

Location Based Services (LBS) for Satellite Based Emergency Communications

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I. INTRODUCTION

Disasters are often combined with the destruction of the local telecommunication infrastructure, causing severe problems to the rescue operations. Disasters may also happen where such infrastructures did not exist beforehand. In an emergency situation first line telecommunication services are of paramount importance. Telecommunications offer a way for victims of a disaster to connect to others, and for rescue workers to co-ordinate their efforts. Both in a pre- and post-disaster phase, communication links are essential.

The existing solution to overcome the communication problems is to use satellite phones in the first hours after the disaster. With the help of more complex and bulky technologies it is possible to rebuild and deploy a wireless telecommunication infrastructure to transmit both voice and data, but these solutions require many hours to several days to be brought to the place of the disaster.

The WISECOM (Wireless Infrastructure over Satellite for Emergency Communications) project, a project co-funded by the European Commission, aims to fill this gap by developing a complete solution that can be rapidly deployed immediately after the disaster, within the first 24 hours, replacing the traditional use of satellite phones. To achieve this WISECOM restores local GSM or 3G infrastructures, allowing normal mobile phones to be used, and enables wireless standard data access (e.g. WiFi or WiMAX). The system uses lightweight and rapidly deployable technologies, the so called WISECOM Access Terminal (WAT), which can be carried by one person on board a flight and be deployed within minutes.

To enable locating lost or trapped people and aiding logistics of search and rescue operations by tracking rescue workers, the WAT will support Location Based Service (LBS). This paper will present some involved aspects in implementing LBS in the WISECOM project. Section II presents some generalities on LBS. Section III discusses the WISECOM architecture and the architecture of LBS implementation in WISECOM scenario. Section IV presents and analyzes the techniques that are used to compute position based on the available information within the system. Section V gives an overview of how LBS can be implemented in GSM network, as one of communication links envisioned in the WAT. Section VI concludes this paper and presents the work to be done in the future.

II. GENERALITIES ON LOCATION BASED SERVICES (LBS)

As the price per minute for voice services in cellular system decreases, operators have started to look for new areas to stabilize their bottom line and ensure future growth [4]. One way to reap additional financial benefits of mobile network is to offer value-added services (VAS). Location Based Services (LBS) is one of the most appealing value-added service option since the availability of user position information may enhance user experience due to the possibility of making many data services more relevant to user context (i.e., delivery of weather information according to the region one is in).

In terms of where the positioning process is done, LBS are classified into two classes: *passive (network-based)* and *active (terminal-based)* LBS.

In the former case users are unable to supply any kind of positioning information and their positions are computed thanks to measurements available in the cellular network. In the latter case user's mobile device participates actively in the positioning procedure, for example sending to the network their GPS positioning measurements.

In addition to this classification, two types of LBS applications can be distinguished: push and pull services. *Push service* implies that the user receives information as a result of his or her whereabouts without having actively requested it. While *pull service*, in contrast, means that a user actively uses an application and, in this context, "pulls" information from the network. An example of a push LBS service is MMS notification about discount campaigning in a nearby shopping mall, while driving in a city. An example of a pull LBS service is when a user requests a list of coffee shops in his or her current vicinity, using a mobile phone.

III. WISECOM SYSTEM ARCHITECTURE

The WISECOM Access Terminal (WAT) plays a central role in WISECOM system. The WAT provides cellular 2G/3G, WiFi, and other access technologies in the disaster segment and acts as an interface between these local access-domains with the transport domain. The envisaged satellite technology for the transport domain is the Inmarsat BGAN and DVB-RCS. The transport domain connects the disaster segment to the disaster-safe segment.

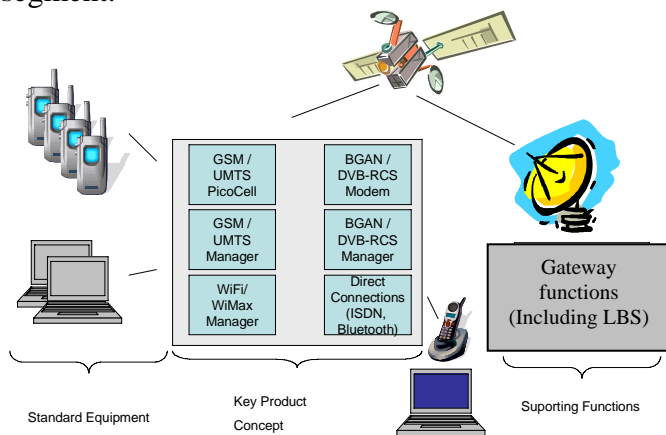


Figure 1 WISECOM overall system architecture

Three users classes considered in WISECOM scenario are defined in [6]: 1) the victims, people

directly affected by the disaster and requiring help (medical assistance, rescue, information about the area and the potential dangers), 2) Search and Rescue teams (SAR), that is, professional workers sent by governmental or non-governmental organizations to the disaster area to help the victims or to limit the damages through the disaster, and 3) other involved people, which are close to the scene of a disaster, but neither affected by the disaster nor taking part in the rescue effort. This classification of user defines the types and the capabilities of the user terminals, and further determines the type of LBS services applicable within the WISECOM context.

A. WISECOM LBS Architecture

LBS services implementation will take part both in disaster and in the disaster-safe segment of WISECOM scenario. The top level system architecture of WISECOM LBS is depicted in Figure 2.

The LBS architecture consists of two services: a local service at the disaster site and a global service in the disaster safe location. Connectivity to the active user devices (special smart phones or PDA-s, scenario using user type 2) is handled by the local service, while connectivity with passive devices (legacy mobile phones, scenario using user types 1 and 3) are handled by the global service, as it requires direct connectivity with the existing mobile infrastructure (Mobile Localization Service and Short Messaging Service).

Push service will be used for example to broadcast warning messages about dangers (poisoned water, further risk of collapse in case of earthquake, etc) related to emergency situations. An example of pull service is when a doctor is trying to locate how many victims need to be urgently treated in her surroundings. Passive LBS will be applicable mostly to victims, while active LBS could be applicable to SAR teams by providing GPS receivers as part of their equipment.

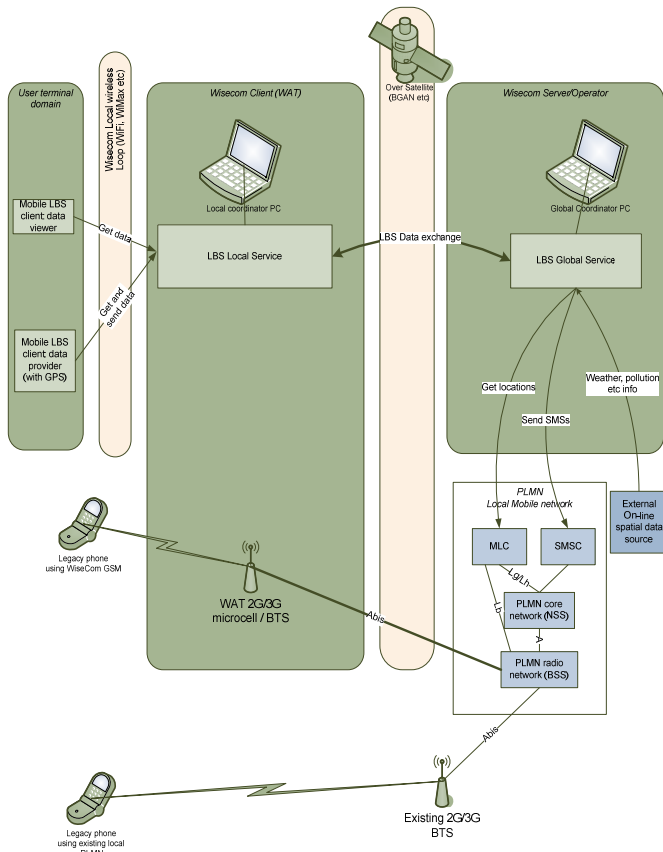


Figure 2 WISECOM LBS architecture

IV. POSITIONING TECHNIQUES

With the widespread use of satellite-based positioning using the Global Positioning System (GPS), it is hard to imagine how one can (or needs to) determine his position on earth using any other method – when free line-of-sight to the required number of GPS satellites is given. In LBS terminology, this is called terminal-based positioning, since the user (or its mobile terminal) computes the position itself using the information provided by the satellites.

There exist, however, some situations where a terminal has no positioning capability, or even if it has, there is no way it can transfer the position information to the interested parties. In fact, this is the case with the majority of GSM and WCDMA mobile phones (outside US). These situations are the ones that are most probably encountered in a disaster. In these situations, one must rely on the mobile network capabilities to locate a certain user. The techniques of how to extract position information from information available in the network is described in the following subsections.

B. Circular and Hyperbolic Trilateration

Trilateration is the method to determine the position of a mobile station (MS) knowing the distances from the MS to three reference base stations (BS).

The *circular trilateration* uses the absolute distances between the MS and three BS. In 2-D, each range measurement r_i defines a circle, where the MS must lie, with centre at the BS and radius equal to the range (c.f. Figure 3):

$$r_i = \sqrt{(X_i - x)^2 + (Y_i - y)^2} \quad (1)$$

Here (X_i, Y_i) is the coordinate of i^{th} BS, and (x, y) is the unknown coordinate of the MS.

A similar system of equations is achieved with the *hyperbolic trilateration*. In this case each equation represents the range difference d_{ij} between the MS and two BS i and j and defines the set of potential positions of the target:

$$d_{ij} = \sqrt{(X_i - x)^2 + (Y_i - y)^2} - \sqrt{(X_j - x)^2 + (Y_j - y)^2} \quad (2)$$

When there are n base stations, with $n \geq 3$, Equations (1) and (2) can be solved using least-square method, after being linearized using Taylor series expansion [3].

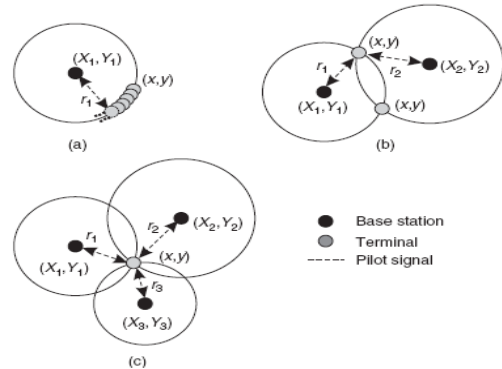


Figure 3 Circular trilateration

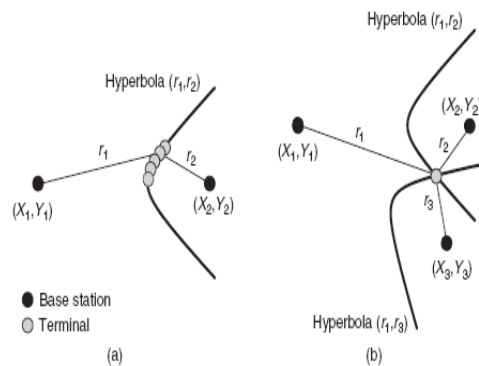


Figure 4 Hyperbolic trilateration

C. Range Determination Methods

Often the range information required to solve trilateration equations (1) and (2) is not directly available. To obtain this information, one must rely on other measurements, such as the received power level in the MS or the signal propagation round-trip time between the BS and MS.

When using the measured signal level, the distance information can be obtained from the signal attenuation along the BS-MS path. If we know the transmit power of the transmitter, the gain of the antennas, and all other losses in cables, connectors, etc, we can obtain the signal attenuation due to the propagation only (the *path loss*). This loss is inversely proportional to some power of the distance between the transmitter and the receiver. For a line-of-sight (LOS) link, for instance, the path loss is inversely proportional to the squared distance. In a mobile radio channel, where line-of-sight condition is not always available, the situation is more complicated, and the radio channel is usually modeled either statistically or interpolated from measurement results.

The *log-distance* or *Okumura-Hata channel model* [5] can be used to obtain a reasonable value of signal path loss in the mobile channel, as a function of (among other variables) distance between the MS and the BS.

Another possibility to determine the range is by using time information. Basically, we need to measure the round-trip propagation delay between the BS and the MS. Range can then be derived using the relation:

$$r = \frac{c\Delta t}{2} \quad (3)$$

with $c = 3 \cdot 10^8$ m/s, the speed of electromagnetic wave propagation, and Δt the round-trip propagation delay.

If all stations (MS and BS) are synchronized, we can use the Time of Arrivals (TOA) of the signal transmitted by the MS in different BS to obtain Δt . We will then obtain absolute range information and may perform circular trilateration.

The synchronization requirement can be relaxed by requiring only the BSs to be synchronized. Here we may use Time Difference of Arrivals (TDOA)

of the signal transmitted by the MS in different BS, and further use hyperbolic trilateration.

D. Error Sources

The noisy nature of the measurements performed to obtain range information causes inaccuracy in the result obtained.

In signal strength measurement the dominant cause of errors is the uncertainty in the mobile channel model. Okumura-Hata model, for example, comes from measurement results in a particular area. The accuracy of the model can be improved if the parameters are adjusted for the specific area where it is to be used.

Multipath may also cause errors in measurement of TOA/TDOA in the BS. The effect of different multipath environment to the errors in time measurement is discussed in [2]. Errors come also from other sources such as the clock inaccuracy, bad geometry among MS and BS, and the inaccuracy in BS coordinates.

V. GSM IMPLEMENTATION OF POSITIONING METHODS

Due to accuracy problems, almost all proposals for implementing LBS in GSM clustered around the idea of using time instead of signal strength information. Two of the most prominent are discussed here, namely the timing advance (TA) and the Uplink Time Difference of Arrival (U-TDOA).

The LBS implementation in GSM is possible by means of additional component called Serving Mobile Location Centre (SMLC) which controls the entire positioning process, including allocation of resources, evaluation of timing measurements, and calculation of position fixes.

E. Timing Advance

An MS can be everywhere within a cell and, due to the difference in the signal propagation time, an overlap between data bursts transmitted by a particular MS with those from different MS in adjacent time slots may happen. To avoid such collisions each BS must perform the process called *adaptive frame alignment*. After estimating the propagation delay of the MS data burst the serving BS sends to MS on the SACCH the Timing

Advance (TA) parameter, which represents the amount of time the MS has to advance its transmission, relative to the normal three-time-slot period after receiving data burst from the BS. TA assumes a value between 0 and 63 bit periods.

Since TA has a resolution of one bit period, which corresponds to $48/13 \mu\text{s}$ in GSM, the accuracy obtained from using TA is approximately $d = 3 \cdot 10^8 \cdot \frac{48 \cdot 10^{-6}}{13} \cdot \frac{1}{2} \approx 554 \text{ m}$.

The TA assignment divides the coverage of a cell into concentric rings with a width of d , in which an MS may be located.

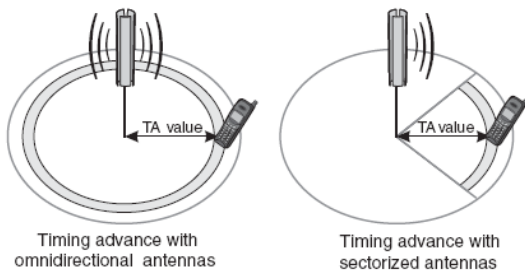


Figure 5 GSM Timing Advance rings

F. Uplink Time Difference of Arrival (U-TDOA)

U-TDOA uses hyperbolic location based on observation of the arrival time of data bursts sent by the MS in the BS. The arrival-time differences among several BSs are then used to compute the position of the MS.

Another component, namely the Location Measurements Units (LMU) should be added to each BS/WAT. An LMU observes the transmission of data bursts from terminals in its surrounding area in order to perform timing measurements and reports its measurements to the SMLC. The process of obtaining TDOA and the signaling involved between the LMU and SMLC are discussed in [3].

To implement U-TDOA in WISECOM system, LMU capability must be added to each WAT and SMLC must be implemented in the BSC, which could be on the other side of the satellite link (disaster-safe segment). Thus the signaling between LMU and SMLC may have to use the satellite capacity. Note that TA method does not require LMU capability in the WAT and the additional satellite capacity between LMU and SMLC, this

may be an important factor in practical implementations.

VI. CONCLUSION

In this paper we presented the LBS aspect within the WISECOM project. Several positioning techniques are analyzed and compared, paying attention to the consequences of their application in this particular satellite system. Future work will include the study of hybrid positioning methods to find the optimal combination of the different available measurements and of a procedure for multipath mitigation. Accuracy and scalability of these techniques will also be investigated. The most suitable and practical technique considering the available resource will be implemented and tested during a WISECOM demonstration, which will take place in Weßling, Germany, around end of October 2007.

ACKNOWLEDGEMENT

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