E-health Oriented Application for Mobile Phones

Andrzej Podziewski
Warsaw University of Technology, Faculty of Electronics and Information Technology
15/19 Nowowiejska Street, 00-665 Warsaw, Poland
E-mail: a.podziewski@gmail.com

Kamil Litwiniuk
Warsaw University of Technology, Faculty of Electronics and Information Technology
15/19 Nowowiejska Street, 00-665 Warsaw, Poland
E-mail: kamillitw@gmail.com

Jarosław Legierski
Orange Labs Poland, 7 Obrzeżna Street, 02-691 Warsaw, Poland
E-mail: jaroslaw.legierski@orange.com

Keywords: service delivery platform, SDP, API exposure, telco 2.0, e-health

Received: September 25, 2012

This paper presents the idea of using mobile operators APIs with an e-health usage scenario. Since numerous elderly people are going missing every year, proposed emergency location service presents a way in which mobile operators' networks, the Internet and possibilities given by rapid improvement of phones' functionalities can converge in order to relieve the problem. The description of presented solution is supplemented with sets of accuracy measurements and usability tests, conducted during test deployment. The results confirm usability potential of the service, giving green light for further research and development. Still, in order to make the service reliable, the algorithms used to determine location and detect falls need to be improved. The article presents a method, which may be used to improve the location accuracy.

Povzetek: Prispevek opisuje metode za pomoč starejšim, predvsem lociranje s pomočjo mobilnega telefona.

1 Introduction

The societies of highly-developed countries are gradually becoming older, and therefore the phenomenon of elderly people going missing becomes noticeable [1]; the main reason being health issues, such as memory losses and spatial orientation problems. Additionally, elderly people are more likely to lose consciousness and fall due to their health problems – such situations always require instant reaction and often hospitalization. Rapid response is not always possible, especially if the location of the person is unknown. Therefore, the main idea behind the proposed service is to provide its users with a reliable and fast-to use location service that could be easily – or even automatically – invoked in case of emergency, without the need to carry additional electronic equipment.

2 Existing Solutions

At the moment, there are numerous GPS-based location systems available, that can be used in medical assistance, such as Finder On-Line [2]. Those solutions are solely designed to work outdoors, where GPS signal is available. Other systems, like ZUPS [3] are designed for indoor location and require dedicated devices and infrastructure. Since mobile network cell-based location outperforms both solutions in range and reliability, it stands out as an interesting area of research. Despite its lower accuracy it has the additional advantage of very low cost. In this paper we investigate the functionality of a simple emergency location system built upon cellular network infrastructure.

3 The Idea of Telco 2.0 and Telco Web Services

In the last years the Internet has gone through major changes. The idea of Web 2.0 has transformed the way in which the network is used and perceived. In the days of Web 1.0, the typical Internet user was mainly a passive consumer of the content such as web portals. Possible user activities were not related to the then-static World Wide Web and limited to sending e-mails, participating in chats or newsgroups. At the moment, Internet users have numerous possibilities of dynamically creating their own content: participating in social networking sites, writing blogs, collaborating on wikis and building web sites using content mashup from other pages and portals [4], [5]. Telecom operators, seeing the immense potential behind the Web 2.0, have aggressively tried to implement a similar, two-sided business models, based on service exposure platforms [6], [7]. Their goal was to monetize existing network assets more efficiently by leveraging third party developers and service providers. This concept is currently known as Telco 2.0 and is actively researched, resulting in numerous new applications like [8],[9],[10],[11],[12]. In the Telco 1.0 model, telecommunication networks are closed for external entities and only the operator is able to create services and telecom applications. In the Telco 2.0 model, operator's networks functionalities are made available for external developers by exposing sets of interfaces in the Internet. This approach allows companies and universities to build, test and deploy their own services based on telecom infrastructure.

From the practical point of view, the most significant difference between Telco 1.0 and 2.0 is the way in which telecom resources are accessed. In Telco 2.0 it is done using the Web Services technology (Fig. 1), which is predominant in the IT sector, as opposed to telecom network- specific protocol stack used in Telco 1.0. Through Telco Web Services, Telco 2.0 implementation supports the most popular access models such as RESTful architecture style (Representational State Transfer – most popular in the Internet [13]) and SOAP (Simple Object Access Protocol), in accordance with SOA (Service-Oriented Architecture) guidelines – a "de facto" standard in the enterprise sector [14].

In comparison with the traditional way, use of Telco 2.0 interfaces allowed for a significant reduction in time required to develop a service. Therefore, as our goal was to confirm whether it was possible to build a usable emergency location service upon mobile network infrastructure, Telco Web Services was chosen as an optimal solution.

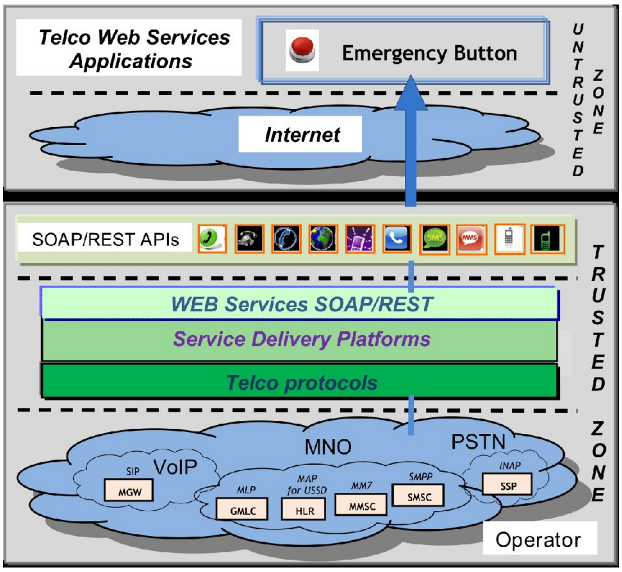

Figure 1: Telco Web Services architecture. Source: [10].

The key operator's network element responsible for communication APIs exposition is the Service Delivery Platform (SDP). South interfaces of this system are connected directly to the network enablers, responsible for telecommunication functions and using telecom oriented specific binary protocols, such as: SMPP (Short Message Peer-to-Peer) and UCP (Universal Computer Protocol) for SMS services; MAP (Mobile Application Part of SS7 Stack) for USSD (Unstructured Supplementary Service Data) or MM7 interface for MMS messages. Because of binary character and specific telecommunication function oriented implementation, these protocols are difficult to use for (mostly) IT oriented programmers. North interfaces of SDP are connected to the Internet. Exposed APIs provide the developers with more user-friendly interfaces in Web Services form. First implementation of WS, dedicated for exposition of communication APIs, was implemented in SOA model as ParlayX standard [15]. In the last years we have observed an expansion of RESTful Web Services in the Internet. In response to this trends, the newest telecommunication APIs specification are resource oriented (e.g. OneAPI standard [16]).

4 The Emergency Button Service

The majority of emergency information and fall detection systems require specifically designed hardware and software, which limits the commercial availability to the wealthiest users. This paper proposes a low priced system that uses reliable, ubiquitous technology – mobile phones that most people carry every day. Every cell phone is suitable to activate the basic service, and using a slightly more expensive smartphone significantly boosts its functionality.

In spite of the above, as typical end users for the service we have chosen people with orientation disorders, memory losses or in danger of losing consciousness, their families or people in any way responsible for their wellbeing (social workers, nursing homes etc.). As will be described later – due to its nature, use of the service can be tailored to fit any situation where base-station location is of enough accuracy.

5 System Architecture

In this chapter, service activation is presented as a way to establish interaction between the Seniors and Guardians. Seniors are the people who require attention due to their health issues. They will be the ones to invoke the service (intentionally – when lost, or automatically – when a fall is detected). Guardians, on the other hand, are those to be informed about senior's location in case of emergency. When the Emergency Button service is invoked, a message containing approximate GPS coordinates and address is sent to Guardian's cell phone. (
Figure 2).

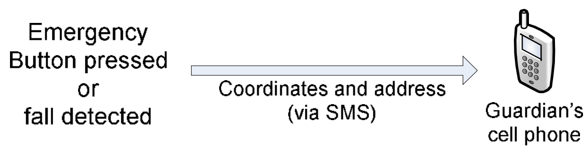

Figure 2: Service invocation scenarios Source: [10].

As stated before, Emergency Button may be invoked in numerous ways. The most basic one is by sending a USSD (Unstructured Supplementary Service Data) message. Specific code can be stored in phone's memory or SIM card and assigned a speed dial button for the ease of access. Change sentence to: Besides, a full-screen widget for Android smartphones was developed. Therefore, the EB Service can be activated by simply touching almost anywhere in the screen while the phone is unlocked. The most prospective way to invoke the service, that was implemented, is the EB Fall. It is an Android application that controls a background service (not to be confused with EB service itself, as it is, in simple words, an application without a user interface running in the background). It is responsible for detecting a fall caused by losing consciousness by the owner using data from built-in accelerometer. If the Senior does not respond within a given period of time, the EB service is activated. The implemented heuristic model of a fall is based on measurements and findings presented in [17] and [18].

In order to implement the service, the following Telco 2.0 API functionalities were used:

- Send USSD – for invoking the service from Senior's cell phone
- Terminal Location – for determining Senior's cell phone location by means of cell identification
- Send SMS – to inform the Guardian about an emergency situation.

As shown in Fig. 3, the main component of the developed service is the application server, where main software components are deployed. The first one is responsible for running the logic of the service – receiving USSD messages, location and sending SMS messages to Guardians. It cooperates with the second module, designed to maintain communication with the database and process incoming requests. The last module is the graphical user interface – a web page allowing the Guardians to register in the service, add Seniors and maintain associations between them and registered Seniors, as well as view recent service activations on a map.

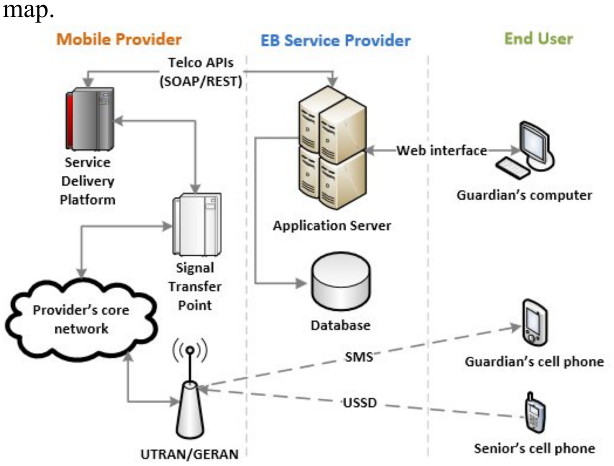

Figure 3: Structure of the developed service. Source [10].

6 Measurements

In order to check the accuracy of location returned by the mobile network, measurements in 60 random locations were taken in Warsaw area – using both GSM and 3G (UMTS) Radio Access Networks (RAN). As reference position we used data from an external GPS device. To assess reliability and actual usability, 7 tests were conducted in order to determine whether it was possible to find a lost person without using measures different than the EB service.

6.1 Accuracy tests

The histograms represent the distribution of location error for both the GSM mode (Fig. 4) and the UMTS mode (Fig. 5). Obtained accuracy was higher in the GSM mode. The reason behind those results is that in Warsaw, GSM cells of the mobile network in use (Orange) were significantly smaller than the UMTS cells [19].

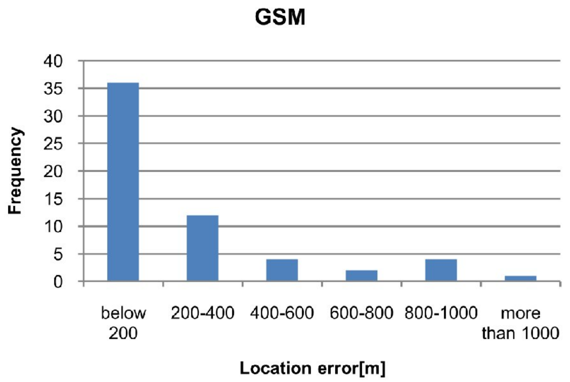

Figure 4: Error of location prediction for the GSM RAN. Source: [10].

Since every mobile carrier's RAN structure is different (ex. an operator might maintain only one type of access network, have higher base station location density etc.), it cannot be stated with certainty that a specific type of network allows for better accuracy. Chances are that if a UMTS network was the only type of RAN maintained by an operator, its performance in means of location error could be much better due to UMTS networks characteristics (relatively small cells to provide good HSPA coverage [20], wide use of picocells [21] adding capacity in areas with dense phone usage).

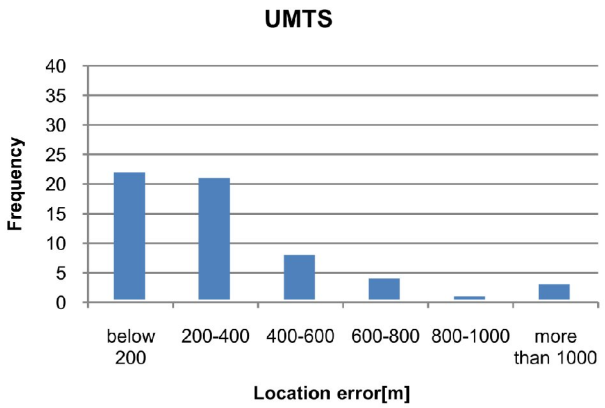

Figure 5: Error of location prediction for the UMTS RAN. Source: [10].

6.2 Usability tests

The results of usability tests were obtained in accordance with the following rules:

- one person (Senior) had to choose a random place in Warsaw to invoke the service and then wait for rescue,
- the other tester (Guardian) had to find the Senior wasting as little time as possible,
- Guardian was only allowed to use means of public transport,
- the service could be invoked only once per test,
- no way of communication between the Guardian and the Senior was allowed other than activating the service.

All the measured distances are "as the crow flies" – the length of a straight line segment connecting the points is given.

Nb.	Distance Guardian-Senior [m]	Senior location error [m]	Time to find [min]
1	1655	198	19
2	3153	210	44
3	1092	125	15
4	377	686	n/a
5	852	377	48
6	3710	290	35
7	410	144	41

Table 1: Results of the usability tests. Source: own research.

Usability tests (tab. 1) show that if the location error is smaller than 200 m, finding a lost person in a very short period of time is possible, like in tests 1 and 3. Still, even if the error is relatively small, it might take a long time if the conditions are unfavorable, like in tests 2 (university campus) and 7 (Warsaw Metro construction site).

When an emergency situation occurs in a densely built up residential area and the location error is higher than 300 meters, finding the Senior is still possible, but requires a very methodical, lengthy search (like in test 5), as the area to be explored grows quadratically with the error. As it increases, and the person in need is not in within sight, time needed to find them increases dramatically, up to a point when doing so in a reasonably short time is almost impossible (test 4). Therefore, small error (less than 200 m) does not necessarily guarantee a short search time, but large (more than 200 m) always results in a lengthy walk.

7 Challenges

Using a mobile phone for location and fall detection has numerous advantages over specialized systems, the main being its low cost and the fact, that it is already considered an indispensable device by most people and is therefore, carried on a daily basis. Still, there are numerous weaknesses to the EB service that need to be taken into account and addressed during future development.

As opposed to GPS-based systems, proposed service works indoors as well as outdoors and is relatively invulnerable to difficult weather conditions. Unfortunately, due to relatively large size of cells in cellular networks, if cell identification alone is used, location errors may be up to several kilometers in sparsely populated areas. This issue might be resolved by implementing a client-side GPS support or triangulation algorithms that would process data from Senior's phone such as signal strength and neighboring base stations. This would require phone-specific software to run on Senior's mobile phone as well as a reliable data connection, making the service more precise, but considerably less universal.

In order to improve the handset location accuracy without any client-side support, the operator should implement more advanced network-based tracking techniques. It is possible to determine the sector in which the mobile phone resides -and estimate the distance to the current station by measuring radio signal propagation time delay [22]. Moreover, triangulation techniques can be used to determine position by using data concerning signal parameters from neighboring base stations. Methods dedicated for terminal location accuracy improvement are discussed in chapter 8.

Since the service is intended to be used in case of loses of consciousness as well, improving the reliability of the implemented fall detection algorithm is a matter of utmost importance. The greatest challenge is the reduction in number of false positives while maintaining high sensitivity to real falls.

In its current form, the service strictly relies on the interfaces provided by the mobile network operator. Consequently, as not all of the cellular operators expose necessary Telco 2.0 interfaces, it is only possible to use it within one network. Hopefully this matter will be resolved by the operators themselves by exposing proper APIs and providing with functional inter-operator links for USSD messages and location services.

Another concern is the possibility of confidentiality breaches that applies to all location-based services. Subscriber's location and movement data is controlled and owned by mobile network operators. Since it has the potential to be used in adversary purposes, it may only be revealed under strict conditions that are defined by telecommunications law of a given country [23]. Therefore, before any commercial deployment, legal precautions need to be taken in order to prevent any misuse of the data provided.

8 Terminal Location Accuracy Improvement Methods

The simplest method used in Location Based Services for mobile terminal location is based on network CelID, sometimes extended by radius calculation between BTS and mobile station defined by Timing Advance (TA) parameter. In this method, the approximate longitude and latitude of mobile terminal are calculated by GMLC (ang. Gateway Mobile Location Centre) based on geographical center of mobile cell. This method is dedicated for GSM system and is currently used by the Emergency Button application. Another mobile terminal location methods in this area are presented bellow [25]:

- U-TDOA (Uplink Time Difference of Arrival) – dedicated for GSM and UMTS, based on the delay of radio signal propagation from terminal to network,
- E-OTD (Enhanced Observed Time Difference) – standard hybrid method for GSM conceptually, method is similar to U-TDOA.
- OTDOA (Observed Time Difference Of Arrival) – standard defined in UMTS system, based on measurement of delay radio propagation signal from network to terminal. OTDOA is based on the measurement of signal delay from minimum three base stations [25],[26],[27]. Using this method, location error can be minimized to 50 m in the cites.

Methods presented above, based on signal propagation time measurement (U-TDOA, E-OTD OTDOA) can be implemented by installing specific hardware and software on provider's side.

Another approach for reducing location error is focused on methods dedicated for implementation on mobile terminal side.

Standard method in this area is A-GPS (Assisted GPS) – typical mobile terminal location method using assisted GPS receiver installed in mobile terminal (dedicated for UMTS).

In last years we cloud observe rapid development of hybrid methods. This kind of location services is based on observation of information from different sources:

- Wireless Network SSID presence,
- Network Measurement Report (signal strength from up to 6 Basic Transceiver Station) observed by mobile terminal [27],[29].
- GPS, Accelerometer and gyroscope.

Information from all the sources presented above is correlated with existing database and utilized to support the calculation of mobile station position.

Unfortunately, hybrid methods are available only for users with smartphones and tablets because of dedicated hardware requirements (WiFi, accelerometer, gyroscope, GPS). An example API based on hybrid methods is described in [30] and is defined as common source of location information (GPS and location inferred from network signals such as IP address, RFID, WiFi and Bluetooth, MAC addresses, and mobile networks cell IDs).

Method	country	suburban	city	Inside the buildings
Cell ID	1-35km	1-10km	50m-1km	50m-1km
Cell ID +TA	1-35km	1-10km	50m-1km	50m-1km
U-TDOA OTDOA	80m	50m	50m	50m
E-OTD	50-150m	50-150m	50-150m	50-150m
A-GPS	30m	40m	30-150m	200m

Table 2: Comparison the accuracy of methods dedicated for mobile terminal location [25].

9 Conclusion

Presented system is a viable solution to low-cost emergency location. Using existing technologies and simplest cell-identification based location, we proved that it is possible to find a lost person in a densely populated area with only the data from the received text message. Further improvement in accuracy and better reliability can be obtained if the operators decide to better their handset tracking technologies. It is probable, since by exposing Telco 2.0 interfaces they received an easy-to-use way of providing location services to external entities. If that is not the case, better accuracy can be obtained by using less universal client-side solutions.

Future work ought to focus on improving the accuracy of returned location, which is crucial in reducing time necessary for finding a lost person. Another problem that needs to be addressed is the limited reliability of the implemented fall detection algorithm.

Despite presented use-case, the service can be easily adapted to different emergency situations, e.g. informing municipal police about dangerous situations in means of public transportation or finding lost children.

References

[1] M. J. Patterson: Who is missing? A study of missing persons in B.C., Simon Fraser University, 2005

[2] Finder Telematic Solutions, available: http://www.finder.pl/

[3] A. Marco, R. Casas, J. L. Falco, H. J. Gracia, J. I. Artigas, A. Roy: Location-based services for elderly and disabled people, Computer Communications Journal, April 2008

[4] N. Banerjee, K. Dasgupta, Telecom Mashups: Enabling Web 2.0 for Telecom Services, ICUIMC '08 Proceedings of the 2nd international conference on Ubiquitous information management and communication, Korea, 2008

[5] S. A. Ahson, M. Ilyas, Service Delivery Platforms, Developing and Deploying Converged Multimedia Services, CRC Press Taylor Francis Group, 2011

[6] M. Średniawa, Telecommunications Reinvented, Proceedings of the XIV Poznań Telecommunications Workshop, Poznań 2010

[7] portal STL Partners http://www.telco2.net/ [7.11.2012]

[8] D. Bogusz, A. Podziewski, K. Litwiniuk, J. Legierski ., Telco 2.0 for UC – an example of integration telecommunications service provider's SDP with enterprise UC system, Conference FedCSIS/FINANS, Wrocław, 2012, IEEE Explore

[9] Litwiniuk K., Czarnecki T., Grabowski S., Legierski J., Bus Stop – Telco 2.0 application supporting public transport in agglomerations, Conference FedCSIS/FINANS, Wrocław, 2012, IEEE Explore

[10] Podziewski A., Litwiniuk K., Legierski J., Emergency Button – a Telco 2.0 application in the e-health environment, Conference FedCSIS/FINANS, Wrocław, 2012, IEEE Explore

[11] H. Rosa, D. Krasińska, USSD Survey Guide, Orange Labs, 2011

[12] A. Tylman, J. Jankowski, Assumptions and scope of Work Control – trial service based on Parlay X technology, Orange Labs, 2010

[13] L. Richardson, Sam Ruby, David Heinemeier Hansson, RESTful Web Services, O'Reilly, 2007

[14] E. Newcomer, Understanding Web Services: XML, WSDL, SOAP, and UDDI, Independent Technology Guides, 2003

[15] Open Service Access (OSA); Parlay X web services, 3GPP Technical Specification TS 29.199-01 ÷ TS 29.199-22

[16] Portal OneAPI http://www.oneapi.gsma.com/ [7.11.2012]

[17] F. Sposaro, G. Tyson, iFall: An Android Application for Fall Monitoring and Response

[18] T. Zhang, J. Wang, P. Liu, and J. Hou: Fall detection by embedding an accelerometer in cellphone and using kfd algorithm. IJCSNS International Journal of Computer Science and Network Security, 6(10), October 2006.

[19] Orange RAN map, available: http://mapa.btsearch.pl/

[20] D. Maidment: Understanding HSDPA's Implementation Challenges, picoChip Designs 2005

[21] R. Kumar: A picocell primer, Texas Instruments 2006

[22] M. O. Sunay, I. Tekin: Mobile location tracking in DS CDMA networks using forward link time difference of arrival and its application to zone-based billing, Global Telecommunications Conference, 1999. GLOBECOM '99

[23] L. Ackerman, J. Kempf, T. Miki: Wireless Location Privacy: Law and Policy in the U.S., EU and Japan

[24] Portal Orange Labs Telco 2.0 University www.tu.rd.tp.pl

[25] J. Stefanski. Metody i standardy pozycjonowania terminali w systemach komórkowych Przegląd Telekomunikacyjny, nr 6, 2006, Wydawnictwo Sigma-NOT, Warszawa, Poland

[26] M. Miernik, Metody i procedury lokalizacji abonenta w sieciach komórkowych GSM2+/3G, Przegląd Telekomunikacyjny 5/2003, Wydawnictwo Sigma-NOT, Warszawa, Poland

[27] J. Stefanski, Radio Link Measurement Methodology for Location Service Applications, Metrology and Measurement Systems, vol. XIX, no. 2

[28] P. Korbel, P. Wawrzyniak, P. Pątek, J. Legierski, NMR Recorder- narzędzie do gromadzenia informacji pomiarowych z terminala komórkowego, KKRRIT 2012, Przegląd Telekomunikacyjny 4/2012

[29] B. Zacharuk, A. Tylman, P. Pątek, S. Grabowski J. Legierski, NMR API – nowy interfejs programistyczny w modelu Telco 2.0 i propozycje jego zastosowań, KKRRiT 2012, Przegląd Telekomunikacyjny 4/2012

[30] Geolocation API http://www.w3.org/TR/geolocation-API/ [7.11.2012]