Location Management in Civil Emergency Wireless Communication

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Abstract. The prompt availability of location information is very important in emergency situations (e.g. accidents, natural or technological disasters etc), when people need help immediately. The precise identification of the caller's position in a mobile network is the foundation of rescue operations. The paper presents technical questions and some solutions in the context of determining and identifying the caller's geographical position in emergency cases, and it rather highlights some practical problems instead a presentation of a scientific solution.

1 Preface

Many challenges and considerations need to be addressed in defining and establishing the functional capabilities to support civil emergency communications in telecommunications networks [10]. One of these capabilities is the location management in the mobile networks.

Services based on user location in mobile networks are called *Location Based Services (LBS)*. Many GSM/UMTS operators support LBS all around the world, mainly in commercial applications. In case of commercial LBS, the information, that the network sends to the user (e.g. the text of an SMS) depends on terminal geographical position. LBS is either a pull or a push type of service. In ETSI/GSM LBS is called "Location Related Service". Another terminology is used related to the service concepts: *LoCation Services (LCS)*. LCS is a service concept in systems (e.g. GSM or UMTS) standardization. LCS specifies all the necessary network elements and entities, their functionalities, interfaces as well as communication messages, by implementing the positioning functionality in a cellular network. Note that LCS does not specify any location based (value added) services except locating emergency calls. There are four categories in use for locating services. These are the Commercial, the Internal, the Emergency and the Lawful Intercept LCS. The Commercial LCS (or Value Added Services) will typically be associated with an application that provides a value-added service through the knowledge of the user's location. The Internal LCS is developed to support internal network operations, for example location assisted handover or traffic and cov-

erage measurement. The Emergency LCS supports the identification of user location in case of emergency calls. In this service, the location of the caller is provided to the emergency service provider to assist them in the response. This service may be mandatory in some jurisdictions. In the United States, for example, this service is mandated for all mobile voice subscribers. The Lawful Intercept LCS supports various legally required or sanctioned services.

The determination of user location in the network is based on the capabilities of terminal and network elements and procedures. There are different types of measuring methods, and it is very important, that the method we choose should meet the requirements of the actually used applications. For example in normal (e.g. a simple speech service) calls the location information relates to MSC Service Area and Location Area. In emergency situation (e.g. emergency call of an accident) this is not enough, the emergency organizations need more accurate (some 10 meters) geographical positioning information to find, for example, the car on the route or along the highway, in case nobody can inform them by phone of the place of accident. Using mobile phones in case of emergency is another way, for the authorities or disaster managing organizations to send warning messages to people who are in danger, for example after an explosion in a chemical factory, or in extraordinary weather conditions, e.g. hurricanes, tornadoes, high wind and rain storms. Civil warning applications also need location information of the subscribers to identify the cell where they actually are, unless the network can't manage to send SMS or CBS to the people being in danger.

Understanding how we can get the location of the users and how we can manage these data in the network information systems, we need to identify some basic concepts:

- *Target:* a person/handset whose geographical position we need.
- *Source of location measuring:* a network element where the location information originated. There are two types of sources: network originated or terminal originated sources. Sometimes a hybrid solution is used.
- *Location measurement system*: this system controls the measurement procedures, collects and evaluates measurement data from different network devices.
- *LBS-provider:* a company or organization, that uses location information of its users to send different types of information to their terminals.

Network based/mobile assisted techniques use mobile network elements to identify the geographical position of the user's terminal. The handset measures some simple transmission parameters (received signal level, timing advance), detects and sends back some identities (like CGI). Network based methods are independent of the users' terminal capabilities, it does not affect the handset.

Mobile based/network assisted techniques require specific hardware/software installations in the mobile phone to measure location. In this case, the handset determines its position, measuring some predefined parameters or GPS coordinates and it sends the measurement reports to the network for further processing.

Hybrid techniques are the different combinations of two of the above techniques. These techniques give the best accuracy of the three.

2 Regulations, Standards

Regulations and standards can describe and lay down the technical and administrative rules of the realizations of the given requirements. The concept of Emergency Telecommunications (EMTEL) addresses a broad spectrum of providing telecommunication services in emergency situations. This is operating in cooperation with the telecommunications industry in the major national and international standard bodies. ITU and ETSI have been identified that address various issues related to the development of effective and comprehensive standards for LCS and the Emergency Telecommunications Services (ETS). EMTEL related standardization work takes place across ETSI's technical committees, projects and partnership projects. EMTEL issued three documentations that are to connect civil emergency wireless communications [3]. These are:

- *TS 102 182:* Requirements for communications from authorities to citizens during emergencies (civil warning)
- *TR 102 444:* Suitability of SMS and CBS for Emergency Messaging
- *TS 102 180*: Requirements for communications of citizens with authorities/organizations in case of distress (emergency call handling)

3 Location Management without LCS

When a subscriber terminates a call (speech, data, SMS etc.) the system must know its location in the GSM/UMTS network. To determine user location in mobile network, we have to know the generic geographical structure of the network, as well as Public Land Mobile Network (PLMN), MSC/VLR Service Area, Location Area and cell. As the mobile subscriber moves within GSM network, the system must know where the subscriber is located. The administration of user location information takes place in HLR and VLR. HLR, that stores the MSC/VLR Service Area code (VLR address) where the mobile was last registered. Location Area Code (LAC) is used for administration of mobile subscriber location within MSC/VLR Service Area. LAC is always stored in Visitor Location Register.

Let us suppose that the mobile is in standby mode. The mobile is connected to serving BTS continuously listening to its broadcast channel (BCCH). When attaching to a new cell it is possible that the mobile recognizes a new Location Area Code on BCCH channel (if MS enters into a cell which is in the same location area where the previous was, LAI does not change). As the location information has a great importance, the network must be informed about this change. At this point the mobile sends a location updating request message toward the MSC (see Fig. 1).

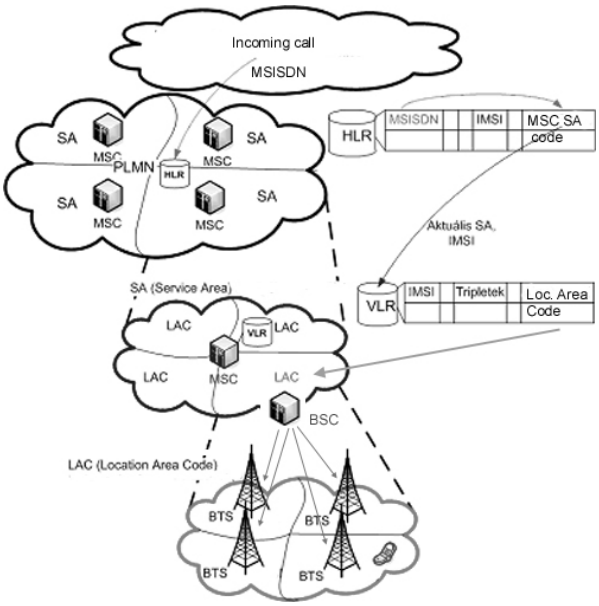

Fig. 1. Location management in case of normal calls (without LCS)

4 Location Management with LCS

When LCS is used, the system has to determine the location information of the terminal more accurately than in the case of normal calls, when the system only knows LAC. In LCS the location information is more complex and gives more accurate data. To support this new concept, new system functions are applied in the GSM/UMTS networks [1]. These two functions are the Serving Mobile Location Center (SMLC) and the Gateway Mobile Location Center (GMLC). SMLC controls the location measurement procedures GMLC receives the LCS service request from LCS clients, and transmits location data from the network. GMLC also supports the routing info request from HLR, when the system determines the serving MSC/VLR Area of the user (Fig. 2.).

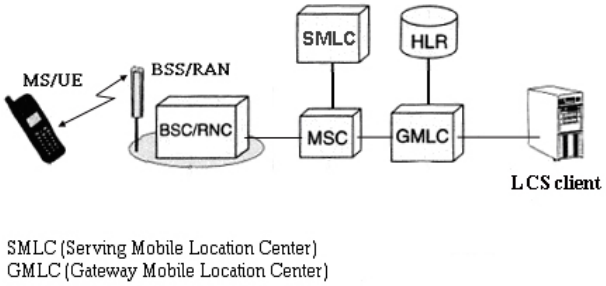

Fig. 2. Network elements for LCS

Fig. 3 and Fig 4 show the network and terminal based location measurement procedures. For better understanding we pull together the network element in one box that are part of the location measurement procedures (BSC/RNC+SMLC).
The network based procedure starts when an LCS client sends a request to GMLC. The GMLC gets the routing info (the identity of the serving MSC) from HLR, and it sends a location info determination request to the serving MSC. As we saw the MSC's VLR stores the actual LAC and BSC or RNC sends a paging message to the user. When the paged terminal returns its answer, the security procedures start under the control of MSC. When the security procedures are successful (e.g. user is authenticated by IMSI) MSC starts the location measurement procedures [8]. When the procedures are finished, the system sends location data to the LCS client. When a terminal based procedure is used, the MS/UE initiates the LCS procedure. First it sends a service request to MSC, and after its security functions, the MSC enables the starting of the measurement procedures. When the procedures are finished, the measurement report is sent to the MSC, GMLC and LCS client.

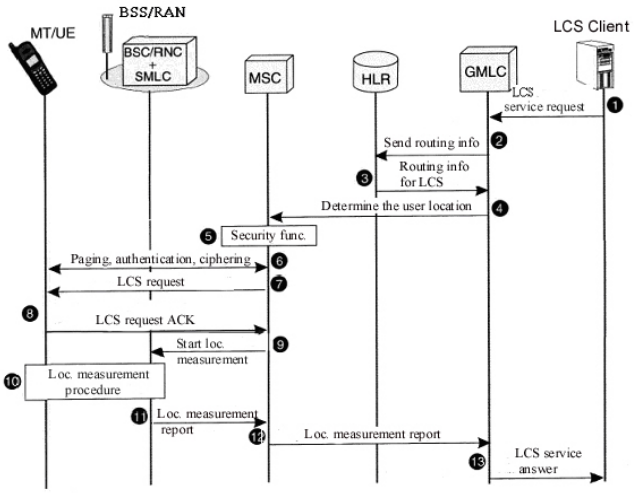

Fig. 3. Network based location determination signalling procedure

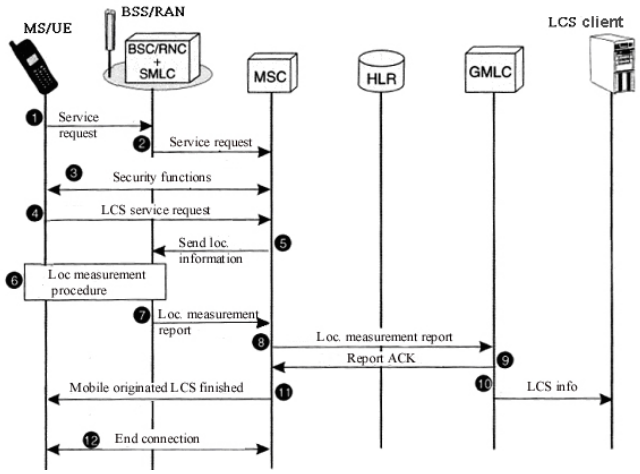

Fig. 4. Terminal based location identification signalling procedure

In case of emergency applications (calling 112 in EU or 911 in US), the LCS information is sent to a special LCS client, which is called Public Safety Answering Point (PSAP). PSAP is directly connected to Emergency Call Centres (ECC), where the geographical position of the caller is directly displayed on a map on the operator's monitor screen in the Emergency Response Centre (ERC). The calls may relate to an injury, traffic accidents, criminal incidents that threaten the law and order, fires or social services emergencies. The ERC operator finds out what has happened and where, gives the assignment a risk classification and then notifies to send help needed to the accident scene.

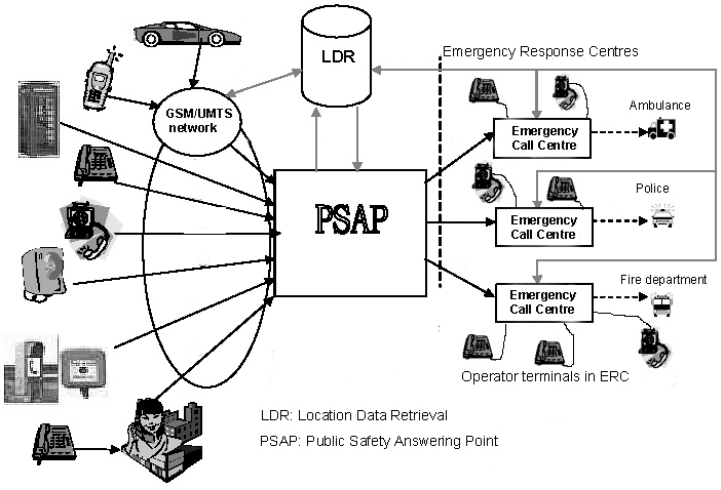

Fig. 5. Location management in case of emergency calls [4]

The member countries of the European Commission are obliged to use E112 in their communication networks (Commission Recommendation 2003/558/EC) [2]. E112 is a location-enhanced emergency call services, which means that the location information of the caller is automatically and immediately transmitted when the call set-up (speech) is completed. In ETSI TS 102 180 the documentation recommends possible network architecture for E112 as shown on Fig. 5. This concept is between two new network functions, telecommunication networks and ECCs. Public Safety Answering Point (PSAP), and Location Data Retrieval (LDR). As the location information can originate from different types of communication networks and terminals (wired, wireless, public, private, etc.), first of all every emergency call is routed to PSAP [4]. When the call is terminated to PSAP, PSAP sends a location information request message toward LDR. Hence the LDR is connected to mobile telecommunication providers SMLCs, the location information will be sent directly to LDR, and then to PSAP. The procedure has to be very fast because the call and location information must receive them practically at the same time in ECC. So, when the operator picks up the phone in ERC and starts the oral connection, he/she can see the geographical location of the caller on his/her computer terminal screen.

5 Geographical Position Measurement Methods and their Accuracy

There are many methods for measuring the geographical location of the terminal/user:

Cell Identification with CGI: Cell Identification is based on Cell Global Identity (CGI): The accuracy of this method can be a few hundred meters (except in UMTS indoor picocell where it is 10-50 m) in urban areas, but in suburban areas and rural zones it can be as poor as 32 km (GSM) and 20 km (in UMTS).

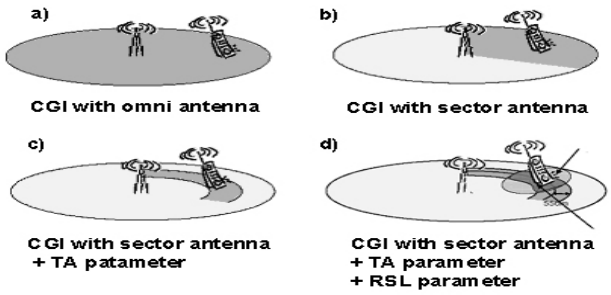

Fig. 6. Accuracy of geographical position using CGI and other parameters [7]

The accuracy depends on the known range of the particular network base station and the type of the antenna. It is also a problem that in UMTS Terrestrial Radio Access Network (UTRAN) the User Equipment (UE) can connect parallel

with two or more base stations (its called macro diversity). In this case, two or more CGI are active at the same time. Fig. 6. shows four different methods when CGI is applied. The most inaccurate method is using an omni-directional antenna. (Fig. 6/a) but using a sector antenna, the serving area is smaller (Fig. 6./b), so the possible location of the user is smaller too. The accuracy is increasing when the mobile measures the Timing Advance parameter on an active downlink channel (Fig. 6./c). The mobile sends back TA to the Base Station, thus the network calculates the distance of the terminal to the Base Station. The distance accuracy of this method is about 50 meters, but the possible area (dark grey area) depends on the cell size. The most accurate method is called E-CGI (Fig. 6/d), when the Received Signal Level (RSL) on the downlink dedicated channel is also measured by the mobile phone [9]. In this case the area where the mobile is located is an area about 500 meters in diameter.

Time Difference Of Arrival (TDOA) and Time Of Arrival (TOA): In TDOA technology the network determines the signal transmission time difference and the distance from the mobile phone to each base station. The TOA is similar to TDOA, but this method uses the absolute time of arrival at a certain base station rather than the difference between two stations.

Angle of arrival (AOA): AOA technique locates the user at the point where the lines along the angles from each base station intersect. To determine this point a reference direction is used (see. Fig. 7.). The calculation of angles is originated from measuring the time delay from the antennas.

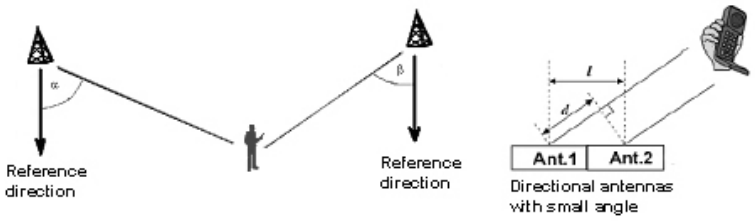

Fig. 7. AOA measuring method

Enhanced Observed Time Difference (E-OTD): This is similar to TDOA, but the position is estimated by the mobile phone, not by the base station. The measuring is based on the hiperbolyc triangle rule (see Fig. 8.). During the procedure, the mobile terminal measures the time difference of sending signals from different base stations (GTD parameters). Hence the Base Stations are not synchronized to each other, there is no time of reference for exact calculation. A new network function has to be used to make this synchronization; this is called Location Management Unit (LMU). The precision of this method depends on the number of available LMUs in the network.

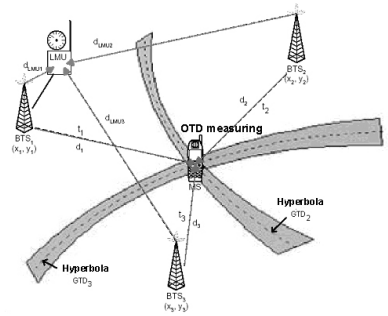

Fig. 8. E-OTD measurement method with LMU

Assisted-GPS: GPS-based technology, which uses a network ground station to eliminate GPS errors caused by the atmosphere or topography (Fig. 9.). The method uses differential GPS technique: the built in GPS receiver determines the GPS coordinates and gets some more GPS reference data from the ground Station through SMLC.

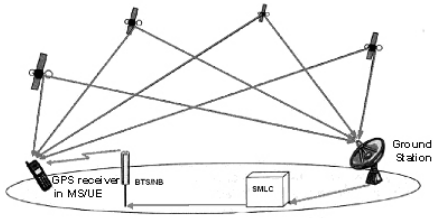

Fig. 9. A-GPS application with SMLC

The efficiency of different location measurement techniques depends not only on the accuracy and terminal capabilities, the importance being where it is used. For example the GPS based technologies do not work inside buildings or tunnels, but the enhanced accuracy technologies also are problematic indoor and outdoor urban areas, where the multipath spreading causes serious fading problems in the receiver. We can say that the better accuracy and more complicated method we use, the application in practice decreases. The main problem with E112 calls is that it is not clearly defined in relevant documentations which of the location measurement method is the best and most efficient in this case. If we examine the possible methods again, we can see that the answer is not simple, there are many factors that have to be considered. These are:

- software/hardware capabilities of mobile phones
- software/hardware capabilities of the network
- where the emergency call is originated from (outdoor, indoor, urban , suburban, rural, forest, mountain, sea etc.)
- is the caller able to give more information about his/her location or not

what kind of help he/she needs, etc.

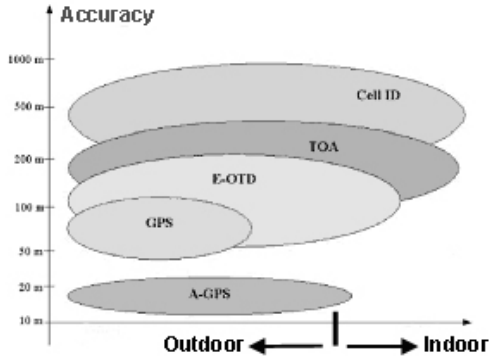

Fig. 10. Accuracy and application of location determination technologies

Considering the factors above, we can say that for emergency calls nowadays the operators use network based measurement methods mainly. Generally CGI identification is used, sometimes E-CGI. Using TOA and TDOA the operator needs further software development in the network, for using E-OTD or A-GPS, the network elements and user terminals need further capabilities. In emergency cases, the location data has to be determined very quickly, that is why the CGI identification is (reading CGI form VLR) now the quickest if the procedure is automatic (1-2 seconds). If it is manual, it takes much more time. Later when the user terminals can measure GPS coordinates, the A-GPS will be the most efficient method for very quick and accurate location determination.

6 Location Management in Civil Warning Systems using SMS and CBS

When SMS or CBS is used in civil warning applications [6], two main aspects have to be considered:

- How many people are affected?
- Haw large is the affected area?

Sending a SMS (a warning message or an instruction) can only target specific MS's and so its suitability to reach large numbers of MS's within a reasonable time frame and geographical area is limited. The Cell Broadcast Service allows text messages to be broadcasted to all MS's in a particular cell area, or all MS's in a selected group of geographical locations (e.g. a given region). The GSM BSC/BTS within the range 2 s to 32 minutes may repeatedly broadcast text messages periodically. In a UMTS environment, the highest repetition rate is 1 second. Fig. 11. and Fig. 12. show the network aspects of two applied solutions [5]. When SMS is applied, the system first identifies the MSISDN number of each user in the given cell (cell where the warning message should be sent). Normally, the SMS sending procedure is same as a speech call (regarding location management), but in warn-

ing applications, the LAC information is not enough (the is many cells with the same LAC), CGI is needed. It is done, by filtering the users from VLR database by CGI. This procedure is time consuming and depends on the number of users records in VLR (some hundreds thousand). The messages are stored in SMSC and the speed sending SMS from SMC to MSC is about 100-200 SMS per seconds [11]. When CBS is used, the operator enters CGI values and text messages to the Network Management System (NMS), selects the repetition time, and starts the broadcasting procedure. If a Cell Broadcast Centre is used in the network, the procedure is quicker and more efficient because in CBC it is possible to make a list of CGIs or messages and the procedure automatically manages to broadcast CBS messages.

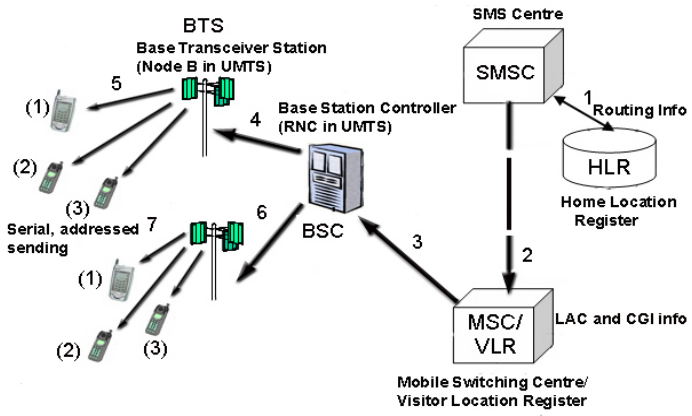

Fig. 11. SMS sending procedure

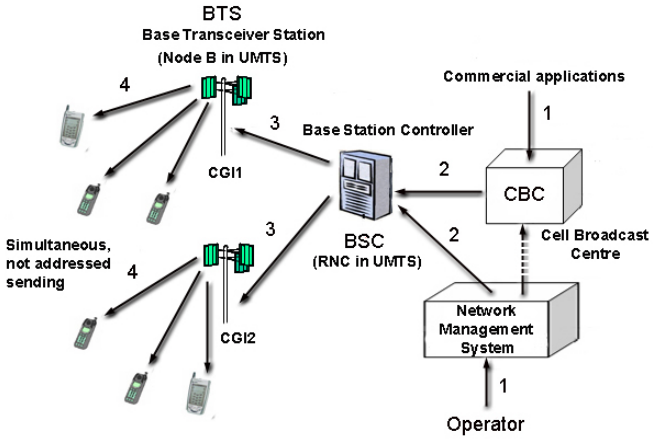

Fig. 12. CBS sending procedure

7 Summary

The accurate and quick determination of user location in the mobile network in emergency situations is very important for rescue operations and for saving lives. There are different types of measurement methods, and it is very important, that the method we choose should meet the requirements of the actually used application. In civil wireless emergency communication two main fields are defined by regulations: emergency calls and sending warning messages through mobile networks. These two applications need different location management procedures and location determination solutions. As this field of telecommunication is less known and less applied in EU countries and in other parts of the World, standardisation bodies, national authorities and rescue organisations should cooperate to develop more efficient and widely usable common civil emergency telecommunication solutions.

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