Univ Access Inf Soc
DOI 10.1007/s10209-013-0318-z

LONG PAPER

# SOSPhone: a mobile application for emergency calls

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**Abstract** The general adoption of mobile devices and its wide network coverage made it possible to make emergency calls virtually everywhere, even in the absence of a valid contact. However, there is still generally the need for audio connection.This restriction is a problem for deaf people, but also for the elderly and people without disabilities who face sudden situations where speech is hard to articulate. In this context, this paper presents SOSPhone, a prototype of a mobile application that was developed to enable users to make emergency calls using an iconographic touch interface running in a touchscreen mobile device. The prototype implements the client-side of the application and was demonstrated and evaluated by a large number of users, including people without any disability, emergency services' professionals and deaf people. This paper describes the SOSPhone prototype and presents the results of the interface evaluation process, which is important to validate the main client-side interaction and architectural principles in order to proceed with the integration with each specific national emergency services' platform.

**Keywords** Mobile accessibility · Emergency call · Iconographic interface · Short message service · Deaf · Elderly · Panic situations

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## 1 Introduction

The proliferation of mobile devices in the last two decades broadened the possibilities for building mobile applications that support the users efficiently in several daily activities. A situation that benefited the overall population was the higher availability of emergency calls, since it became available on any mobile phone. However, it is still hard for some people to make an emergency call because of disabilities or trauma situations. One obvious case is that of deaf people, who are unable to communicate through a voice call. Other examples include elderly people with some disease or sudden critical situation that makes it difficult to articulate words (such as riots, hostages, smoke inhalation or any vocal disease), or even the case of shock/panic situations under violent occurrences.

According to the World Report on Disability 2011 [32], the number of disabled people in the world is presently estimated as one billion, corresponding approximately to 15 % of the current world's population. The preface of this report states that *"[...] people with disabilities experience barriers in accessing services that many of us have long taken for granted [...]"*. The same report indicates that 124.2 million people in the world have hearing loss, corresponding to about 2 % of the world's population, approximately half of them with age above 60 years old.

In Portugal, according to the 2001 census, there were more than 636,000 disabled people, including over 84,000 with hearing impairments.[1] Furthermore, in both Portugal and worldwide, there is a higher degree of illiteracy among people with hearing impairments.

This paper presents a mobile application that enables making emergency calls without requiring audio

[1] http://www.pordata.pt.

Published online: 22 September 2013

capabilities. This application offers to the user an iconographic touch interface that enables him to contact the emergency center by selecting the icons that represent the occurrence being reported, as well as clicking a few boxes to answer simple questions such as the number of victims in the incident. The result of this selection process is an SMS message that is sent to the emergency center containing the codes corresponding to the information selected, along with the user profile and coordinates of the caller. The prototype described herein refers only to the client-side architectural and interface aspects, since the implementation of the server-side is highly dependent on the specific information system used to manage the emergency service.

The remaining of this paper proceeds exploring some background concepts of the field and then presents the main considerations that lead to the implementation of the application, which is described in Sect. 5. Section 6 presents some results produced by a set of user experiments that were carried out to test the application, and Section 7 concludes with some final remarks.

## 2 Background

Emergency can be defined as a sudden or unpredicted situation with risk to health, life, property or environment that requires action to correct or to protect. In most countries, there are services associated with each of the identified risks in order to respond to each kind of emergency, usually firefighters, police and medical emergency. To trigger the necessary means to help in an emergency situation, it is required that: (1) the emergency situation is reported to the authorities and (2) there is a service capable of receiving the request and ensuring the allocation of the necessary resources for assistance. Concerning an effective response, and the aggregation of services in a public-safety answering point (PSAP), worldwide nations have created official emergency numbers for improving emergency response in accordance with citizens requirements.

In Europe, the single European emergency call number 112 has been introduced by the Council Decision of 29 July 1991 (91/396/EEC). The European Emergency Number Association (EENA[2]) was created in 1999 to promote emergency services reached by the number 112 throughout the European Union, acting as a discussion and interconnection forum of about 600 emergency services' representatives from 42 European countries. In the United States, the Federal Communications Commission (FCC) is responsible since 1999 for the official and universal emergency call number for all telephone services: 9-1-1.[3]

In recent years, emergency call numbers have dealt with several problems mainly due to the effectiveness and reliability of the systems. The problems can be divided into two major groups: (1) telecom access and (2) emergency services. Regarding telecom access, there was a need to ensure the access of users from different operators without any contact restrictions. Moreover, calls need to be routed to PSAP and include meta-information such as the caller ID or the terminal ID and, if possible, geo-location information. These challenges require the cooperation of telecoms, emergency response organizations and PSAPs in order to ensure a coordinated management of the infrastructure. At the emergency services' level, the major problems are related with false calls and its detection. Other problems are concerned with the aggregation of all emergency domains in a single PSAP, requiring an operation model appropriated for the management of the different services in the emergency chain.

In order to fulfill some of these requirements, emergency services' providers have introduced enhanced versions of the systems that provide dispatchers with additional information, such as the caller identification number and the location of the mobile device. Moreover, the developments in mobile and IP communications have introduced new challenges in emergency services. Nowadays, the new generation of emergency call numbers (NG9-1-1 and NG112) is being discussed as a long-term solution, in order to ensure total communication. FCC defines the Next Generation 9-1-1 Initiative as a "research and development project to help define the system architecture and develop a transition plan to establish a digital, Internet Protocol (IP)-based foundation for the delivery of multimedia 9-1-1 calls". The NG112 has similar aims, intending to make emergency services more interoperable using Next Generation Networks by establishing requirements for accessing emergency services via a whole range of IP communications.

For both, the expectation is that NG emergency services would enable the usage of a wide range of new technologies in common use today— such as laptops, IP phones, IP wireless devices, short message service (SMS), and IP and video relay services (VRS)—identify the location of a call and recognize the technology generating it in order to route the call to the appropriate responder in a timely manner.

Despite the challenges of new technologies for emergency services, there still exists a common problem in emergency services: access for all. The Universal Declaration of Human Rights [31] and further legislation define that *"we all want to live in communities where we can*

[2] http://www.eena.org/.

[3] http://www.fcc.gov/911.

*participate fully and equally"*. However, in practice, people with special needs find access barriers to assert their rights in their everyday life. Universal access for emergency services is a right of all citizens. Authorities are aware of that, and currently, as emergency services are not accessible to the majority of disabled people, they are developing efforts to find a short-term solution for this problem. US authorities established the Emergency Access Advisory Committee (EAAC) with the mission of making *"recommendations to the FCC regarding policies and practices for the purpose of achieving equal access to emergency services by individuals with disabilities"*.[4]

The European Commission also realized that the emergency call number 112 is currently not accessible to the majority of disabled people and only 7 countries were reported to have implemented an accessible 112 for people with disabilities in order to accomplish the Universal Service Directive of 2009. Moreover, the EENA established a committee to make recommendations on 112 Accessibility for People with Disabilities. The first results were announced in reports and recommendations released in January 2012 [7, 29].

From a technological perspective, creating a universal access emergency system is a challenge for the research community. Therefore, the emergency services' accessibility has been subject of a myriad of studies and projects. In the next section, the current and future solutions for the accessibility of emergency services are explored from different perspectives.

## 3 Related work

Universal access is a need for emergency services, as is evident from the efforts undertaken in recent years. It is also a challenge to which the scientific community participates on several levels.

In a broad perspective, Kyng et al. [20] identify the challenges in designing interactive systems for emergency response, arguing that *"the dynamic changes in the situation [...] makes it extremely difficult for anyone to obtain and maintain a situational overview, both on superior and specific levels"*. Given the specific nature of the emergency services' accessibility, and the efforts that have been carried out, several aspects must be taken into account when implementing a solution [29]: speed; reliability; mobility; availability; cost; relay services; and level of provision for necessary functional requirements at PSAPs.

A key aspect to be considered is the communication channels to be used by emergency services, alternatively to traditional voice channels. The accessibility of communications has been the subject of debate and reflection for several times, by national and international organizations [8, 9], according to international guidelines (Directive 2002/22/EC of 7th March 2002 on Universal Service and Users Rights relating to Electronic Communications Networks and Services). These discussions to define the steps toward making telecommunications accessible for all have lead to some recommendations for telecoms and emergency services regarding phone services, features of fixed line phones and mobile phones; broadband internet services; and billing services [9].

In a 2012 study [29], EENA compares some technological solutions to nonverbal communication with emergency services, namely fax, location-based solutions (LBS), chat service, SMS to 112 and relay services. The study focused on speed, reliability, mobility, spreadability and cost of the solutions. The conclusions revealed that the fax is the slowest and worst solution; LBS and chat have benefits considering the speed and reliability; and SMS is less effective due to speed issues and limited as some users have restrictions to express through written language, although it is relatively widely used and the most balanced solution.

The usage of emergency systems by deaf citizens has been explored in other perspectives and using different types of technologies. Zafrulla et al. [33] propose the usage of a TTY phone for access to emergency services by deaf people. In addition, other studies suggest the use of SMS and TTY as preferential mechanisms by deaf users to communicate. Concerning the preferences of deaf people in the United Kingdom, Pilling and Barrett [27] concluded in their study that participants used several forms of text communication, including SMS, TTY, voice/TTY relay services, fax and e-mail, selecting them for particular purposes. Moreover, Mueller [24] concluded that the participants in his study preferred text-only message or the video assembled from modular segments, depicting a continuous sign language video. Despite this, other projects focus on interpreter services, for mediating the communication in emergencies, as in [6]. Furthermore, in a recent study, Flynn et al. [12] evaluated the emergency communication effectiveness for deaf in several countries. In this study, they realize that the most common form of communication was SMS messages, with exception of Spain and Greece that use a prototype of the REACH112 system. Complementary, and focussing only on the United States, Mitchell et al. [23] present the development of a prototype for mobile phone-based emergency based on regulatory parameters for existing and new alert systems.

The use of SMS is also a widely explored mechanism for dissemination of information to deaf people. The dissemination of information has a particular interest in the

[4] http://www.fcc.gov/encyclopedia/emergency-access-advisory-committee-eaac.

context of emergency and disaster situations, where a unified communication channel is created, to which users are adapted and acquainted with its use. The usage of this mechanism is explored in [11, 18, 22, 30].

However, there are many operational problems concerning the usage of SMS communication technology, as claimed by Song et al. [28]. The authors propose a solution for the integration of SMS and IM in the next generation of emergency services, an IP/SIP-based emergency communications system. The major contributions of this work rely on the communication infrastructure, in particular in the reliability of SMS messaging, message fragmentation and location conveyance.

Other key requirements of universal access emergency systems are mobility, location and availability. Mobile phones are key components of the emergency chain, and their accessibility should also be taken into consideration in order to provide an universal access service. Regarding the most challenging group in emergency accessibility, deaf citizens, and concerning the usage of mobile phones, Liu et al. [21] argue that *"deaf individuals experience difficulties using existing functions on mobile phones"*. The authors propose a multifunctional approach for the development of mobile phone interfaces as an assistive platform to improve the living quality of deaf individuals, which was implemented in a conceptual prototype: the PeacePHONE [21]. On a different approach, Castro et al. [4] evaluate the problem from a geriatric perspective, using a mobile application for in-home elderly care in order to assist nurses in attending emergency calls from elders.

The usage of mobile applications for generic accessible communication is being used in Spain by Telesor.[5] The company developed an application for *"accessible communication for all"*, which is available in Android Market and Apple AppStore, that enables real-time communication through a mediation service for deaf and hard of hearing people. The service is aimed for use by public institutions and businesses to ensure customer support for people with special needs.

Especially driven for help requests, the Red Panic Button application,[6] available for Android and iOS, ensures its users with a mechanism for sending emergency alerts using SMS, email or social networks. The Android application allows the integration with system accessibility services (TalkBack, KickBack and SoundBack) and provides the ability to establish a communication channel after the emergency request is performed. However, the application does not allow the description of the emergency situation and does not have any mechanism that enables the detection of false requests. Moreover, the application can be used without any kind of registration or restriction. Within this scope, the ubilert project (Ubiquous Alert[7]), which exploits mobile technologies to allow a simple and effective way of asking for help in an emergency (health, civil, criminal), should be highlighted. However, this solution has the same problems as the previously presented Red Panic Button.

Research on the universal access to emergency services using mobile applications has also been a hot topic. Buttussi et al. [3] proposes a mobile system to deal with the communication barrier between emergency medical responders and deaf people, enhancing the communication by the transaction of a collection of emergency-related sentences to sign language [3]. The usage of sign language is also explored in the solution proposed by Nakazono et al. [25]. The authors developed the VUTE 2009 prototype, which can be used to call an ambulance and/or fire engine in an emergency using motion pictograms that incorporate the expressive manner of sign language.

Regarding the interaction with mobile devices, some authors point out that the usage of alternate input methods, based on pictograms and/or icons, can enhance the usability of the applications by users with special needs. Bhattacharya and Basu [1] have developed a novel user–computer interaction model to facilitate interaction by a suitably designed interface. The system is based on the selection of icons from the interface in order to construct a sequence of root words that is converted into a grammatically correct sentence by the system. The authors claim that *"The system has been found to be very useful, and the responses have been very encouraging"*. Further experiments using icon/pictogram-based interfaces have been used in emergency situation as [16, 17], where the authors explore the usage of an electronic pad device version of the SOS card to assist communications between rescue staffs and hearing impaired patients, by pointing pictures with texts on the cards using a finger.

From a broader perspective, many research projects have focused on the accessibility of emergency services. In 2003, the Wireless Information Services for Deaf People on the Move (WISDOM) project [15] aimed the creation of a solution to the needs of deaf people for interaction and for visual information.

More recently, many European countries have led pilot experiments in emergency services' accessibility, specifically targeted at deaf and hard of hearing citizens. This is considered a major challenge since current systems, on PSAP level, are predominantly voice-centric. Thus, these people need alternative communication channels to the emergency services as their disability limits their communication options. Among the ongoing experiments, the cases of England and Iceland stand out, which rely on the

[5] http://www.telesor.es.

[6] http://www.redpanicbutton.com.

[7] http://ubilert.pt.to.

use of SMS to communicate emergency situations, as well as France whose pilot uses the concept of *deaf 112 operator* [29]. Meanwhile, from those short-term proposals presented in the EAAC report [7], the highlighted options rely on the following: Central All-Text Router/Relay for Emergency Mobile Text Calls (CAT); SMS; SMS to TTY Calls.

Regarding NG emergency services, universal access is a major issue. EENA is participating in three European projects to evolve the European emergency system: CHORIST[8] aiming to find solutions to increase rapidity and effectiveness of interventions [19]; HeERO[9] that addresses the pan-European in-vehicle emergency call service; and REACH112[10] with the goal of implementing *"an accessible alternative to traditional voice telephony suitable for all"*. Moreover, other projects also aim to contribute with proposals for universal access to emergency services in the long-term. The ACCESSIBLE project aims *"to provide an integrated simulation assessment environment for supporting the production of accessible software applications mobile or not"* [5]. The ubiquitous IP centric Government & Enterprise Next Generation Networks Vision 2010 (U-2010) is another European project with the aim of providing the most capable means of communication and the most effective access to information for anybody required to act in case of accident, incident, catastrophe or crisis, while using existing or future telecommunication infrastructures [13]. The PEACE project intends to use IP multimedia subsystem (IMS) in order to provide a general emergency management framework for extreme emergency situations [2].

In spite of the presented solutions and the in-development projects, there is still a lack of an effective and reliable way for people with special needs to contact emergency services. In the following sections, an alternative approach is proposed, based on a mobile application.

## 4 Analysis

Currently existing accessible solutions to place emergency calls, as previously presented, are based on text communication, both synchronous and asynchronous; video communication; and/or mobile applications.

The usage of a text-based communication solution has as main drawback on the fact that the mother tongue of many deaf citizens is sign language, and consequently, some of them are illiterate. Moreover, most of asynchronous text-based communication proposes fall back on SMS messages that make the use of emergency systems slow, since they are held through several exchanges of messages to explain the situation to PSAP. Technologically, synchronous text-based communication solutions are usually based on TTY or instant messaging, which represent a better alternative than SMS messages. However, they still require a high volume of message exchange to describe the emergency situation and may require data network access.

The disadvantage of video communication solutions using sign language for emergency calls is that it requires a permanent sign language interpreter in the PSAP or the usage of mediation services. Furthermore, it needs the availability of network bandwidth for video transmission. The previously presented studies [24] also point out that users prefer text-only messages or the video assembled from modular segments as communication technologies, to the detriment of the usage of continuous sign language video.

Most of the existing solutions employ the development of specific mobile applications for calling emergency services. In some cases, they include a predefined triage mechanism to enhance the response to the emergency request. However, most of them have text interfaces that, for the above reasons, restrict the use of the application. Moreover, current applications flaw on the description of the emergency situation and the establishment of a post-request bidirectional channel of communication.

Given the previously presented, one possible solution to ensure universal access to emergency services' involves an application for mobile devices, which can be tailored to other devices with communication abilities, geared to the requirements outlined. The application should combine some of the solutions put forward in a way to reach out users' needs and preferences, as well as the operational reality of the PSAPs. Since the current solutions are flawed at these levels and the need for a system that answers in short-term to the accessibility requirements of emergency services, the main goal of this work is the development of a mobile application that allows effective communication with the PSAPs: the SOSPhone. The research methodology followed the design science perspective [26], a common method for software engineering research, combined with specific HCI usability evaluation methodologies adapted to each interactive phase [10, 14].

The development process is summarized in Fig. 1. Three iterative evaluation phases were defined:

- Generic users evaluation phase;
- Users with special need evaluation phase;
- Operational evaluation phase.

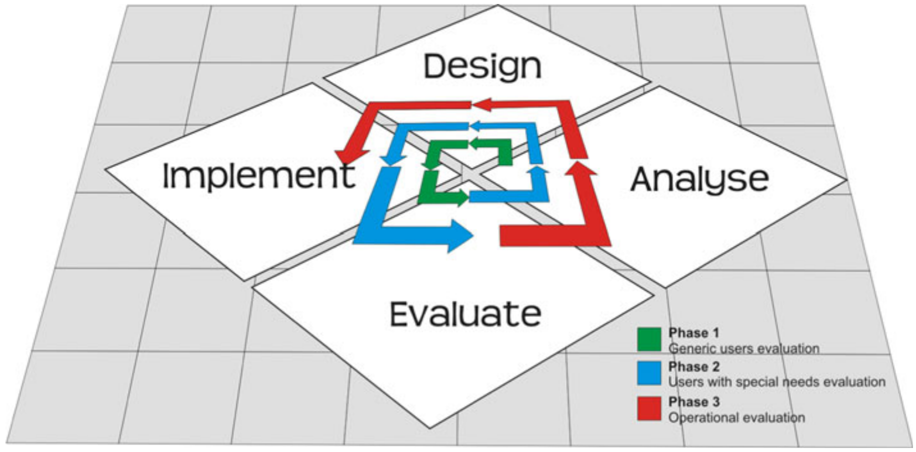
The definition of the phases took into account the objectives of evaluation in line with the specified requirements and the methodology. The different iterations have

[8] http://www.chorist.eu.

[9] http://www.heero-pilot.eu.

[10] http://www.reach112.eu.

Fig. 1 Development process




specific objectives, in a top-down approach, starting with the generic requirements and specializing them according to the needs of each identified group. A concrete accessible problem was selected: deaf citizens. Choosing a concrete problem allowed to gather the main requirements for the application and perform refinements and generalizations that could guide to a universal and accessible solution. These refinements were made according to the needs and possibilities of application usage by other citizens, such as people with restricted movement, the elderly and people without special needs, but in momentary panic. Moreover, usual problems associated with emergency calls systems, such as false calls and emergency location, were taken into consideration for the system requirements.

The strategy was then to begin by generic users, conducting a questionnaire for the evaluation of the solution. To supplement this approach, interviews with specific users were also carried out, in particular health professionals (doctors and nurses). The second phase of the process refined the generic evaluation by interviewing a group of deaf users in order to gauge their needs and the adequacy of the solution to their everyday life. The last phase involved taking into account operational requirements, having initiated contacts with the authorities and carrying out interviews with the leading authorities related to emergency services: firefighters (through Portuguese National Authority for Civil Protection—ANPC), police (responsible for serving 112 in Portugal) and medical emergency (Portuguese National Institute for Medical Emergency - INEM). The operational evaluation phase concerns the definition and evaluation of the mobile application that gathers the emergency situation information to the PSAP. The integration of the application with the existing PSAP systems requires specific requirement analysis, since in Europe, each PSAP uses a particular operational model, as described in [29]. The entire process was backed by deaf users who ensured the adequacy of the data collected by the specific needs of this group.

The first phase of the process started with the analysis of existing solutions for gathering the current state of the art in the domain and recording the requirements for an accessible mobile application for emergency calls. In this phase, the following generic requirements were identified:

- Iconographic interface (R1-1)—The user interface should avoid the usage of text in order to allow all users to access emergency service calls. The situations should be described by large and accessible icons with high contrast. Icons should be selected from reference symbology.[11]
- Touch screen input (R1-2)—The input of information should be easy for people with mobility problems.
- Embedded emergency flow protocol (R1-3)—The application should allow the user to describe the situation with the highest detail possible, following the usual emergency protocols used by emergency control centers in order to facilitate the integration with existing systems.
- Low bandwidth communication with the emergency control center (R1-4)—The usage of the network bandwidth should be reduced to allow faster communication of the emergency situation.
- Automatic location of the incident (implicit or explicit) (R1-5).
- User call identification (R1-6).
- Required user registration (R1-7)—Registration of users will complement the identification of the caller and provide further information to prevent false calls.

Concerning the development of the prototype, the application was required to be created in the shortest period of time, in order to allow the validation of the user interaction model and a thorough analysis of the solution in the following phases. A first version of the SOSPhone prototype was created with these requirements. The prototype

[11] http://www.fgdc.gov/HSWG/index.html.

was tested with group of users as described in Sect. 6. The following phase, the special needs users' evaluation phase, started with the analysis of the results of the generic user's evaluation. The main requirements collected were related to:

- Emergency flow (R2-1): The adaptation of the emergency flow should be supported in order to fulfill the evolution requirements of the emergency services and enable the introduction of new flows;
- Mobile platform (R2-2): The solution should be oriented to major mobile operating systems (respectively, SymbianOS, iOS and Android).[12]
- Interface and icon design (R2-3): The interface should be more attractive and follow each mobile operating system mechanisms. Moreover, the icons should have an accurate representation of each situation and include a textual label.

The design and implementation of the second prototype of the SOSPhone had major changes in order to include the requirements gathered from the users' evaluation. The evaluation of this prototype was performed by conducting interviews with deaf users in the International Day of the Deaf 2011. This evaluation is further detailed in Sect. 6.

As the results of the evaluation reveal a satisfaction of the users with the application and did not require many adaptations, the same prototype was used in order to evaluate the possible integration in the Portuguese emergency service.

As mentioned earlier, several meetings and interviews were carried out with the responsible for emergency services in Portugal, namely ANPC, police/112.pt and INEM. This evaluation phase, originally planned for phase 3, was included in phase 2. The analysis of the interviews and meetings allowed to include the following requirements:

- Activation of the application: Despite the registration of the user, the application should be activated in order to be used (R3-1);
- Bidirectional communication channel establishment between the user and the PSAP after the report of the emergency situation (R3-2);
- Definition of extra mechanisms to detect false call, based on automatic analysis of the description upon standard workflows (R3-3).

These requirements were included in the design and implementation of the last phase of the prototype that should be the basis for the production application that could be integrated in the short-term in the Portuguese emergency services. Moreover, this phase also revealed challenges in the infrastructure in order to support the integration with the SOSPhone prototype, which will not be covered in this paper. Among them, the following are worth mentioning: (1) the inclusion of location information by telecoms in the header of the SMS message; (2) the reliability of SMS as it relies on store-and-forward mechanisms; and (3) the ensurance of an automatic reply to the emergency request. Furthermore, the information gathered from the mobile application must be compliant with the emergency protocol used by the PSAP in order to be integrated with current information systems used by the operators. Thus, the information sent in the SMS message should be processed and supplied to the PSAP information systems, allowing total integration in order to ensure a unified interface for the operators, apart from the channel of communication used to send the emergency request (SMS, voice, etc).

In the following section, the details of the implementation of the prototypes are presented and discussed.

## 5 Application prototypes

The development of prototypes of the application served to make successive refinements of a solution for universal access to emergency services, and support for the several evaluations carried out. Following a spiral methodology, previously presented, three versions of the prototype were developed. The development process was associated with an analysis and the resulting evolution of application requirements.

Briefly, the implemented solution seeks to explore an interface that draws on icons for describing an emergency situation. The application flow is ruled by the protocol defined by the emergency services for emergency occurrence data collection. The communication between the caller and the PSAP is performed using one SMS message which is encoded throughout the description of the occurrence and includes location information provided by the device. Figure 2 shows some screenshots of the application in the various phases of the prototype.

The implementation of each version of the prototype had special features associated with the objectives of subsequent evaluations, so in the following subsections, some of the details of implementation and architectural design of the solution are presented and discussed.

### 5.1 Phase 1 prototype

The main goal of the generic users' evaluation phase was to evaluate the receptivity of group of users to the proposed solution. The presented requirements for this phase were evaluated in order to implement only the features related

[12] http://gs.statcounter.com/#mobile_os-ww-monthly-201202-201202-bar.


**Fig. 2** Mobile application prototypes: phase 1 (*left*), phase 2 (*center*), phase 3 (*right*)

with the user interface. This approach allowed a fast development of the prototype focusing on the evaluation process. Therefore, the developed application prototype included the implementation of all requirements and a partial implementation of the R1-3—embedded emergency flow protocol. The restrictions added to the implementation of R1-3 were introduced in order to simplify the emergency protocol and to embed it in the source code of the application without the perception of the user to this decision.

The technological option selected for the implementation was the Windows Phone 7 (WP7) platform, as it provides a basic set of hardware requirements that include assisted GPS, compass and capacitive, 4-point multi-touch screen. These requirements allow a direct implementation of requirements R1-2 and R1-4. Moreover, the choice of the WP7 platform for the development of the first prototype was concerned with the skills of the development team for rapid prototyping and the availability of mobile devices for the user experiments.

According to the requirements for the application, the iconographic interface (R1-1) was implemented using icons from reference symbology and taking into consideration the mobile web application best practices[13] and the essentials for cross-disability accessible cell phones.[14] The icons were grouped in several emergency situations according to occurrence severeness, so the display is not overloaded with too much information (Fig. 2), allowing an enhanced usage by people with low mobility.

Regarding the implementation of the embedded emergency flow protocol (R1-3), a simple example of a protocol was implemented, in order to allow the interaction with the application in a selected set of emergency situations. The implementation of the emergency protocol flow resorts to conditional switch-case structures.

In order to ensure low bandwidth communication with the emergency control center (R1-4), the prototype sends an SMS message. The message is limited to 160 characters and has 3 fields: emergency occurrence code; user data; and geographic information (Fig. 3). The emergency occurrence code is generated through the interaction process with the user describing the emergency situation. It is based on letters and digits that represent each selection of options (each interaction screen is limited to 10 options in order to allow multiple selection). The user registration data are included in the user data field, respectively name, age and social security number. When available through the embedded GPS, location information (R1-5) is also included in the SMS message, in the geographic information field, which is optional. The encoded message is sent to the PSAP SMS center that decodes its contents and processes the data in order to supply it to the operator through the PSAP information system as an usual new occurrence screen.

Finally, the user registration (R1-6, R1-7) is performed when the application is executed for the first time and is mandatory. Usually, a mobile phone is personal, so the registration data will only be gathered once. However, the registration data can be changed in the last step of the emergency call, before sending the SMS message.

### 5.2 Phase 2 prototype

Based on the methodology defined and on the requirements specified for the implementation of the prototype, two substantive decisions were taken at the beginning of this

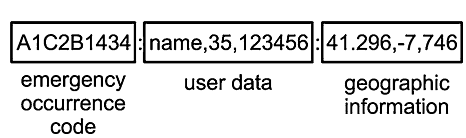



**Fig. 3** Structure of SOSPhone SMS message

13 http://www.w3.org/TR/mwabp/.

14 http://trace.wisc.edu/docs/2010-phone-essentials/index.php.

phase: (1) change of the prototype development platform; (2) redesign of the architecture of the solution reflecting all requirements and including the embedded emergency flow protocol (R1-3). Changing the development platform was decided due to two factors, one of which was a deciding factor: the accessibility of the WP7 platform.[15] The other factor is the market share of WP7 that currently is insignificant, when compared to Symbian, Android and iOS. This was reported by several users and reflected by the requirement R2-2. Thus, and taking into account the discontinuity in the development of the Symbian by Nokia,[16] the option should be on the Android or iOS platform. The choice rested on the Android platform given its potential growth, and the flexibility of integration with system solutions in the face of its iOS counterpart. In what concerns the redesign of the architecture, the rational for the decision was the need to reimplement the prototype for the Android platform and the requirement for including support for dynamic adaptation of emergency flow protocols (R1-3 and R2-1). The defined architecture has then as objectives the support requirements implemented in phase 1 and the inclusion of mechanisms that allow the definition of flows declaratively and dynamic, without changing the application source code. It is also a requirement that the architecture is flexible enough to allow the adaptation of flows using dynamic in-application updates via data networks (3G/Wi-Fi). To ensure those requirements, the application data are internally represented by the *lingua franca* for exchanging information—XML—allowing the on-application update of protocols using data networks. The emergency flow protocol is defined according to the XML schema shown in Fig. 4. Generally, a protocol is a set of states and transitions. The states may be a user interface, defined by an associated file, or an action described by a class, method and parameters. Transitions are a tuple (to, from) where the origin is an icon of the user interface and the destination is a state (interface or action). Moreover, transitions also include a transition code that is used for the encoding of the occurrence description.

In this phase of development, there was the need to redesign the interface and adapt the icons (R2-3) in order to ensure a more reliable representation of the situations that they meant to describe. The design evolution at the user interface level is discernible in Fig. 2. Moreover, the flows were also suited to the needs reported by users in the experiments and three types of emergency were introduced: panic—request immediate help; personal emergency—a situation that involves the person himself; and emergency with others—in which the individuals involved are people other than the user. Each of these situations has been associated with a specific flow, reflecting the data collecting need for each occurrence.

### 5.3 Phase 3 prototype

The last prototype was based on the version developed in the previous phase, including the amendments that result from the experiments reported through R3-X requirements.

The requirements identified required changes at the application start-up level in order to support the application activation by registered users (R3-1). Registration is a process that should be associated with the emergency services' infrastructure, maintaining a database with information of which users can use the application and their device ID/phone number. The activation solution is similar to that used in mobile banking applications that require sending an SMS within the application for registration and an authorization ticket is sent, which is then used in all communications between the application and the system. Thus, an initial interface was included, allowing users in the first use of the application to require its activation.

At the end of the interactive description of the occurrence, in the 'send SOS' user interface, support to the creation of a bidirectional channel of communication between the user and the PSAP was included, which is activated after transmission of the description of the situation (R3-2). This feature, known as *live chat*, is similar to an instant messaging service (in asynchronous mode), and its backend communication is provided by the exchange of SMS messages. The messages are limited to 160 characters in order to avoid fragmentation and therefore implementation of extra part mechanisms in the infrastructure of emergency services. The service interface is shown in Fig. 2.

Finally, and according to information received from emergency services, the type of emergency 'panic' was removed from the options. In addition, validation mechanisms for emergency requests were studied (R3-3). Therefore, the description of an occurrence could include contradictory information, and based on this information, the infrastructure of the emergency services, through preprocessing of the message, could establish a communication channel, in the cases where doubts concerning the veracity of the occurrence exist.

## 6 User experiments

In order to assess the users' receptivity to the application, and following the research methodology mentioned before, a set of user experiments were carried out in different

[15] http://www.afb.org/afbpress/pub.asp?DocID=aw110802&select=1#1.

[16] http://www.developer.nokia.com/Community/Blogs/blog/nokia-developer-news/2011/03/25/open-letter-to-developer-community.

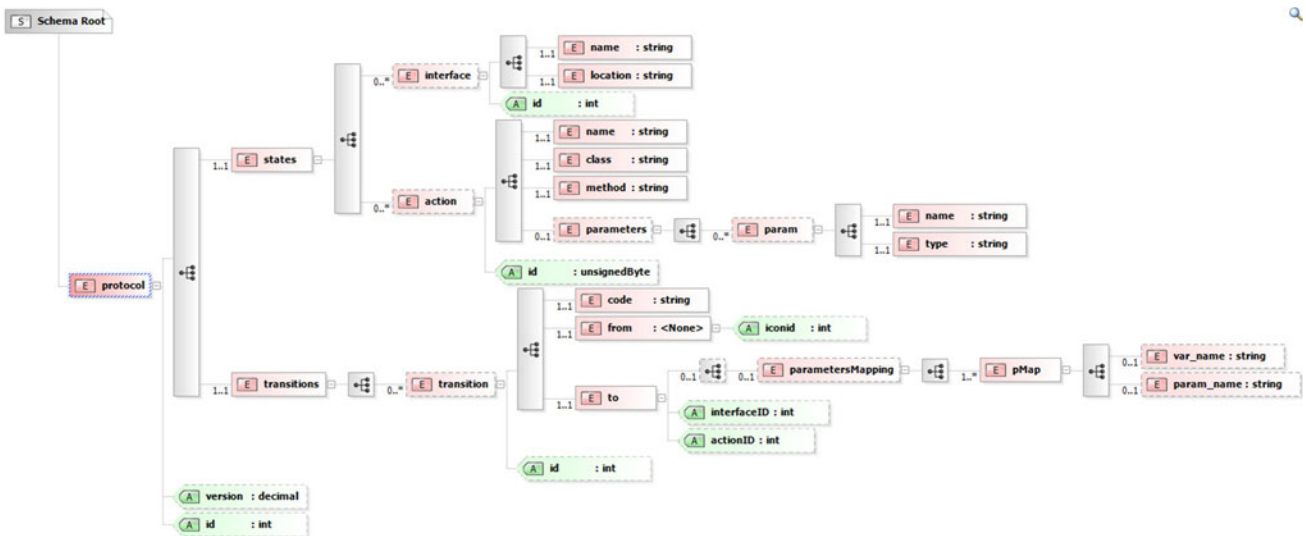



**Fig. 4** Emergency flow protocol XML schema

situations with potentially different types of users. For this purpose, 4 groups were selected:

- G1—academic users (students and staff): this was the first group of 30 users, that served as beta testers;
- G2—shopping mall passersby: this was a more heterogeneous group of 70 users, which offered the opportunity to test the application with more people and with several conditions—without any disability, disabled or elder people;
- G3—health services' professionals: the users were an undefined number of hospital doctors and nurses and an emergency team;
- G4—deaf association: the users were deaf people and thus potential recipients of the application.

Those experiments with groups G1 and G2 (see Fig. 5), that fit in Phase 1 of the evaluation process, yielded a total of 198 records of simulated emergency situations that allowed 100 distinct users to try the SOSPhone application. These records contain information about the time necessary to complete the emergency request, as well as the success level of the experiment (correct identification of the emergency situation). The overall statistics indicate a 37.4 % of unsuccessful experiments, which were mainly due to difficulties in identifying the situation through the icons, as can be seen in the more detailed results that will be presented further in this section. Moreover, the average time necessary to complete the call was 51 s, with a minimum of 10 s and a maximum of 3 min. These values are just indicative, as the real flow of questions to be presented to the user in a production environment is slightly different from the one used in the prototype and can differ depending on the country in which the application is to be used. Nevertheless, these values indicate a short time for interacting successfully with the emergency authorities, which will allow a fast response.

**Fig. 5** G2 experiments

Experiments with group G3 were carried out during a period of one week in a hospital, as a supplement for Phase 1 of the evaluation process, in order to gather some information from the people that deal with medical emergency situations on a daily basis. During this stage, it was possible to present the SOSPhone to doctors and nurses of the Emergency Room (ER), who gave qualitative information about using the application and some advice on how to improve it. No quantitative information was recorded due to the busy context of the ER that required a more informal and unstructured approach to the collection of information, and subject to the rare moments of calm these professionals have. Nevertheless, it was possible to collect important impressions from them, among which the most significant are:

- Include consciousness status in every situation
- Indicate the victims' breathing status
- In case of wounds and fractures, indicate whether victim has fever
- In case of strokes, indicate whether the victim is able to speak
- In case of fall, indicate its cause
- For mild cases, include indication for going to an ER instead of requesting an ambulance
- Include an icon symbolizing shortness of breath
- Allow defining a meeting point or describing a reference point, when location information is not present or is not enough detailed.

The experiments with group G4 (Fig. 6), constituting a preliminary Phase 2 evaluation, were carried out during the celebration of the International Day of the Deaf 2011, organized by the Portuguese Federation of Deaf Associations, and that had about 500 participants. The celebration nature of this event, which occurred mainly as a march followed by a lunch in a city park, the high number of participants and the nonverbal communication required, made it hard to collect structured data, which could be easily erroneous. However, the impressions collected from the deaf users, with the aid of a sign language interpreter, were very enthusiastic, with the application being unanimously considered as extremely useful and with the deaf showing interest in acquiring it immediately, even if they had to buy a new cell phone for this purpose. Indeed, this shows how much this solution is valuable for the deaf, even as a prototype still requiring some improvements. Nevertheless, the prototype was a new version, with new icons and some changes reflecting the information collected with groups G1, G2 and G3. At the time of writing of this paper, the authors are planning further experiments with a group of deaf people, this time in a controlled environment that allows the structured collection of quantitative and qualitative data.

**Fig. 6** G4 experiments. Frame taken from video available in SOSPhone Facebook—http://www.facebook.com/SOSPhone

### 6.1 Academic users (G1)

The users' experiments with group G1 consisted of using the application in four hypothetical scenarios (described textually) that tried to incorporate different emergency situations and the associated selections that must be carried out in the application, resulting in a message being sent to a simulated emergency center:

- S1: one boy and one girl presenting serious disturbances resulting from excess of alcohol;
- S2: one person with sudden shortness of breath, chest pain and rapid heartbeat;
- S3: a mid-aged person with sudden faint;
- S1R: repetition of S1, because in the first time the users were still adapting to the interface and thus this repetition would assess the same scenario in a situation where the user was already more used with the application.

During the tests, the users answered a small questionnaire asking simple questions about how easy they found the application to use, scoring its overall perception of the quality of the application and optionally giving suggestions for improvement. The person in charge of conducting the tests also annotated the time required to complete every scenario and the correctness in completing the task. The G1 test was conducted with 30 users with ages ranging from 18 to 62 years old, in which they completed 117 emergency requests (one user completed only S1), and the results are summarized in Table 1.

The analysis of the results reveals that in scenarios S1 and S1R (repetition of S1), it was hard for the users to identify the intoxication icon with an alcoholic problem. This is an important result that will enable to modify the iconographic language to make it more intuitive. For scenarios S2 and S3, the results were very similar, with the majority of the users being able to complete the call successfully. The average time spent to complete the call was higher in the first scenario, which is due to the impact of first use, but then it decreased to about half that time in subsequent scenarios, even in the repetition one (S1R). Not surprisingly, the maximum time required to complete the task was 3 min in scenario S1, and the minimum was just 15 s in S1R.

Regarding the qualitative assessment of the applications by the users, they were asked to classify it as "Very Bad", "Bad", "Reasonable", "Good" or "Very Good". From the 30 respondents of the questionnaire, 17 considered it as "Very Good", 12 as "Good" and 1 as "Reasonable". This is a promising result that can be improved with the corrections that can be made with the collected feedback. The users were also asked to give suggestions on how to improve the application. Of these suggestions, 3 are

**Table 1** Summary of results for G1 group

| Scenario | S1 | S2 | S3 | S1R |
|---|---|---|---|---|
| Number of calls completed correctly | 7 (35 %) | 25 (86.2 %) | 24 (82.8 %) | 12 (41.4 %) |
| Average time to complete the call (min:sec) | 1:33 | 0:45 | 0:40 | 0:45 |

considered important: change the intoxication icon to include clearly the situation of excess of alcohol; identify whether the victim is the phone owner; and identify whether there is any bleeding.

### 6.2 Passersby in a shopping mall (G2)

For the group G2, a total of 6 scenarios were adopted, without the repeated S1R, as it was preferred not to request the attention of passers-by. It was decided to present a random situation to each person. The scenarios were small movies performed by actresses that were being exhibited in loop in a video display. The 3 scenarios were the same as for from G1, while the others were as follows:

- S4: two people suffer a running over accident;
- S5: a person with cramps, shortness of breath and nausea shortly after a meal;
- S6: in a cafe, an extremely hot pot of water fell on the skin.

The passers-by who agreed to make the test were asked to identify the problem that they were watching in the video display and request emergency assistance accordingly. The users were also asked to answer simple questions about how easy they found the application to use, scoring its overall perception of the quality of the application and optionally giving suggestions for improvement. The time required to complete the task and the correctness in completing it were also recorded. There were a total of 70 users who tested 81 situations, because a few users wanted to try more than once. The results are summarized in Table 2.

Once again, scenario S1 obtained a poor performance in terms of correctness. Scenario S3 has also shown a high percentage of incorrect identifications, which did not occur with group G1. This difference can be explained by the fact that in G1, the scenario was concisely described, while in G2, the acting introduced contextual elements that might have confused the users—because the faint occurred in a bar it was sometimes confused with alcohol intoxication. The other four scenarios achieved better results.

The video that was passing in the display included a short demonstrations of the usage of the application. The purpose of these short demonstrations was to provide the users with a sight on how to use the application, since it was not possible to have preliminary training sessions and the prototype still did not embed any tutorial. This option seems to have influenced the results in terms of the time required to complete the requests, because the average time is similar in all scenarios and improved comparatively to group G1. This average time is less than a minute in all scenarios, which is also a promising result. The minimum time was just 10 s (curiously in the S3 scenario) and the maximum was 2 min and 5 s.

## 7 Conclusions and future work

This paper presented a prototype of a mobile application, named SOSPhone, that enables making emergency calls without audio communication, by selecting icons in a touchscreen mobile device. This application has the potential to be particularly important for deaf and elder people, as well as in situations of panic or some other sudden incident that makes it difficult to articulate speech.

The development process, following a design science approach, included 3 evaluation phases that gathered information on the usage of the application by more than 100 users. These evaluation phases included quantitative tests with over 100 beta testers that enabled collecting preliminary information that was important for refining the application, and also proved the validity of the presented approach, which is seen as very promising by all users. Qualitative information was also collected through interviews with health professionals, emergency and security services, civil protection and deaf people, informing the development process to accommodate adequately all emergency situations, maintaining at least the same level of service that is possible to regular users of emergency phone calls. Presently, quantitative tests with a large number of deaf users are being planned with a deaf association, in

**Table 2** Summary of results for G2 group

| Scenario | S1 | S2 | S3 | S4 | S5 | S6 |
|---|---|---|---|---|---|---|
| Number of calls completed correctly | 5 (31.3 %) | 5 (71.4 %) | 6 (50 %) | 13 (100 %) | 15 (75 %) | 12 (92.3 %) |
| Average time to complete the call (min:sec) | 0:47 | 0:51 | 0:43 | 0:38 | 0:50 | 0:41 |

order to have additional feedback from the users that can benefit more from the SOSPhone application. Another important issue is the availability of the application for the major mobile OS platforms (currently, it is implemented for Windows Phones and Android-based mobile devices, but it is also planned for iPhone, Blackberry and Symbian platforms).

The prototype was implemented with the aim of proving the validity of this approach to accessibility in emergency calls. Currently, the application is being redesigned to incorporate operational requirements for its integration with the Portuguese emergency services. Further extensive tests will be needed to validate the application in a production scenario, which includes testing thoroughly the recognizability of all the icons in the interface. Several suggestions received from various sources are also being accommodated, such as the inclusion of a tutorial video before the activation of the application, to familiarize users with the available features and required interactivity.

**Acknowledgments** The authors of this paper would like to thank David Fonseca, a deaf engineer who was an enthusiastic user and provided important help in defining some of the application requirements and validating the presented approach from a deaf perspective. Also crucial was the contribution of several entities, by facilitating visits to emergency control centers and interviews with several professionals: the 112.pt South Emergency Control Center ("Centro Operacional Sul do serviço 112.pt"), the Portuguese National Institute for Medical Emergency (INEM—"Instituto Nacional de Emergência Médica"), the Vila Real Commander of the Portuguese National Authority for Civil Protection (ANPC—"Autoridade Nacional de Proteção Civil") and the Emergency Room professionals of the Vila Real Hospital (CHTMAD—"Centro Hospitalar de Trás-os-Montes e Alto Douro").

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