varying from 0 to 1 was included every signal generation, aiming to achieve a more realistic simulation. The real measurements of signal intensities are vulnerable to many types of failures, such as imprecise clock synchronization, refraction and multipath propagation, which can induct errors on the measurement and, consequently, affect the whole positioning process.

In the actual implementation of the LBS, every 10 seconds, the application of triangulation would read the signal intensities from the nearby base stations to subsequent calculation of the position. To simulate this process, the simulator software component has a server routine that listens for queries from the application of triangulation in the terminal, then sends as response the signal intensities of the microcell in the region framed in which the terminal is positioned. To simplify testing, we executed the application on the mobile device emulator that came with *Android* API. In the server routine, we determined the path taken by an ambulance through the creation of a trace, which consists of a collection of microcells coordinates that make up the path to be outlined by the ambulance. For example, if we determine the ambulance start from the microcell *(0,0)* to the microcell *(5,5)* in a diagonal path, the corresponding trace would be composed of the coordinates *(0,0) (1,1), (2,2), (3,3) (4,4)* and *(5,5)*.

Thus, for each request from the application of triangulation, the simulator server routine returns an array containing the signal intensities of the nine base stations, which is extracted from the field of *matrix* on the microcell indicated by the coordinate of the current trace. In the case of the previous trace, the first request from the device simulator return the vector that stores the signal intensities contained in the field *matrix* [0][0]. In the second request would be returned the vector in the field *matrix* [1][1], and so on. Note that, since the coordinates of the trace represent the position of the ambulance for each 10 seconds, one can also represent situations where the ambulance was not moving (perhaps because it stopped at a traffic light, congested within a traffic jam or parked, etc.) by simple repetition of successive coordinates in trace and simulate higher speeds entering coordinates more spaced from each other.

[1] Update interval of positioning data

4. RESULTS

Superimpose the region of framework on a particular residential area of the São Carlos city located in the vicinity of Santa Casa de Misericordia Hospital, as illustrated in Figure 5, by positioning the bottom left of the microcell of origin, represented by field *matrix* [0] [0] in latitude and -22.01649 longitude -47.90211.

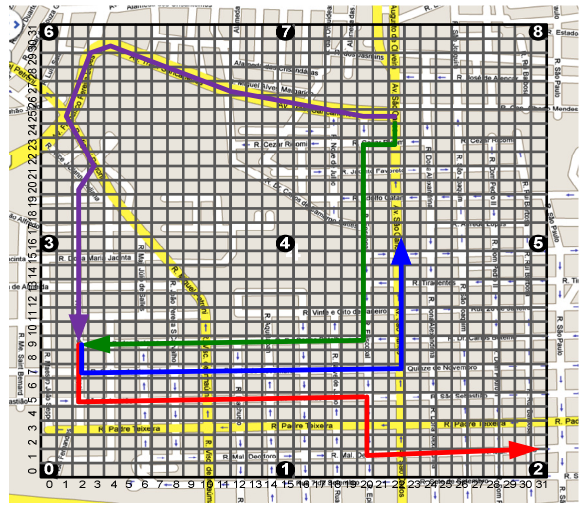

Figure 5. Overlap region in a framework of Sao Carlos

We had four *traces*, T_1, T_2, T_3 e T_4 to represent the paths of four ambulances that region, illustrated in the preceding Figure 6, respectively, by the directional lines of red, blue, green and purple.

After the first run of the simulation traces using the above, the positions obtained by the application of triangulation allowed to redraw the path of four ambulances on the map, as shown in Figure 6, where each directional arrow is matched with the arrows of the same color of Figure 5.

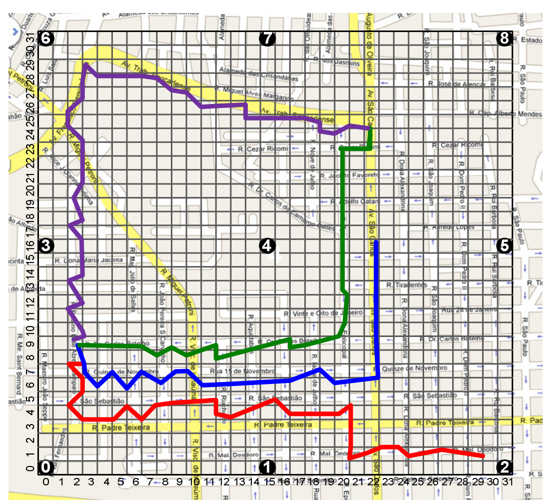

Figure 6. Results of the first run of the simulation

Note that certain positions differ from the expected one according to an error potential due to error intentionally introduced during the filling of the *matrix* to simulate the faults that occur in measurements of pilot signals by the real devices. In this case, the average deviation was 30.95 meters for the first *trace*; 40.31 meters for second, 28.50 meters to 48.74 meters and third for the quarter.

We perform the simulation two more times using the same *traces*. The average deviation observed for the three plays are identified in the graph of Figure 7.

It is possible to note that the average deviation in all executions was limited to 50.17 meters, which indicates an accuracy of 50 meters for each position calculated. In the future, one should be applied advanced mathematical techniques that help to get a more accurate result, for example, iterative methods.

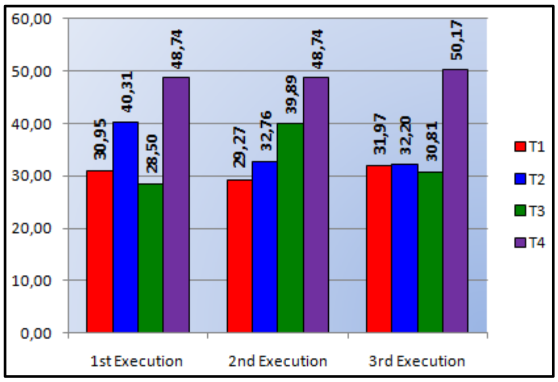

Figure 7. Average deviation obtained in i.i.d. executions of the simulation (in meters)

5. CONCLUSION AND FUTURE WORK

The integration of positioning in GSM cellular networks is a viable and low cost, since the wide adoption of such mobile telephony standard and the possibility of adapting existing infrastructure without the need to build it from scratch. The simplified LBS developed in this work was based on triangulation of GSM antennas for the positioning of ambulances within a city, with an accuracy of about 50 meters. However, advanced mathematical techniques can be employed in order to obtain a more accurate calculated position. Moreover, regarding the mode of transmission of positioning data calculated by this terminal in the ambulance to the central processing unit, which was implemented via HTTP *socket*, one can consider the future possibility of sending such information via SMS, releasing the device need to have Internet access.

Besides, both choices of ambulance and choices of the health centers are made based on information about the patient transmitted to the medic, i.e. a patient who endured cardio respiratory arrest is directed to a nearest health center by an ambulance type advanced composite by a medical, nurses and nursing assistants. In this context, a decision support system is being built to assist the medic in choosing the most appropriate and fastest type of ambulance and health center.

6. ACKNOWLEDGMENTS

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7. REFERENCES

[1] A. Varshavsky, *et al*. Are GSM phones THE solution for localization? In *7th IEEE Workshop on Mobile Computing Systems and Applications (HotMobile)*, 2006.

[2] Y.-C. Cheng, *et al*. Accuracy characterization for metropolitan-scale Wi-Fi localization, Intel Research Seattle, Tech. Rep. IRS-TR-05-003, Jan. 2005.

[3] Kurose, James F. Redes de computadores e a Internet. Addison Wesley, 2003.

[4] Chen, M.Y., *et al*. Practical Metropolitan-Scale Positioning for GSM Phones. in *Proc. 7th Int. Conf. Ubiquitous Computing (UbiComp)*, (2006).

[5] K. Axel., Location-Based Services: Fundamentals and Operation, John Wiley & Sons, Hoboken, NJ, USA, 2005.

[6] A. LaMarca, *et al*. Self-mapping in 802.11 location systems. In *International Conference on Ubiquitous Computing (UbiComp)*, 2005.

[7] Lecheta, Ricardo R.. Google Android: Aprenda a Criar Aplicações Para Dispositivos Móveis com Android SDK. Novatec, 2009.

[8] Google. Google Android. December 2009. Available at http://code.google.com/intl/en/android/.

[9] GSM Coverage Maps and Roaming Information GSM World's listing of countries, frequencies, and roaming agreements. Available at http://www.gsmworld.com/roaming/gsminfo/index.shtml