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EmergenSIG: An Integrated Location-based System for Emergency Management

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Abstract

Several solutions have been proposed for emergencies scenarios. These solutions include real-time data communication, location-aware, coordination, and decision-making support systems. In this context, this dissertation presents a location-awareness system fully oriented to emergency scenarios, called EmergenSIG. This approach provides and gathers important field information from an occurrence (emergency situation) and shares it to all the different agents. They include police, firefighters, medical emergency teams, among others, mobilized to the same operations theater (OT). Therefore, allowing a faster and integrated response to all the involved agents, enhancing the emergency management of the occurrence. The core of this proposal is based on a low cost solution oriented to the agents on the field (EmergenSIG mobile application), which interacts with the EmergenSIG Web application, oriented to the civil protection entities, through REST Web services. EmergenSIG focuses on medical emergencies and wildfires. It was evaluated and demonstrated in different mobile devices considering different screen sizes following a user-centered design. The system was also been evaluated and validated by real entities and civil protection agents on simulated emergency scenarios.

Keywords

Emergency Support, Mobile collaborative application, Real time communication, Mobile Computing, Real time Geo-location Based, Mobile Health, Agent Based application.

Resumo

Várias soluções têm sido propostas para cenários de emergências médicas . Estas soluções incluem comunicações de dados em tempo real ,sensíveis á localização , coordenação e sistemas de apoio à tomada de decisão. Neste contexto, esta dissertação apresenta um sistema sensível à localização totalmente orientada para cenários de emergência, chamada EmergenSIG. Esta abordagem proporciona e reúne importantes informações de uma ocorrência (situação de emergência) compartilhando-a para todos os diferentes agentes. Nos quais se incluem a polícia, bombeiros, equipas de emergência médica, entre outros, que se mobilizaram para o mesmo teatro de operações (TO). Portanto, permite uma resposta mais rápida e integrada para todos os agentes envolvidos, aumentando a eficácia da gestão da emergência de uma ocorrência. O cerne desta proposta é baseada numa solução de baixo custo direcionada para os agentes no terreno (aplicação móvel EmergenSIG), que interage com o aplicativo Web EmergenSIG, orientada para as entidades da proteção civil, através de serviços Web REST. O EmergenSIG centra-se em emergências médicas e incêndios florestais. Foi avaliada e demonstrada em diferentes dispositivos móveis, considerando diferentes tamanhos de ecrã e seguindo um design centrado no utilizador. O sistema também foi avaliado e validado por entidades reais e agentes da proteção civil em cenários de emergência simulados.

Palavras Chave

Suporte à Emergência, Aplicação móvel colaborativa, Comunicação em tempo real, Computação móvel, Georreferenciação em tempo real, Tecnologias móveis para a saúde, Aplicação orientada a agentes

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Acronyms

AES	Advanced Encryption Standard
AJAX	Asynchronous JavaScript and XML
ANPC	Autoridade Nacional da Proteção Civil
DBAS	Database Administrator
DCRO	District Command of Relief Operations
EMS	Emergency Medical Systems
GCUP	Guidance Center of Urgent Patients
GIS	Geographic Information System
GPS	Global Positioning System
GUID	Globally Unique Identifier
GSM	Global System for Mobile Communications
HTML	Hypertext Markup Language
HTTP	Hypertext Transfer Protocol
HTTPS	HyperText Transfer Protocol Secure
IMEI	International Mobile Equipment Identify
INEM	Instituto Nacional de Emergência Médica
IP	Internet Protocol
IT	Information Technology
JAX-RS	Java API for RESTful Web Services
JSP	Java Server Pages
JSON	JavaScript Object Notation
JSR	Java Specification Request
LBS	Location Based Services
LCRO	Local Commander of Relief Operations
MERV	Medical Emergency Car and Resuscitation
MITA	Multimedia Information Technology and Applications
NCRO	National Command of Relief Operations
OT	Operations Theater
PHR	Personal Health Record

SIM	Subscriber Identify Module
SitPo	Situation Point
SQL	Structured Query Language
SOA	Service Oriented Architectures
UUID	Universally Unique Identifier
VLCI	Veiculo Ligeiro de Combate a Incêndios
VRCI	Veiculo Rural de Combate a Incêndios

1. Introduction

1.1 Focus

In Portugal, the base of the civil protection is typically based on Humanitarian Associations [1]. These associations takes the responsibility to handle firefighters departments supporting the corresponding costs, organize the response conditions, and prepare their capacity taking into account the different characteristics of the territory (urban, rural) under their responsibility.

Civil Protection is one of the activities of each state, autonomous regions, and local authorities, or by citizens and private entities in order to prevent collective risks inherent to serious accidents or disasters, to mitigate its effects, to protect and rescue people and properties in danger when those situations occur [2]. Civil Protection activity is permanent, multidisciplinary and multisectoral, fitting Public Administration agencies and departments to promote necessary conditions, in a decentralized way, without prejudicing support of mutual entities and agencies of the same level or from higher levels. The Civil Protection objectives include the following: *i)* prevent collective risks and serious accident occurrence or disaster result; *ii)* mitigate the risk and limit their collective effects; *iii)* help and assist people and other living things; *iv)* protect endangered cultural assets and values; *v)* environmental and high public interest; and *vi)* support people's normal life replacement in areas affected by serious accident or catastrophes [2]. In Portugal, the hierarchy of National Authority of Civil Protection (ANPC) (Figure 1) is led by a National Command of Relief Operations (NCRO). It has competences into operation coordination of the District Commands of Relief Operations (DCRO), which includes 18 centers, each one responsible for one district along the country

[3]. These entities are responsible to produce an initial plan to solve a given emergency that occurs in their respective district area effectively. If the evolution of the occurrence is favourable and, therefore, the consequences reach a superior level of concerns, the NCRO have the authority to manage the national resources (human and materials), to assist the district entities on its resolution. The DCRO is the entity responsible to inform and manage the respective Firefighters Departments Operations, which are triggered on their respective territory (District). In rare exceptions, the firefighters can went to an emergency without the pre order of a DCRO, and if this happen, the firefighters must warn the DCRO about all the emergency information available in an oportune moment.



Figure 1. Logo of National Authority of Civil Protection (ANPC).

The Portuguese National Institute of Medical Emergency (INEM), is one of the entities that composes the National Civil Protection (Figure 2). INEM is the agency of the Ministry of Health, responsible to coordinate the Integrated System of Medical Emergency (SIEM). SIEM includes a set of entities that cooperate with one goal: to provide assistance to victims of accident or sudden illness. These entities are Police, INEM, Firefighters Department, Red Cross, Portuguese Hospitals, and Health Centers. The SIEM management operations are triggered after call to the European Emergency Number - 112. The help request calls performed through 112, which is relate to emergencies or medical emergency, are transferred to the Guidance Center of Urgent Patients (GCUP). INEM has four operating GCUP located in Lisbon, Oporto, Coimbra, and Faro. GCUP should meet and

evaluate the requests for help received, in a shortest time, in order to determine the resources needed and appropriate for each case. GCUP coordinates and manages a set of assistance means (bikes, rescue ambulances, medical vehicles, and helicopters) following pre-determined criteria according to the clinical situation of victims, the proximity of the site of occurrence, and accessibility to the place of occurrence [4]. This service monitors the rescue teams on the ground through clinical information received.



Figure 2. INEM logo.

A Medical Emergency (Figure 3) is an activity in the area of health that encompasses everything that goes from the place where there is an emergency situation until getting definitive patient treatment. The concept of Pre-hospital Medical Emergency defines all the assistance provided outside a hospital environment, providing an adequate answer to an emergent situation. This response is diverse, ranging from a simple medical advice, remote guidance, or sending Medical Emergency teams to the patient location [5].

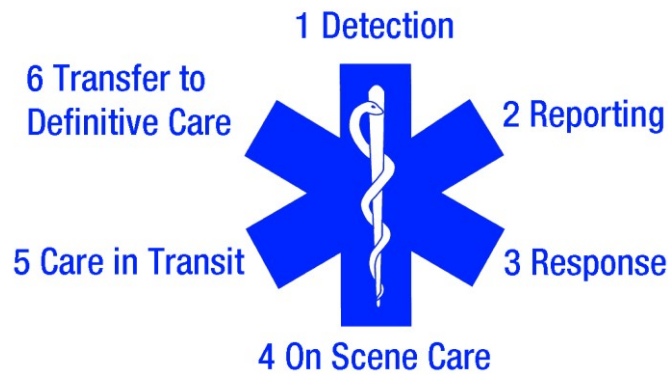


Figure 3. Illustration of the life star.

Most of the Portuguese firefighters departments provide pre-hospital care to citizens under the tutelage of the INEM (National Institute of Medical Emergency). This way, it provides health assistance at remote areas from a hospital. This type of assistance is identified by basic life support. In more serious situations, a Medical Emergency and Resuscitation Vehicle (MERV) is requested to assist with advance life support. This type of operations is handled by the corresponding Guidance Center of Urgent Patients (GCUP) of the region. In Portugal, there are four GCUP's, distributed in different regions along the country (Figure 4) [6].

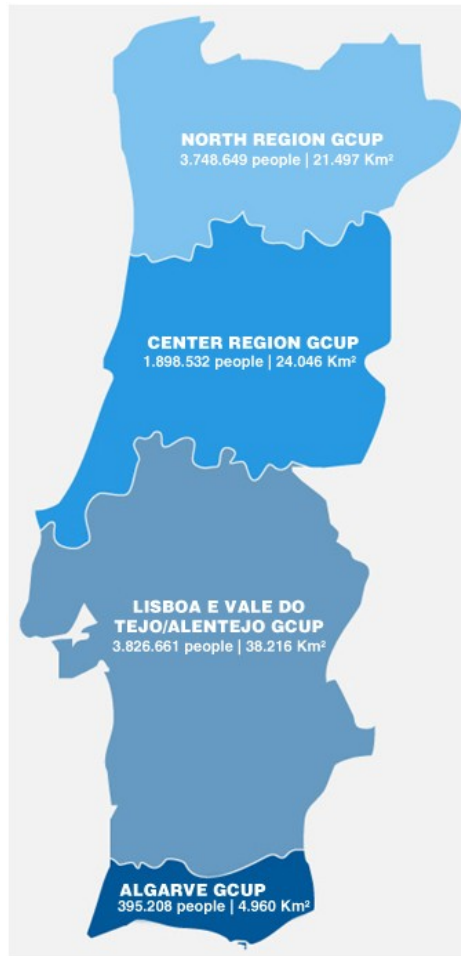


Figure 4. Regions under responsibility of the respective GCUP (4 regions).

The emergency response centers of National Protection Civil Operations include National Command Relief Operations (NCRO), District Command of Relief Operations (DCRO), and Guidance Center of Urgent Patients (GCUP). They promote an integrated response of Police Departments, Firefighters Departments and Hospitals. It is considered the agents as the police agents, firefighters, medical emergency teams, militaries, and civil protection staff agents. Usually, emergency scenarios include wildfires, urban fire, car accidents, sudden illness, etc. Portugal is a well-known country by the effectiveness of their civil protection, although it is well-known the agents increasingly requires a centralized system that enables the interconnection of different entities and forces to

stimulate the cooperation, real time coordination, efficiency, and smarter management in order to promote the efficiency of the emergency resolution. Till now, agents are not assisted by any common technological tool enabling them to have a more comprehensive knowledge of the real geographical extension of occurrence and its evolution according to the adopted emergency response. Therefore, the emergency response must be proactive, effective, and as fast as possible. It should use predefined methods to each type of catastrophe, crisis, or casual emergency scenario, such as wildfire, urban fire, car accident, floods, health emergency, etc. [7]. In terms of emergency management, the members of different emergency responders centers need to cooperate in order to reach a common solution.

Unfortunately, Portugal suffers a large number of wildfires triggered in summer time. Moreover, the amount of burned wild forest area, houses, and people belongings destroyed cause a large incoming to the country [8]. The main factors that increase the number of these occurrences are the weather, the type of combustibles available in forests, and geography [7, 9]. This kind of emergencies tend to consume large areas of forest, even if agents are deployed appropriately on site, but there are some issues that difficult the primary operations on emergency, such as the bad state of pathways to remote regions. Although agents mobilized from other district to assist the occurrence operations, usually do not know the geography of the occurrence location, leading to some delays in the response process. Furthermore, in the Portuguese territory there are dispersed clusters of people in rural areas, creating difficulties to the emergency response procedures, due to firefighters defined priority (defence endangered isolated people and their belongings). This situation, in large scale emergency events such Tavira wildfire (in 2012) [7], can lead to some negligence with sparse support conditions to agents on the field.

The majority of the firefighters agents are typically volunteers. This volunteering model denotes enormous fragilities, both in the associative

and operational components. It increases flaws, not only, at the level of the initial and on going training, but also in the context of the culture of the individual and collective safety [9]. Therefore, any solution guided to this type of agents must be user-friendly, providing quick actions, oriented to the respective agents and easy to use preventing additional costs of their training.

Currently, in medical emergency scenarios, firefighters call with mobile phone the respective GCUP in order to transmit the patient health condition, which leads several times to a significant time delay caused by the GCUP telephonic service. All the seconds during the transportation are important in cases such cerebral haemorrhage or commonly called by stroke, as is described in Moutinho, et al. [10]. It is also extremely important in cases such as heart arrests [11], which immediately requires advance life support on the hospital facilities or by MERV teams on defined place (patient location or place combined between the MERV staff and firefighters) [12]. Several technological tools have been developed to prevent this type of procedure. However, the tests in the field have shown poor results for I/Mobile application while Mobile clinic and Navigator INEM presented better results [13].

The continuous evolution of mobile technology and communications offer new possibilities to several emergent areas, such as, emergency management. Mobile devices and applications are now capable to promote a tactical effectiveness on several emergency operations scenarios. The use of mobile devices and applications can stimulate this cooperation, coordination, and communication among teams to achieve the common approach without a setback [14]. Although this type of applications must support the agents on the field, enabling them to make their own decisions and actions more quickly and effective. To achieve this criteria, it must exist reliable and real time information sharing between all the entities involved in the OT [7, 15, 16]. Then, this dissertation focuses on the organic of the civil protection and the relation between different civil

protection entities and agents, applied to Portugal that is very similar to other countries in Europe. The proposed solution is based on the information sharing between Entities and Agents in order to obtain filtered and gathered real-time information of an Emergency scenario, distributed to the different responsible and independent entities, including INEM and ANPC. In order to support this proposal, a collaborative tool for providing and collecting real-time data of field agents and sharing it among them (emergency responders teams) and their entities, called EmergenSIG, is proposed. It promotes cooperation in a plethora of incidents, such as wildfires, urban fires, medical emergency, and accidents. Moreover, it allows geo-locating, tracking, and gathering information about the incident evolution and statistic data collection that is extremely useful for agents mobilized to a specific emergency scenario. This application promotes the integration of different forces that guarantee the people protection and rescue, such as, medical emergency teams, police agents, and firefighters. Moreover, it also includes entities (Emergency responders centers) that are commonly involved on tactical support to field agents, such as, firefighters departments, DCRO's, GCUP's, and NCRO. The EmergenSIG framework is an agent based low-cost solution that focuses on data exchange effectiveness, real-time agents tracking, decision support, multiple-agent information sharing, and patient health data collection. EmergenSIG is described in detail. Furthermore, it is evaluated, demonstrated, and validated through experiments emulating real case scenarios with real agents. These agents participated in a survey to evaluate the usability and the performance of the proposed system.

Therefore, the solution presented must be useful, precise and provide a friendly user interface to help the multiple type of agents, taking primarily in consideration the level of anxiety [17] of the agents evolved in such type of operations and secondly the low resources available to training this agents and the capacity of the Humanitarian Associations to support expensive IT solutions.

1.2 Problem Definition and Objectives

Currently, in Portugal, there are no technological tools that inform the local commander of relief operations (LCRO) or other involved agents about the current state of the occurrence, its evolution, the involved entities and agents, routes to the emergency location or even real-time information. It can include information related to the current location of all the involved vehicles, about agent status or emergency situations points [7]. Currently, this problem is demonstrated in [18]. It describes this problematic based on a real situation where only few vehicles are geo-located in emergency response operations, which lead to a lack of location-aware in cases with an large number of involved agents. These technological solutions have been deployed on the key vehicles of INEM. However, many ambulances owned by firefighters department do not have these solutions leading some lack of information about the patients that are on the way to a hospital or even the estimated time for its arrival.

The main objective of this dissertation is the proposal and development of a integrated location-based system to handle, generate, and share the occurrence data of the OT, in almost real time. The OT data sharing is extremely important for all the entities and agents involved, in order to improve the emergency management in scenarios with a large number of agents involved.

To accomplish this main objective, the following intermediate objectives were identified:

An extensive analysis of the state of the art on ubiquitous computing and location based services (LBS), along with the necessary review of the most relevant and available mobile applications oriented to emergency response agents.

- The system requirements analysis in order to fetch all the system necessities and functionalities.
- The analysis, study, and design of the EmergenSIG framework architecture.
- Design and development of the EmergenSIG system mobile application and the corresponding Web portal.
- EmergenSIG system demonstration and validation through real users and a survey application to users assessing their quality of experience and usability.

1.3 Main Contributions

The dissertation presents fifth mainly contributions for the advance of the state of the art on wildfire emergencies and health/medical emergencies oriented solutions.

The first contribution of this thesis is a review of the related literature addressing ubiquitous computing, location-based systems for emergency management, and available mobile applications. This contribution is presented in chapter two.

The second contribution is an location-based emergency management solution. The proposal presents low-cost solution that focuses on data exchange effectiveness, real-time agents tracking, decision making support, multiple-agent information sharing, and centered-user designed. It focus an agent - entity support on the emergency response procedures. Described in chapter 4 and 5.

The third contribution consists in an integrated location-based system for medical emergencies. It presents solutions to the problematic lack of patient location and health condition knowledge, by hospital

urgencies staff during the patient transportation. It also focuses on the agents effectiveness on the initial emergency response procedures in the OT. This study entitled "EmergenSIG: An Integrated Location-based System for Medical Emergencies" was presented at the International Conference on Multimedia Information Technology and Applications (MITA 2013) July 2-6, 2013, Bali, Indonesia [19]. Presented in chapter 4 and 5.

The fourth contribution, includes in a solution oriented to wildfires emergency management. It provides a method to calculate an wildfire progression estimative for one hour of deflagration. Furthermore, it provides graphical information, to the entities and agents involved in OT operations. Presented in subsection 5.1 - EmergenSIG Mobile Application.

The fifth contribution, is proposed an method to record and provide to entities, the occurrence events history. It is designed to Web application interface. Presented in subsection 5.2 - EmergenSIG Web application

1.4 Dissertation Organization

This dissertation is organized in seven chapters. This chapter, the first, presents the context of the dissertation, focusing on the topic under study, defines the research problem and objectives, presents the main contributions, and ends with the dissertation structure.

Chapter 2 - Related Work - Presents an extensive review of the state of the art on Ubiquitous Computing and Location Based Services (LBS). Furthermore it also presents the most relevant and available mobile applications oriented to emergency response agents.

Chapter 3 - Requirements Analysis - This chapter presents all the requirements analysis for EmergenSIG.

Chapter 4 - EmergenSIG System Architecture - This chapter presents and describes the EmergenSIG System architecture, explaining the relation between agents and entities and the description of the most important system modules.

Chapter 5 - System Demonstration This chapter, demonstrates the design and the functionalities of the EmergenSIG Web application, EmergenSIG mobile application and public services.

Chapter 6- System validation - This chapter presents simulated cases scenarios with use of EmergenSIG system and its performance evaluation results.

Chapter 7 - Conclusions and Future Work - Concludes the dissertation and presents a few remarks for future work.

2. Related Work

This chapter elaborates on ubiquitous and location based emergency response approaches available in the related literature. It presents the most significant and available systems and applications regarding emergency management support system. Moreover, it compares the EmergenSIG proposal to the surveyed ones.

2.1 Ubiquitous Computing

Ubiquitous computing, describe a vision introduced by Marc Weiser's in early 90's on the scientific community. He presented a concept where the integration of computing and environment, with man-technology interaction with a total abstraction of the user, allowing the user, to access and process information anytime and anywhere [20]. However, Weiser vision had a major difficulty, taking to the account, the state of the technology in his time. Today, his vision is a reality. More and more, smaller devices with a large computing power are always connected to the Internet. The ubiquitous collaboration between mobile devices and webservices technologies, made the vision of Weiser's came true, allowing connection of powerful resources available on the Web, with the processing power on our hands, without the user need to have advance technical knowledge or know how it function [21]. During the past two decades, the number of developers has increased, in part due to the free and open source community, that has been developed high quality software. This high quality open-source software proved to be a serious rival to property software produced by commercial companies [22]. The advance on the potentially of the Mobile computing, allow more and more possibilities. Currently the use of Smartphone's is growing rapidly [23]. The rise of

smartphones such as Android and iPhone and others, allow the capability to process intensive activities such as multimedia playback, document editing, and audio/video streaming via dedicated coprocessors. However, mobile devices have different computing powers, human-machine interaction resources, general limitations of network, battery life cycles, and other specific topics. These are important constraints in mobile computing [24].

Regarding emergency scenarios, ubiquitous computing offered in the last decade several significant solutions. In [25] the authors presented a prototype implementation of a system, named SociCare. It's a ubiquitous context aware mobile community emergency system. SociCare was developed to help emergency call centers coordinate voluntary helpers nearby of the emergency situation. The ubiquitous computing is used to track real-time context information of certified voluntary helpers. In [26] Koufi *et. al*, proposed a Personal Health Records (PHR) system based on Emergency Medical Systems (EMS) at a cloud computing environment. The work focused on providing ubiquitous access to medical information and dealing with emergency cases. The system was developed over service-oriented architectures (SOA), facilitating interoperable services between distributed systems to order to exchange and get data. The advantages were focused in cloud computing in order to produce a flexible and scalable system, providing secure access to sensitive data. In [27] the authors proposed an architecture which includes several advanced applications such as live video streaming, voice-over-IP, location information, status, which require high bandwidth. The proposal is an architecture that can provide a common system in the case of emergencies by interconnections several heterogeneous multi-operator networks, through a wireless mesh network. They performed a test and measured the performance of a video streaming in a real metropolitan wireless mesh network, showing that it is possible to use high quality video transmissions.

2.2 Location Based Services

Smartphones are now equipped with a variety of sensors including inertial sensors (accelerometers and gyroscopes) and multiple position sensors (GPS, Wi-Fi, and cellular radios) that compose the location based services (LBS). These capabilities have made smartphones an attractive platform for mobile application development. Actual smartphones allows rapid developing mobile applications, which can process data from multiple sensors continuously, to determine user's context [28, 29]. Contemporary LBS also known as 'location-aware services', 'wireless location services', 'mobile location services, are related to the use of the Global Positioning System (GPS) and to information service applications such as Geographic Information System (GIS) [30]. The LBS integrate wireless technology, positioning technology, and location information management, which have a significant potential to improve existing public services such as emergency related ones. Nowadays, with mobile devices, is easier to have access to all range of contents regardless the location of the user. Location-aware situation reporting, and agents tracking are of great importance to manage any emergency scenario where multiple and diverse entities may be involved and whose cooperation is a key issue [15]. The spatial data and related technologies have been proven to be crucial for effective collaboration and decision making in emergency management [16]. Geo-location of the vehicles and agents can improve the collaboration dynamically in specific operations theatre (OT) where may be involved multiple and diverse entities whose cooperation is important. In [20] it is demonstrated an LBS application that presents a distributed LBS framework, that provide to the agents *"any kind of information at any time"*, e.g. information about weather, local news, and others. The LBSs [31-33], In the last years, the scientific community has reported, numerous IT solutions to deal with real-time communication, localization-aware, coordination, and decision making challenges in emergency scenarios [34].

In [35], it is presented the Mobile Shadow, an example of the LBS application based, using the concept of location awareness computing. This architecture is targeted at three issues: proactive location-aware, scalability and fault tolerance issues, providing services that can be access by the user with their user agent. The WORKPAD solution presented in [14], provides an architecture, to improve the collaboration in emergency management in Italy, based in two-level architecture: a first level is deployed on the field and a second level that involve the servers of the emergency responders centers. WORKPAD can be divided in two different architectures: Front-end and Back-end. The Front-end architecture is directed to the Rescue operators that are equipped with PDAs and co-work is orchestrated by a Process Management System (PMS), which is hosted on the most powerful device, typically the leader device. The PMS shares also all information data between the agents with their software applications and provides some automatic services to access the external data sources. The PMS are the engine that performs the tasks according to user's responsibility. The back-end side represents the data sources from several servers that front-end devices can query, thus obtaining aggregated information. In this solution on the organizational view the back-ends perspective include the control rooms/headquarters of the diverse organizations that have rescuers involved at front-end [36]. In Derekenaris, G., et al. [37], is described a solution oriented to management for ambulances guidance, the solution is based on Geographic Information System (GIS), Global Position System (GPS) and Global System for Mobile Communication (GSM). The purpose of this study is to formulate a calculation algorithm designed to find the shortest route to any destination (patient house, hospitals, roads, etc.) for any ambulance/emergency vehicles or vice-versa. In [38], was proposed an integrated system, that allow the creation of synergy between multiple available resources operating in particular OT by providing a set of services that enable the sharing of context-aware information between the various agents using technology's such GSM, GPS, Wi-Fi applied to Pocket Pc's. This study, allows

data sharing between all actors, their own coordinates and geographic graphical information, inserted by any agent, to inform each other about recommended routes or other useful information. As features, this paper presents a rate of 1Hz frequency of sending messages to the server with the coordinates of the vehicle ensuring instant updating of the vehicles coordinates. This study [39], similarly to the EmergenSIG, gives the possibility to Firefighters in Chile, to reduce the use of radios in your communications through an interconnected system between the firefighters and the command center, making use of technologies such as GSM and GPS. This solution provides the following features:

- **Destination service**, this service allows to a specific entity to choose a destination, using latitude and longitude on the map provided, or else the destination is shared by the way of web server by command center, improving the efficiency and rapidity of the agents arrival to emergency site.
- **Distance Calculation** is a tool that allows the agent to calculate the distance between two points defined on the map, giving the possibility to know which destinations or points are more closer, and manage their actions.
- **Information management** functionality allows the agents to consult relevant information about the emergency, exchange information with the other command center or with other firefighters and show the various layers of information from maps provided.

MobileMap is a front-end functionality that allows the user, to make queries about geographic Information such as maps of particular areas, location of specific street or vehicles attending the occurrence. In Mobile map is provided few tools, that provides support to the agents on the field:

- **Navigation Service:** each an handheld device has pre-load maps of the city, including interest points such as hydrants, hospitals, police station and others.

- Information management, provide a set of functionality such the possibility of review of the emergency information, setting the information layers on the map, and exchange information with the command center and other firemen. This information is retrieved from the command center when the device is connected to a GSM network.- User current location show the user location by identifying the user location on the center of the map.
- Fire truck location show the other vehicles on current occurrence, and the interest points available in that location.

This approach [40] presents a system for communicating data through a middleware that allows transaction data by subscriptions / publications in asynchronous mode, benefiting from savings in transaction data and ensuring data reliability, since it agrees with the possibility of scalable system resources. This system is an alternative to the use of synchronous request, they are not very well considered in emergency support systems. However, this article presents a model of transaction data and not exactly a specific application-oriented agents deployed by emergency scenario, with functions essential to the ongoing operations or functionality in performing important tasks in early stages of the intervention. In [41] the authors proposed a system for emergency medical occurrences, called EmerLoc based upon the location aware technology. The system uses a set of sensors that are attached to the body of the patient. They used a micro-computing unit that is responsible for processing the sensor reading and a central monitoring unit. The positioning functionality was implemented outdoor and indoor, through GPS and UCLA Nibble system respectively. The information captured is used to the doctor in a hospital environment, which allows the visualization of the data e.g., body temperature, heart pressure, arterial pressure, heart rate, etc. Kamarudin and Salam [42] proposed the use of Pull & Push location based service to reduce the problems confronted by police and fire fighters. They focus on the problem of the accuracy and in the time taken in an

emergency case. As EmergenSIG, the focus is getting the right information at the right time in their mobile devices. The approach used was the use of RSS and web service to provide news for the application. In [43], Peter Thornycroft proposed an Emergency Call Location using Location based services for cellular phones using Wi-Fi. The proposed system wants enable on-campus location-based services at University of Cincinnati. The main idea is identify the call by the incoming trunk ID as a call-center call and the caller is identified from the automatic number identifier (ANI). During the call, the application shows the caller's location on campus map and measuring and determination its location sending the information without any further intervention.

LBSs [44] offer many advantages to users and several important and intelligent information using their current location. In [45], the author proposed the implementation and the using of Google Web Services and Walk Score Transit APIs to give multiple services to the mobile user. The system was written to Android OS, and the main idea is provide maps navigation, marketing/advertising reminders and location search such as ATMs or Restaurants from his current location. In emergency situations, as described in this dissertation, LBS can be aimed at speeding up the work of ambulance teams via GPS and smartphones. In [46] the authors developed a system focused in allow that ambulance and hospital personnel work together, which can be very useful in large accidents. The system can help people in problems like type of injuries, number of people injured, real-time communication, logistic problems, etc. Moreover, the pre-hospital LBS system for disaster management was evaluated at Malaysia, and concluded that can be a huge help by given a "big picture" in emergency case. In contrast, LBSs are not just use for navigation or emergency scenarios. In [47] is proposed a system to motivate the use of mobile devices for personal safety services. They discuss features of an emergency alert service, which activate the social group of the victim. Further, that group

can provide help. The system has several inherent challenges as legal issues, privacy, emergency dialog and geo-positioning problems.

2.3 Systems and Mobile applications for emergency scenarios

This section describes the most significant systems and applications that are already available to emergency oriented occurrences and are not described in the scientific community. There is already a set of software deployed on INEM such as NAVIGATOR, whose features, trace the route more favourable for the location or residence of the patient and also trace the route more favourable to reach the hospital [48].

MOBILE CLINIC system allows Emergency Ambulance technicians receive data directly from GCUP, without needing to be done any kind of phone call. This system is complemented with functionality for the technicians enabling, occurrence data record such vital signs and other observations of the health state of the patient, which are sent directly to the hospital, so there is no need to proceed the triage in urgency, which makes the system more quickly and effectively [48]. SIRESP is an integrated network of Emergency and Public Safety, is a network that integrates all and any national force, increasing the centralization of command and response. SIRESP adopted the European standard TETRA. The Primary functions are: Group Communication Support, Direct Mode, Data transfer Service, Radio Remote Programming, Quick Call Establishment, Security, Encryption and Geo-tagging. There is also [49], produced by IFTHEN that allows gather all the activity information on a particular TO, for this to be possible the agent must be fitted with a GPS PHONETRACK a Motorola smartphone that uses Windows Phone. Which can be complemented with software developed by the company. With a mobile phone with Mobile

IFFIRE a vehicle can make the tracking of the entire journey made since the departure of the base until their return, with geo-tag (in time and space) arrival at the place of occurrence, the record of casualties and sick patient in the car, the arrival at the hospital, the availability and unavailability of the vehicles, etc. With Mobile IFFIRE can georeferenced resources in operations theater (vehicles, fire engines and other equipment and entities involved), fronts fire, water points, access, risk areas, perimeters and areas burnt, the position of checkpoints and any other information of interest to the coordination of the event. Can be viewed the map with the route and georeferenced points in phone itself, on Google Earth, Virtual Earth or in any other geo-tagging software (GIS). Might save the geo-tagged data for each occurrence, thus with a complete and accurate record of services performed.

In the mobile applications stores have been found some solutions that have served as examples for the development of this system, such as the Mobile Emergency call [50], consisting an Android Mobile Application, that place an emergency call in case of accidents. The FEMA Android app[51], oriented to the general public, which provides "preparedness information for different types of disasters" and other useful information to inform the public during and after the disaster. AtHoc Notifier Mobile Application [52], provides a 2-way communication to the emergency response teams, by allowing them to share videos, photos, audio, text, maps and receive audio-visual alerts form anywhere. In [53], Tennessee Emergency Management Agency presents the Ready TN, an Android application that provides, knowledge to the citizens about the hazards in their community and the "preparations they should take to be ready, during any emergency". The Mobile Emergency Application [54] developed by Dept. of Information Engineering of University of Florence, "is an application to manage emergency in hospitals and large areas via mobiles", allowing the users to notify the emergencies, find the effective path to exit of the critical area, get support to solve contingency problems, be

informed by any change of occurrence information. iMap Weather Radio[55], is other mobile application, designed to alert the users about "life-threatening weather events", in near their location, also provides useful information, to avoid the weather event and allow the user view multimedia content by streaming about weather coverage for up-to-the minute information. The Hurricane by American Red Cross[56], "consider one of the top six hurricane tracking apps", oriented only to the hurricane climate events.

By the related word, it is possible to verify that there has been described multiple applications targeted to emergency management which are oriented to all types of emergencies. Many of them are focused on specific cases of emergency scenarios. Other solution requires the use of additional equipment, or even a specific type of device, which is not available for many agents. Another peculiarity comes from the fact that none of the available solutions has been developed is based on a national range, and in an integrated manner, promoting the cooperation between different entities and agents, following the prevailed hierarchy. It was to fill this gap that the EmergenSIG was formulated. Granting, that all the different entities and their agents can effectively connect and share information through a common occurrence scenario. The proposed system, called EmergenSIG, gathers contributions from the above-presented mobile applications creating a more complete and comprehensive proposal in the context of mobile and ubiquitous computing, and location-based services on emergency management theme.

3. Requirements Analysis

This chapter presents the essential requirements, whereas this proposal are based, use cases diagrams, where is described the most complex and the general use case, and for last, the resume of the used technologies for the system development and deployment.

3.1 Essential requirements

EmergenSIG is based on following essential requirements:

The agent interface (Mobile Application) must be as easy to use as possible, with minimal input from the user. Screen size and orientation; together with stylus input minimization dictate and interface with large buttons, soft key use and appropriate font size, to enable on-the-move application use. The minimum radius of miscalculation coordinate of the location-based service module must be less than 10 meters of the real agent location. The Mobile Application is oriented to all emergency responders teams chief's on the field. The Mobile application must relate the agent with the vehicle which is operating, facilitating the recognition of the vehicle, the team and their chief by their holder's entities (Emergency Responders Command Centers).

EmergenSIG mobile application should be supported by any mobile device, giving special attention to the IP67 certified mobile devices, which are mostly Android SO Mobile devices. IP67 (IP- International Protection Rating) classifies the protection degree of the mobile device against the intrusion of solid objects, dust, accidental contact, and water, which in this case IP67 certified mobile device represent full protection against dust and maximum 1 meter depth in liquid submersion.

The Entities Application (EmergenSIG web application), must inform in real-time all the events resulting from the actions of their agents. All the information about the state of mobile device (last coordinates update and coordinates timestamp) must be available on second level (low priority). The coordinates timestamp, inform the entities and the system about how much time elapsed since the agent its stop or for some reason is offline. The entities should receive all the information that concerns to the agents on the field under their responsibility. The EmergenSIG must respect the hierarchy of the different entities involved in particular Emergency Scenario (Occurrence), even their relations between agents and entities. The mobile application, should save as possible data transaction to the webservices, when the mobile device are using primarily the GSM network, reducing this way the costs associated. EmergenSIG framework must be fault-tolerant with scalable resources. The maps provided must be current, and updated. This is an important aspect, because mostly in rural areas or forest areas, the dirt roads with time becomes covered with vegetation and further become inaccessible for some vehicles, without opportune agent knowledge .

3.2 Use Case Diagrams

Use case diagrams represent the features of the EmergenSIG framework and their interaction with the user, which in this is case are Agents. In this section is presented the most significant use cases.

In Figure 5 is presented the use case diagram *Receive Specific Situation Points*. This use case represent one of the most important functionalities of the EmergenSIG system. Following the agents hierarchical criteria, the process of receiving the Situation Points, implies data filtering for the different users privileges. Furthermore, for the agents actors, the

system only allow the LCRO agent, to view all Situation Points (SitPo) submitted by the others simple agents in the OT. Simple agent, only can view the last SitPo submitted by LCRO, which represent the general occurrence SitPo. In entities actors, the SitPo data, is filtered according to the agents involved or territory under their responsibility.

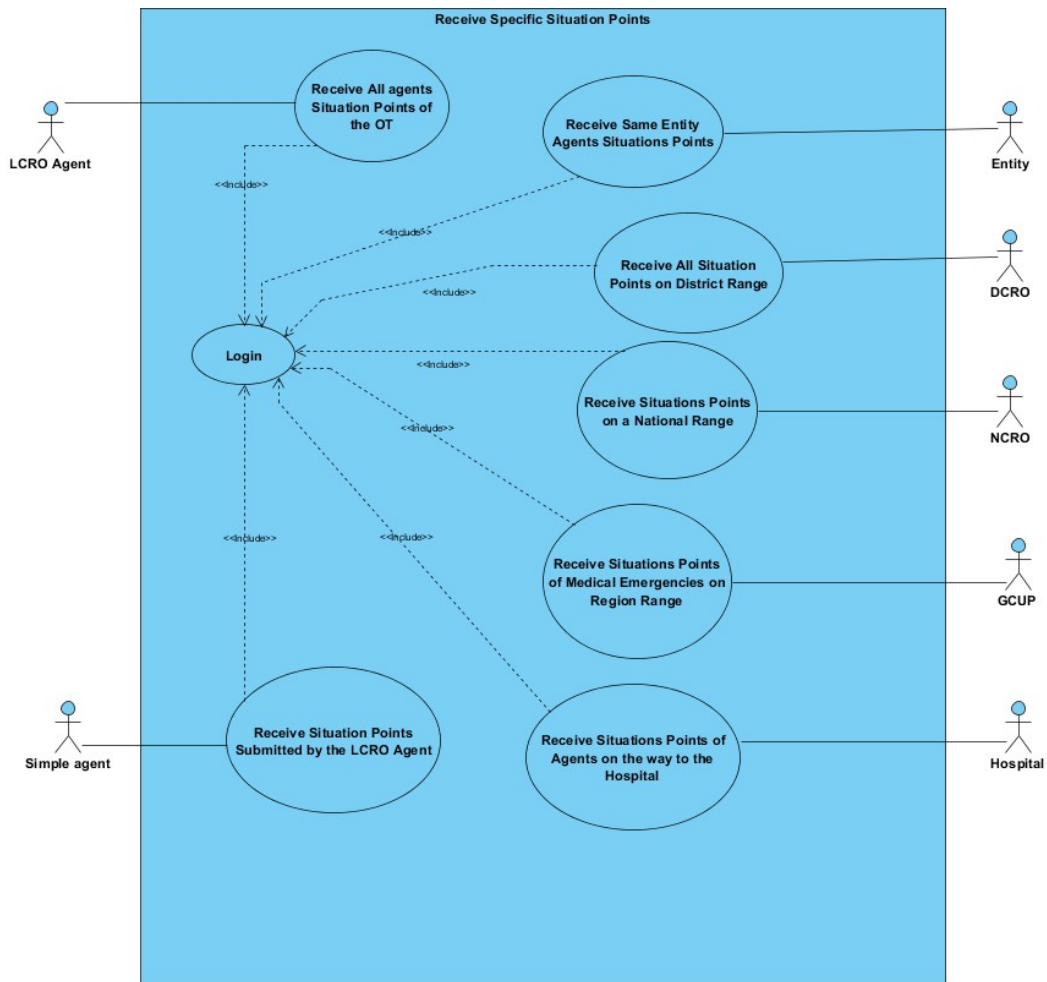


Figure 5 - Use Case Receive Specific Situation Points.

The use case of *Receive Specific Agent Status scenario*, figured in Figure 6, demonstrates the use cases, when the actors receive the operational status, submitted by the agents on the field. In this case also

demonstrate the use of the privacy concept used in use case *Receive Specific Situation Points*.

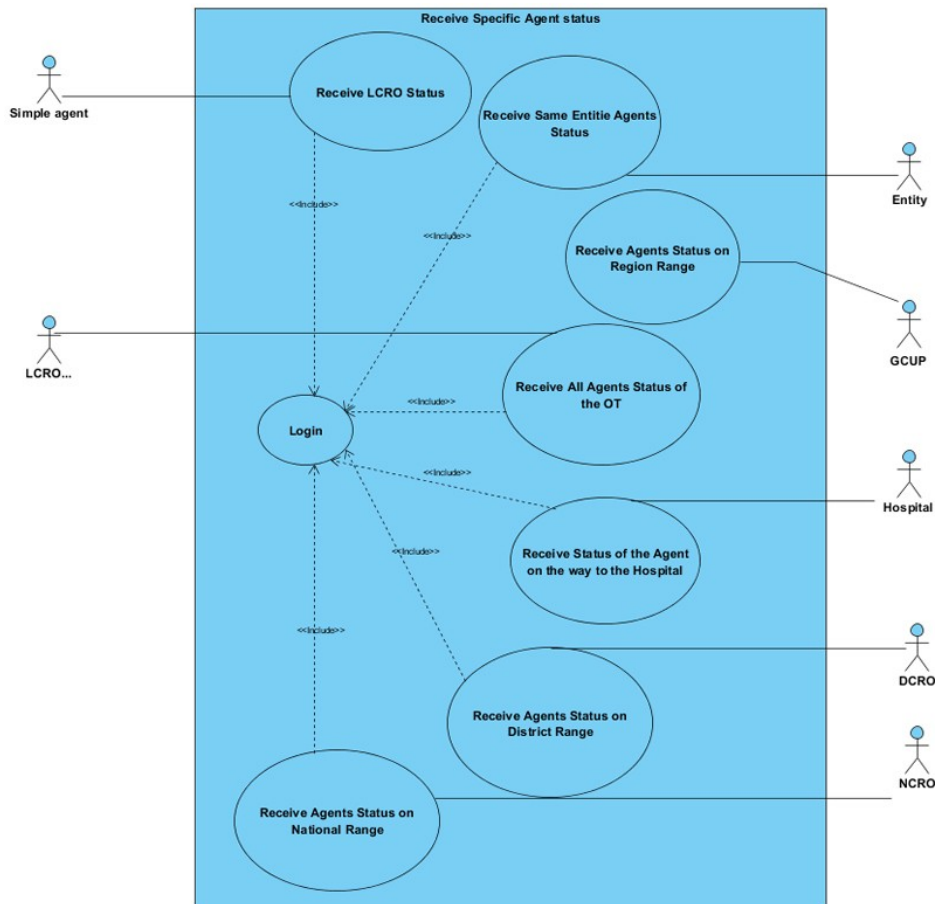


Figure 6- Use Case Receive Specific Agent Status.

In use case *Receive Specific Agent Location* (Figure 7), represents the scenario, when the actors receive the geographic location of the agents in the OT. Only the LCRO actor have total access to the others agents location data. The simple agent, only have privileges to view the LCRO position in the OT.

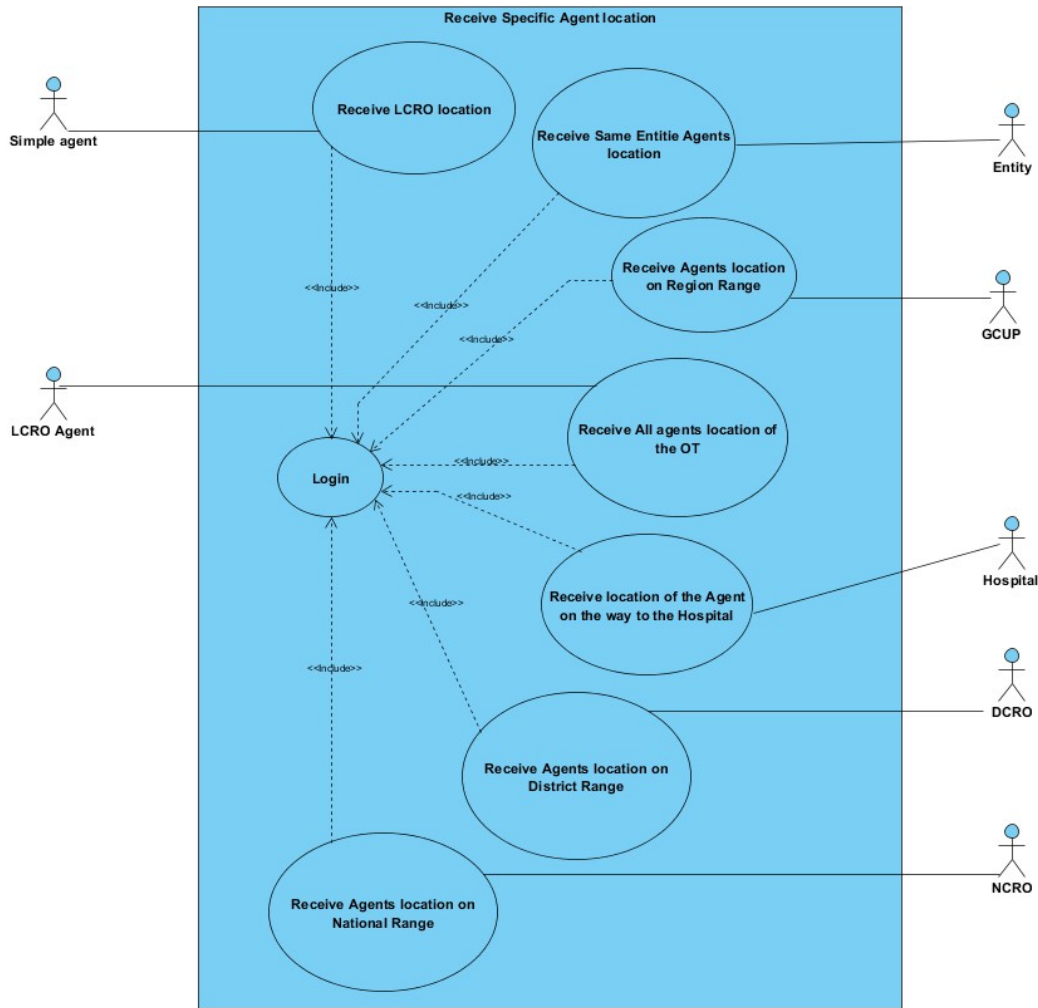


Figure 7 -Use Case Receive Specific Agent Location.

In Figure 8, is figured de use case diagram of the *Receive Specific Processed Occurrence Information* scenario. This diagram, represents the functionality of receiving processed data, by external services (such Google direction web service) or by the SitPo handlers. SitPo handlers (described more detailed forwards), have the responsibility to read and understand the SitPo data sent by the agents. Furthermore, draws shapes on the operational interface (map view) according the data sent by the agents in the field. This functionality is provided on EmergenSIG mobile application and web application. In this use case, is possible to verify slightly differences on the agent actors side. Contrary, the uses cases presented before the simple agent, have privileges to receive all processed

occurrence data from the occurrence. In other words, the simples agents receive this way the SitPo's sent by others agents, but only can see on the map in graphical manners. In this proposal the *Processed Occurrence Information* are responsible, to warn the agents actors and the entities actors, about the hazards derived by the emergency and their response process. Also can provide to the actors, useful information to support them in the emergency response process.

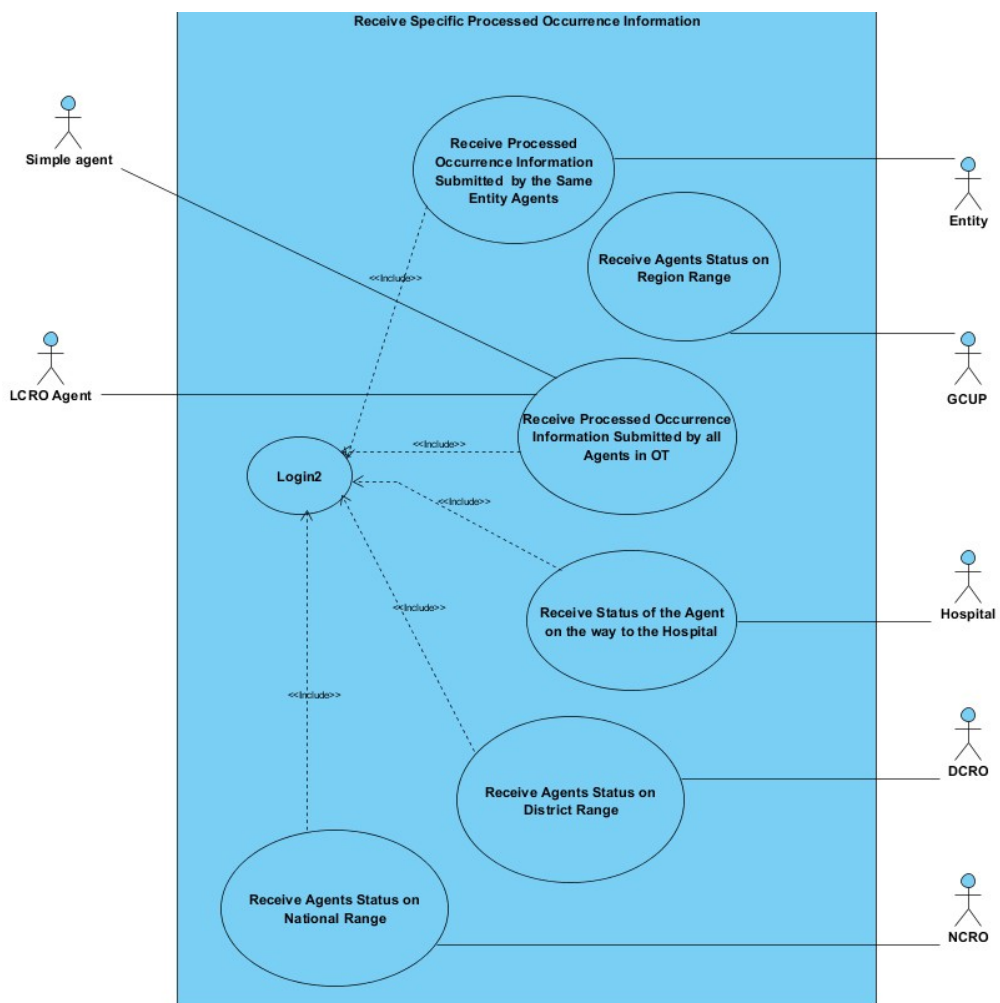


Figure 8- Use Case Receive Specific Processed Occurrence Information.

The use case diagram below (Figure 9) shows the system overview with some level of abstraction, representing the most important uses cases

and their interaction with the actors. The diagram presents the functionalities of the EmergenSIG System.

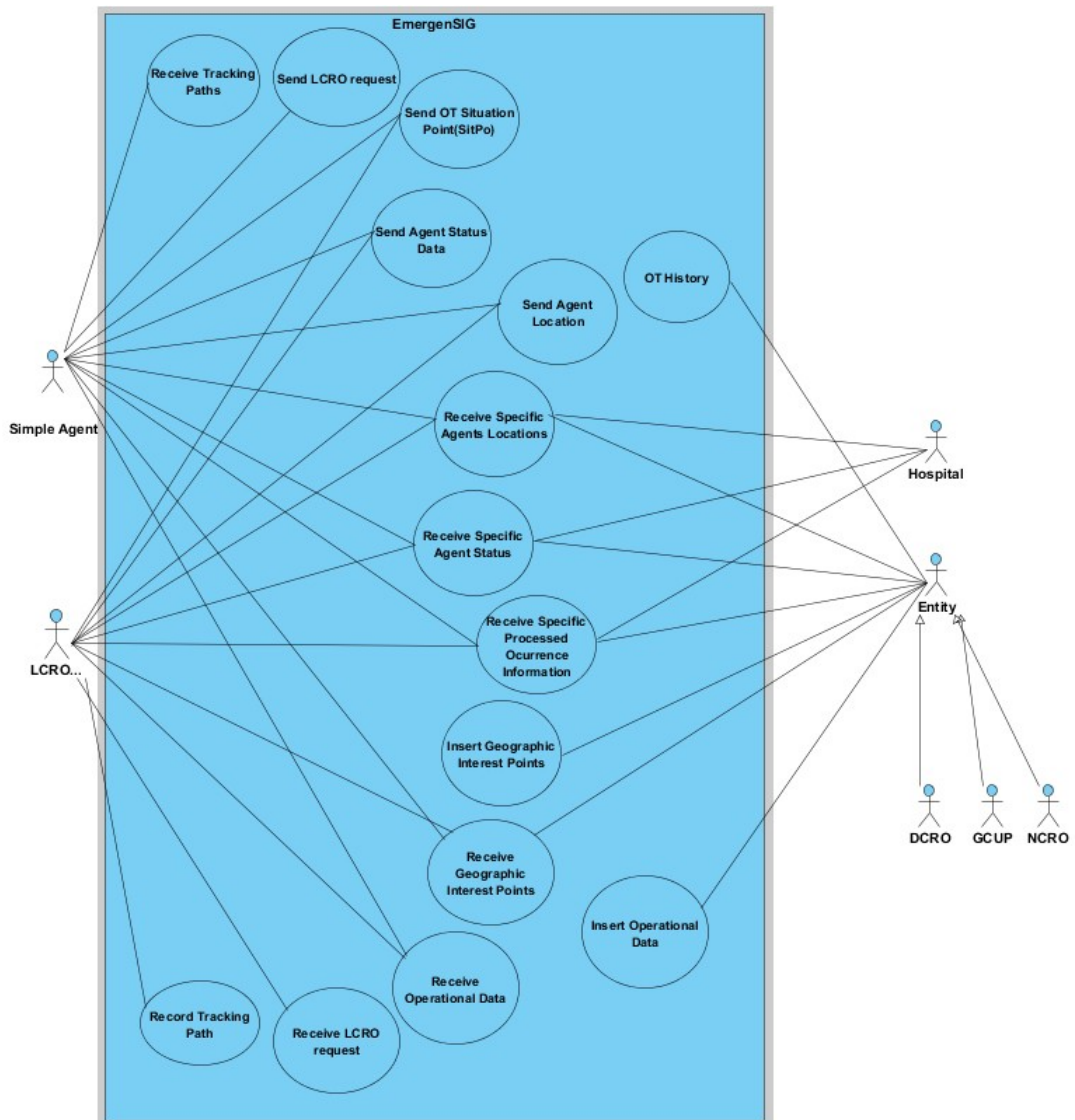


Figure 9 -General Use Case Diagram of EmergenSIG.

3.3 Activity Diagrams

The activity diagrams are used to describe the business operational components of a system step-by-step, and the overall flow of control.

Figure 10 shows the activity diagram of the agent credentials certification. The agent credentials certification, is the very first functionality of the EmergenSIG mobile application that confirm the agent entity, as in same time, verify the mobile credentials. Accreditation of the Mobile device, is divided in two steps. The first step, is the process that allows the mobile device, to performing the EmergenSIG mobile application, this is achieved by the registration made by the entity of the agent. The registration process is done by simply insert the phone number of the device (SIM card), and the system returns a modified UUID for username and partial UUID for password. After the agent insert the credentials on the EmergenSIG mobile application, provided by the entity, the EmergenSIG system validates the credentials and automatically receive and record the International Mobile Equipment Identity (IMEI) of the mobile device, relating this way the mobile credentials, phone number and the IMEI of the mobile device. After this process the mobile phone record on its memory, an hash key provided by the successfully device certification process. After this process completed successfully, the next uses of the EmergenSIG mobile application, are directed always to the second step. The second step consists on the validation of the hash token recorded in the memory of the mobile device. If the hash tag is valid, the system allows the agent to make their system login. The mobile device registration, was thought to allow the device to accept different agents and allow the entity blocking devices permission, when is confirmed improper use of the EmergenSIG mobile application. This process implies a permanent blockage of the device. To make the device operational again, the agent needs to uninstall the application and require to the entity a new mobile device

authentication credentials. The login is a process that identifies and allows the agent and the entity to use the EmergenSIG application. The agent login credentials are registered by the entity on EmergenSIG web application.

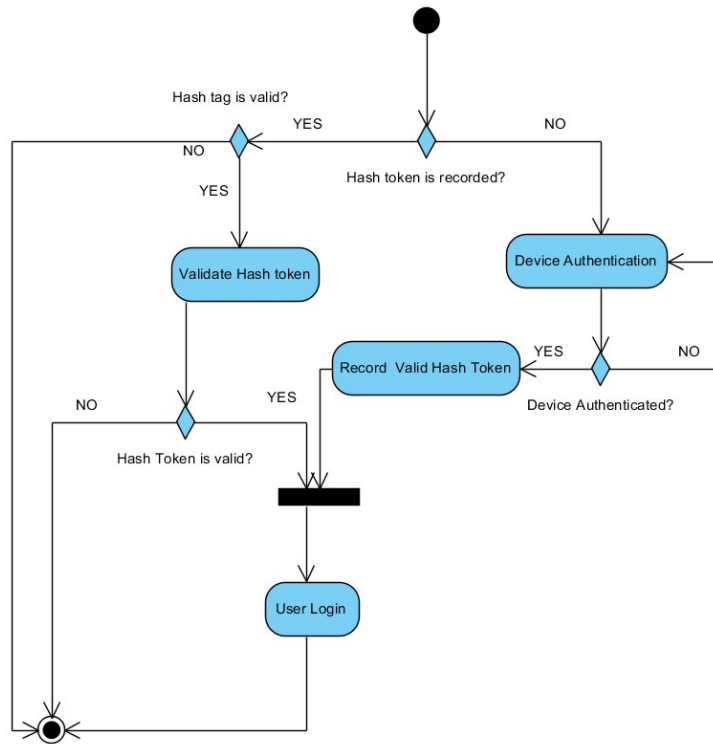


Figure 10 - Activity Diagram of device authentication algorithm.

The Figure 11, presents the general activity diagram with significant activities defined for EmergenSIG application.

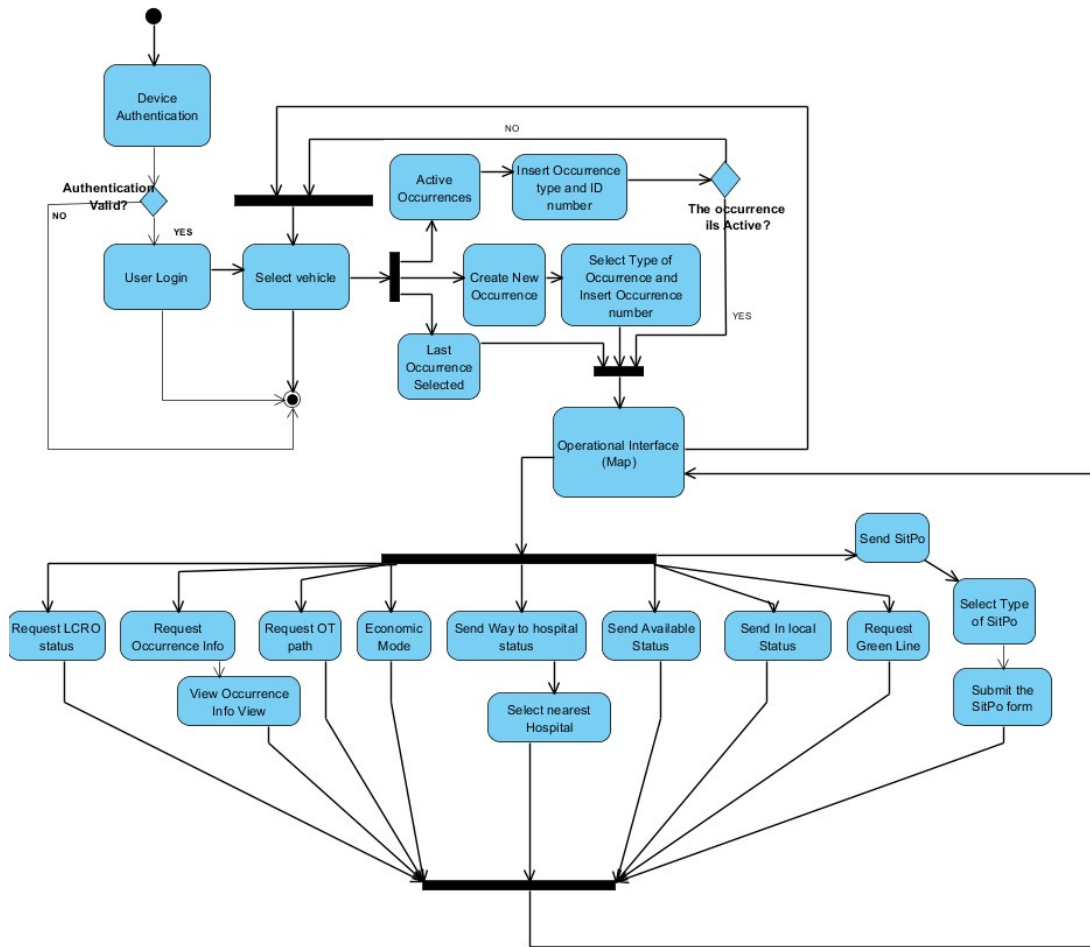


Figure 11 - General Activity Diagram.

3.1 Class Diagrams

Class diagram is a representation of the structure and relationships of all classes that serve as a model for objects. In Figure 12, is presented the class diagram with attributes and methods. Furthermore, in the diagram, is possible to observe the dependency of some classes to the Connection Secure Class, due to encryption and decipher processes triggered by the requests madden by EmergenSIG mobile application.

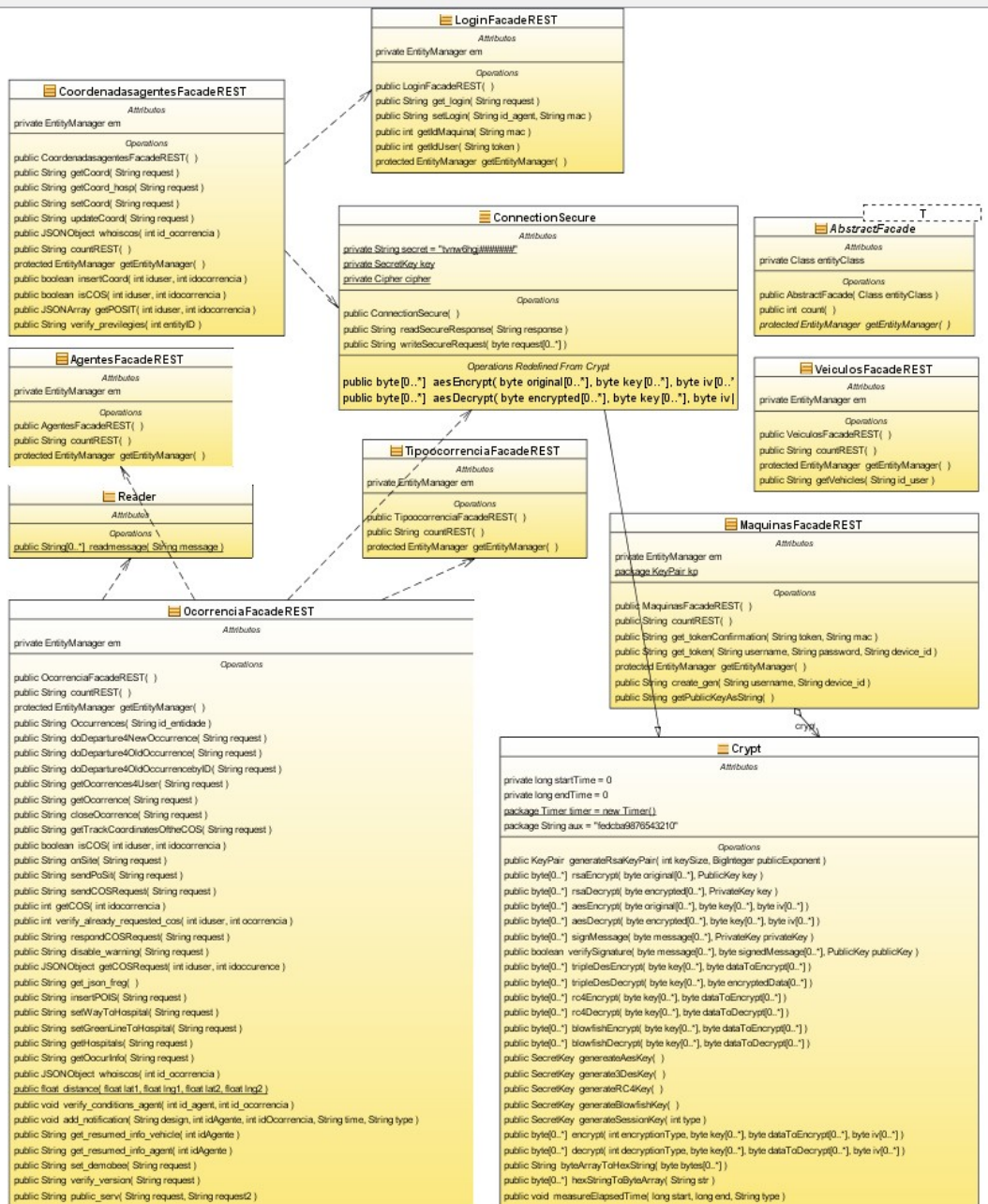


Figure 12 - Class diagram of REST web services

In Figure 13, shows the disposed classes of the Android application. The diagram shows the dependence of some activities to the *ConnectWebService* class.

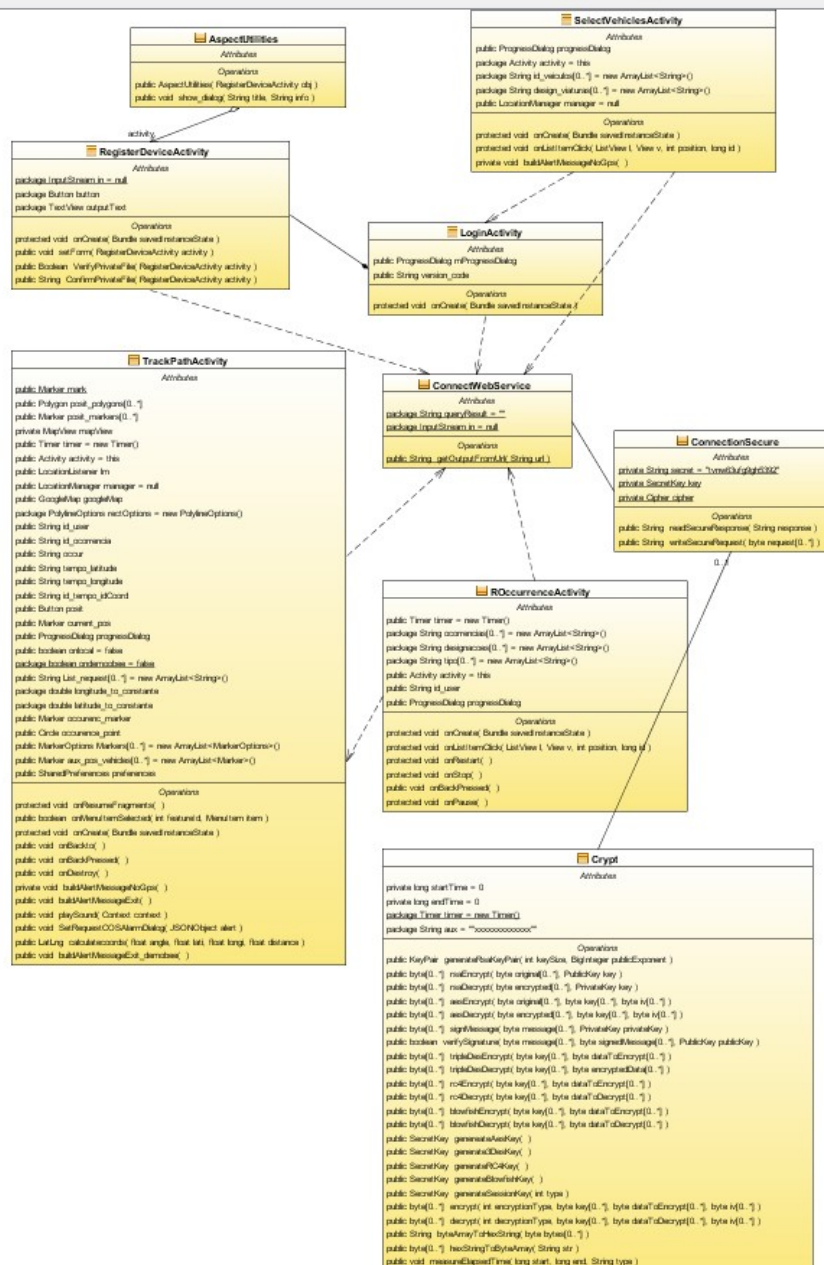


Figure 13 - Class Diagram Slice of the Android Activities

3.2 Used technologies

The EmergenSIG is composed by three different modules. The EmergenSIG mobile application, the EmergenSIG web application and the REST Web Services. EmergenSIG mobile application targets mobile devices

running Android platform, which is a software stack for mobile devices that includes an operating system, middleware and key applications [57]. The EmergenSIG mobile application was developed in Java programming language, by using the Android SDK in the Eclipse IDE (Integrated Development Environment) with the ADT (Android *Requirements Analysis* Development Tools) plugin. The ADT is designed to include a powerful and integrated environment on Android applications [58]. To manage the communications to the REST webservices, was used the AsyncTask which is an Android Native Class, that allows the execution of operations in background and publish the result on the UI thread. In EmergenSIG mobile application the AsyncTask class are responsible to communicate in asynchronous mode with the REST Web Services oriented to the mobile devices.

EmergenSIG web application, was been structured in HTML markup language and Cascading Style Sheets (CSS) with support of server-side algorithms developed in Java Server Pages (JSP) programming language. In the client-side, it was used JavaScript, with support of Asynchronous JavaScript and XML (AJAX) methods, in order to make all the requests to the EmergenSIG REST Webservices. Also, was used some jQuery functions, to make the user actions more fluid and attractive. The data set transacted between the EmergenSIG web Application and the EmergenSIG REST Webservices, are in JavaScript Object Notation (JSON) data format.

EmergenSIG REST Webservices, was been developed in NetBeans 7.2.1 IDE that supports rapid development of REST web services using JSR 311 - Java API for REST Webservices (JAX-RS) and Jersey. These methods of REST web services are connected to MySQL 5.5.28 database located in the local server. For the database development and DB administration , was used the Workbench 5.2.33 CE, an unified visual tool for database architects, developers, and DBAs. Workbench provides data modeling, SQL development, and comprehensive administration tools for server configuration, user administration, backup, etc.[59]

This proposal was deployed and tested Intel Xeon E5405 @ 2.00Ghz server with 4 GB RAM, performing in distributed computing, or in other words in Cloud Computing.

4. EmergenSIG System Architecture

In this section, it is presented the general EmergenSIG system architecture, and in the particular way, the EmergenSIG Web Application architecture and the EmergenSIG Mobile Application. Moreover is described the system Security, entities and agents privacy, the system agent-entity relationship and for last a summary of the general EmergenSIG summary, where is described the EmergenSIG functionalities and their user targets.

4.1 System Agent-Entity Relationship

The EmergenSIG is a Framework oriented to the agents and entities involved in any emergency resolution operations, for this reason the development of this system was based on the needs of the agents by adopting User-Centered design [31]. User-Centered design relies on continuous interaction with end users to understand how organizations are arranged during the occurrences or disasters, what information is critical, and how teams exchange this information among themselves and with their operational centers (entities) [36]. EmergenSIG is a framework oriented to the continuous evolution allowing future increment of new methods oriented to the specific emergencies resolution. The objective is to improve the emergency management process, during the initial and during emergency response in almost real-time, benefiting this way the proliferation of the emergency data to the entities that are generated on the field by their respective agents.

EmergenSIG system architecture is presented in Figure 14 and includes four main modules: *i*) agents, *ii*) entities, *iii*) administration center, and *iv*) public services. Its mobile application (developed for Android OS) is oriented to the agents. They can send and receive

information, through encrypted REST Web services via GSM/Wi-Fi Network using HTTP protocol. The agent in this architecture can be all type of rescuers in determined occurrence. (E.g., Police agent, firefighter, MERV medic/nurse, civil protection agent and others). Entities interact with the system through the EmergenSIG Web application, developed in Java Server Pages (JSP). It consumes several Web services requested by JavaScript in background, updating the information displayed in defined intervals, almost, in real-time. In this case the entities are all responsible of the department to send emergency rescuers to a determined occurrence to resolve it (E.g., Firefighter department, police, army, hospital, National Command of Relief Operations, District Command of Relief Operations and others).

The administration center provides administration privileges to users, such as the possibility to add entities, view the general information updates, add geographic information, and other features for database management. This view was designed and created for the NCRO department location due to the exchange of sensitive data and for security reasons.

The **GIS database** contains markers that characterize interesting geographical information to the agents and their entities, such as interest points, agent coordinates, hospital coordinates, hydrants points etc. The operational database contains all the information about entities vehicles, OT historic, registered agent devices, agent's information and all related data. The proposed architecture allows entities to control only their agents and no others that are associated to a different entity roles.

The **Operational database** contains all the operational information, about the agents, their entities, mobile devices and vehicles. This database was thought to provide useful operational data to the agents and LCRO in determined OT during the response process in the OT, such the grade of the agent, his name, the designation and type of vehicle where he is being

transported, the agent phone number, the entity of the agent and the agent ID. This database is also based on the actual emergency rescuers identify other agents on the field (OT) and how the agents communicates between them by the radio. This process is made by simple call the vehicle designation, and the agent entity location. For example, if the vehicle designation is VRC01 and the entity location is Covilhã, is called by VRCI-01 Covilhã Agent, for this reason, was chosen to relate the maximum of information of the entity, enabling their quick identification and providing all important information about the agent, their vehicle, phone number and the description of their entity. The phone number of the agent is obtained through the process Accreditation of the Device Figure 10 - Activity Diagram of device authentication algorithm.(Figure 20) explained more forward

Public services are provided by Web services that use JSON format documents that reply information concerning the current state of incidents on client location. This Web service receives the client place, by defining on the request input the district name and the county name. The response includes information about the current/local incidents that are active at that place, such as, the type of active incidents on the client location, emergency situation points, number of involved agents, incident time and their precise OT epicenter location.

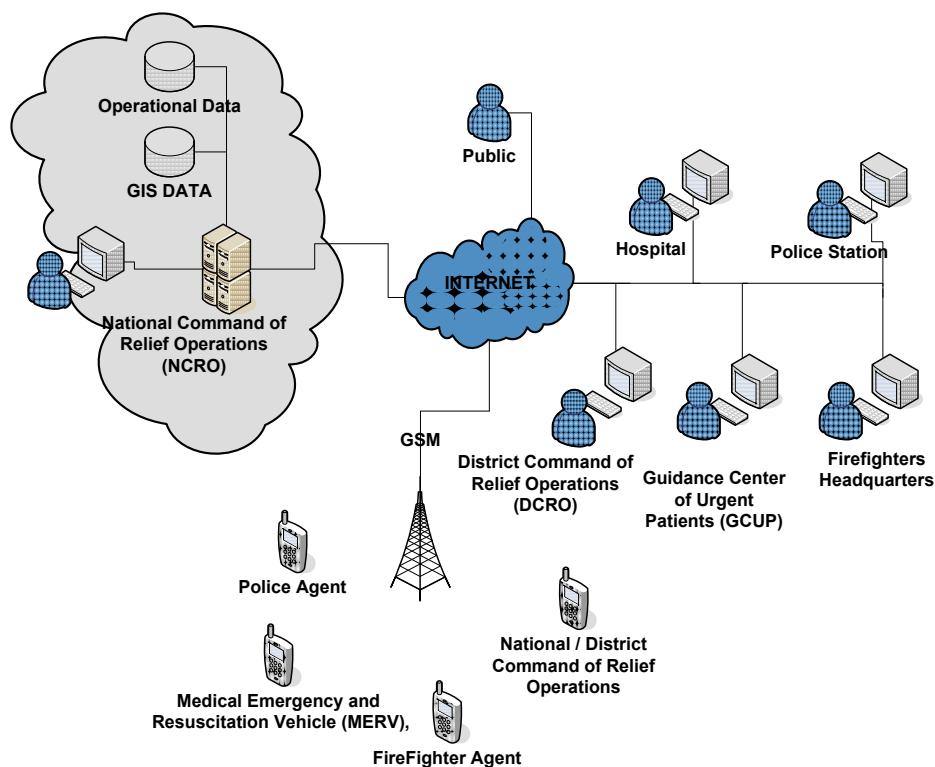


Figure 14 -EmergenSIG System Architecture.

4.2 EmergenSIG Mobile Application Architecture

In this section is presented de Architecture of the EmergenSIG Mobile Application (Figure 15).

The EmergenSIG mobile application is designed to support different screen sized devices, providing user-friendly design, making its use more effective and more easy, even in stressful situations, same situations, that the emergency responders faces. The EmergenSIG mobile application is oriented to the agent that composes the emergency response process. The EmergenSIG Mobile Application is targeted for the transaction of relevant data, from the field or from the operations theater (TO) to the control centers, which in this dissertation are considered by entities. This application was developed for Android devices, supporting the versions

Android 2.0.1 to Android 4.3. EmergenSIG is composed by a set of modules or functions, for different Goals.

SitPo Modules, these type of modules or functions execute important tasks in the application, they are the responsible to provide tools for agent to describe and have knowledge of the evolution of any kind of emergency. These functions are called Modules, for in algorithm abstract manner show that they are independent and each SitPo module is only oriented to a specific emergency. This allows the general application aggregate more SitPo modules in the future, without the rest of the code have to be changed, independently of the complexity inherent to this modules.

The Situation Points modules, are composed by two types of sub functions:

The **SitPo forms** - this functionality provides an specific activity in the mobile application, which allows the user to describe the situation of the occurrence and their evolution. This is achieved by creating simple and intuitive report, with specific questions about the current occurrence. Furthermore, if necessary, this functions can access to the module of the mobile device, complementing the information inserted by the agent, with more important information, such as device orientation, atmospheric pressure, light condition, device temperature (rare), device inclination etc.

The **SitPo handlers** are responsible to read and interpret the data received by the system, which was generated by SitPo forms. Furthermore, these important functions, interpret the SitPo information, generating also visual content about all SitPo Information sent by all agents. These types of graphical data are inserted into the maps of the agent's application.

In this dissertation, only the wildfires and wealth wmergency SitPo's are given a special appreciation, due to their results significance.

Operational Functions - these functions are responsible to provide agent a set of tools, such as Listing all available entity Vehicles (from Operational Database), Listing all Active Occurrences (from Operational Database), Drawing on the map the path of the first unit that arrive on the Operations Theater (from GIS Database), Drawing Interest Points (from GIS Database), Drawing the graphical information about the other agents (in same OT) location and information (from Operational Database), the Overview of the Occurrence information (from Operational Database) and Economic Mode, that allow to the mobile application only send the coordinates of agent location, pausing any others communications.

Agent Status is based on a set of different functions that describes the actual state of the agent (user) in the EmergenSIG system. The available agent status is the following:

In The Local - Inform the respective entities and LCRO, that the agent just arrived at the OT.

Available - Inform the entities that was demobilized from the OT, and its on the way to their base or department facilities.

On The Way To The Hospital - Is a special feature, that informs not only their respective entities and the LCRO, but also the hospital, about the new agent destination. This feature is special because the entity, which in this case a hospital, is informed about other entity agent, once the agent belongs from other entities. This is achieve by listing to the agent the ten nearest hospitals of the agent location and allowing the user the selection of the recipient hospital. Therefore the selected hospitals can be informed about all agents in the system, that are on the way to their facilities. The list of the nearest hospitals, are sent by the EmergenSIG system to the mobile device, with the ten more nearest hospitals to the last agent location. This process is done simply by using the Euclidean distance, between the device and an Hospital selected.

On The Way To The OT - Inform the entity owner and LCRO that the agent is on the way to the emergency site or Operations Theater (OT).

SitPo Sent - Inform the entity communications operator (entity) and the LCRO of the same OT, that the agent sent a Situation Point in that moment and redirects to the SitPo collected information. SitPo is a set of functionalities targeted to describe the status of specific types of emergency.

Hospital Green Line Requested - This feature is another special functionality in the system, also oriented to the hospital, which the hospital is informed that there are one patient on the way to the hospital, that requires advanced health care urgently. The objective is to request to the hospital, with maximum readiness the resuscitation room. This feature is very useful, when the health state of the patient becomes unstable and is life-threatening during their transportation.

LCRO status requested - This feature allows to the agents, request the Local Commander of Relief Operations Status of the OT. This feature is oriented to the agents with more grades, who want to take charge the emergency response operations.

Location Commander of Relief Operations Status - Inform the entities and the agents of the same OT, that the agent is the LCRO of the OT.

Offline status - This status is sent to LCRO and their respective entities, informing that the agent just arrived at its base or department facilities, describing that the agent its offline.

The EmergenSIG mobile application was developed to sense also, the dependency of some status. Some use cases for example:

- When the Agent wants to send a SitPo, the system send in first time the "In the OT" status, so only after send the SitPo status.

- In the case that the agent wants to send a "Hospital Green Line" before sent "On The Way to the Hospital" status, the application recommends to first, send the "On the Way to The Hospital" status.
- The offline status is available only, after the agent sends the "Available Status" first.
- After the agent pull the Offline status, the EmergenSIG mobile application turns off.

All of this status, are composed by a time-stamp, to inform the system and the respective entities, when they happened.

Location manager is an Android native class that provides access to the system location services. These services allow the EmergenSIG mobile system to obtain geographical location of the agent or device and instantly send the location coordinates to the EmergenSIG system, through REST Web services. In the EmergenSIG mobile application, was developed to calculate the geographical location, with maximum error of 10 meters of the real location, by filtering the horizontal accuracy of the Android Location Provider. Moreover the system only determine the geographical location of the agent of 10 in 10 meters, ensuring this way, the pre-established requirements, which are conform with economization of data transaction. The map API used is Google Map Android API v2. It is an API provided by Google Play Services. The base of the choice of this API, was centered by the set of tools provided by this API, as the currency of the satellite images provided, which is a fact extremely important in the area of emergency management. It is essential to provide current maps to the agents in the field that can show them for example, the actual state of unpaved roads (Rural Areas), which over time will be covered by vegetation, making the paths inaccessible to the vehicles, if are not properly requalified over some time, can causes some delays to the agents arrival in the OT. Moreover, also provides to the user knowledge about, the extension of the continuous vegetation, type of vegetation, water zones etc.

Control Unit, is a set of functions applied in the REST Webservices oriented to the mobile devices, that are called every time by the system, when the agents (Android) want to make an specific action, that is sent to the Server. The Control Unit is responsible to grant the well functioning of the system, by controlling and confirming all the actions performed by the agents. The control unit is responsible to:

- **Validate Login sessions** and verify the existence of multiple sessions of one agent profile, if this case is confirmed the first session is deactivated.
- **Control the creation of the occurrences**, verify in the system if there exists other occurrence, which is active with same ID and same location, if it is confirmed, the system do not allow the operation.
- **Closing occurrences processes**, allow the system to close an active occurrence. This functionality is triggered when the only one agent in active occurrence, stays offline during maximum period of 60 min.
- **Managing the LCRO status request**, by redirecting any LCRO status request to the actual LCRO, and define the actual LCRO agent, consonantly the response of the actual LCRO. Furthermore the Control Unit is responsibly to assign automatically the LCRO status to the more graduated agent, when the actual LCRO exist the OT.
- **Auto LCRO assignment**, this functionality is responsible to the LCRO status assignment in two different situations. When the current LCRO agent, send a "Available" Status, the system assigns to other agent the LCRO status, by the selection of one more graduated agent. The second *Situation* occurs when the system assigns the LCRO status to the first agent that arrives in OT.

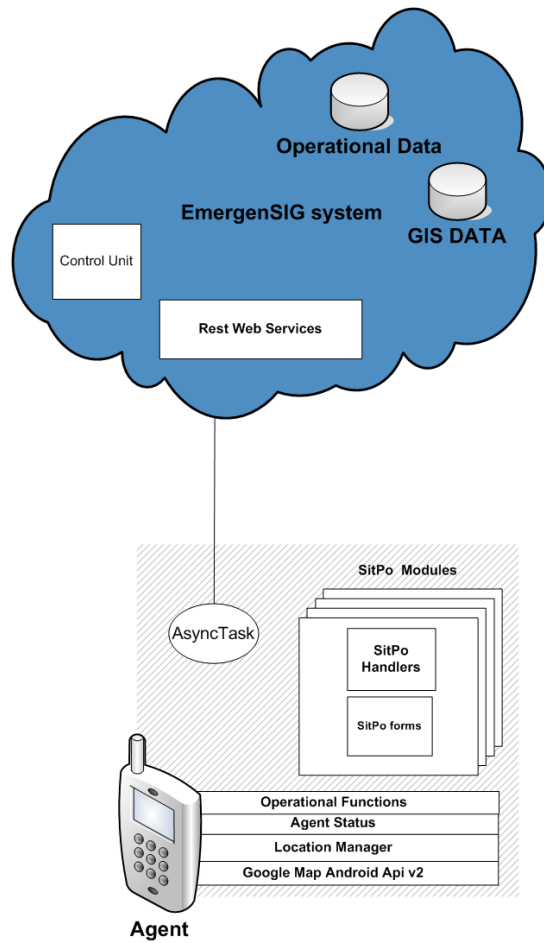


Figure 15 - EmergenSIG Mobile application system architecture.

4.3 EmergenSIG Web Application Architecture

This section describes the EmergenSIG Web Application Architecture and their different essential elements (Figured in Figure 16). EmergenSIG Web application is oriented to the respective entities of the agents that are integrant part of the emergency response operations in OT. The primary objective is to control the agents that are operating in the OT and allow the support in real time to the agents by their own entity. This web application, are developed in Java Server Pages, with JavaScript for client-side interaction. Above, is described the most important, features and

modules, that composes the architecture of the EmergenSIG Web Application.

Operational functions, provides a set of functionalities oriented to the entities. These functions allow the entity to:

- Add/Modify/Delete Vehicles, designed to agent selection through EmergenSIG mobile application
- Agent device registration, allowing the agent to use their EmergenSIG mobile application in the device.
- Consult the historic, this functionality allows the entities consult the history of specific occurrence, including the agent location, SitPo sent, in certain time. The entity user, must select one specific time to the system, in order to retrieve occurrence state in that time (Any eventual SitPo's and Vehicles/Agent Locations).
- Save occurrence history in to a file, allowing the entity to record the occurrence history (only SitPo data) in text file, easily understandable by people.
- Add/Delete interest point, allow the entity user to insert geographical interest point, to be shared for all agents that are in interest point location.
- Consult in real time, the active occurrence information under its domain, in other words, all occurrences created by their agents or under their responsibility.
- Agent Status information, provides textualized information about the agent's status on determined occurrence and their geographical location on the map.

About the SitPo modules, unlike the mobile version, the EmergenSIG web application only uses the SitPo handlers, which are responsible to interpret the SitPo forms sent by the agents on the field, translating this way, the SitPo text data, into graphical information to the entity user final user. The graphical data, have the ability, to show e.g., the wind direction, wildfire estimated extension progression shapes, and others.

To provide the map functionality, it was used the Google Map JavaScript V3 is the most recent version of Google maps API, with new capabilities, that helps the entity user, to control their units and providing to them more effective support. One important functionalities consists on the "street view", that allow the user to see from the street view the site of the emergency, and gather this way more detailed information about the site. Furthermore, with this tool and through the API Web services, is also possible to calculate the estimated route duration taken by the agents in order to achieve one specific destination (e.g. Hospitals), based on the current traffic condition in the local.

All communications are realized in AJAX by sending and receiving Java Script Object Notation (JSON) data.

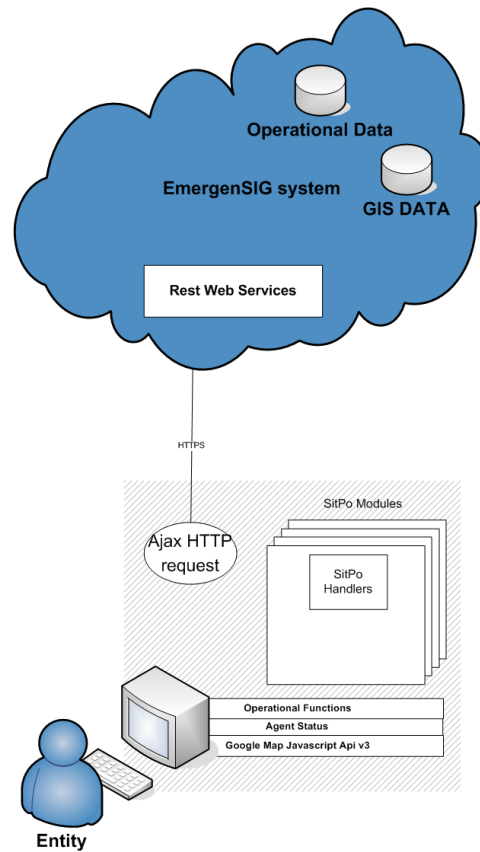


Figure 16 - EmergenSIG Web application system architecture.

4.4 Hospital interface (Special Case)

Currently, in some cases, the hospitals only have knowledge of the patient health condition, when arrive to the hospital, and in some cases the *green line alert*, is triggered after their arrival, leading to some delays in providing advanced life support. For this reason the Hospital was designed to be a special entity only oriented to the agents when transports a patient to an hospital facility, unlike the other entities that have the capacity to receive all relevant occurrence data. This special entity only view the data sent by the agents and not the entire data of the occurrence. In other words, this entity can receive all information about the agents that are on the way to the hospital, by receiving the location of the agents, the estimated time for the agent and patient arrival, receive the health

condition of the patient that was transported, and receive green line alerts, while the patient is on the way. In order to warn the hospital staff to create conditions in their facilities to receive the patient in the resuscitation room with advanced life support and appropriate medical staff. The functionality, in other words anticipates the patient arrival.

4.5 System Agent-Entity Relationship

EmergenSIG framework, is centered in two -level architecture: a first level oriented to the agents on the field, always headed by one leader (LCRO) agent on the field. A second level is oriented to the entities or rescue organizations of the respective agents on the field.

The first level is composed by the Android Mobile Application, which is based on pre-defined agent, by their skills and responsibility of the process of the emergency management, provide multiple functionalities to support the agents on the field, directing the resultant information to the entities, that have responsibilities in such emergency management operations.

In the second level, is provided Java Server Pages (JSP) oriented to the entities or emergency responders centers. This Web Pages, provides a set of functionality, that allows the entities to acknowledge in almost real time, the information resultant in the process of emergency management in the field, generated by the actions of their agents.

The first and second level is figured in Figure 17 that shows the relationship between the agents and their own entities. Between the agents and entities, must exist a shared set of data that it is called Occurrence Data.

Occurrence Data in EmergenSIG framework is strictly necessary to create a data set that is shared between the agents and entities, in other words, the agents and entities must create at least one active occurrence in the system to allow information sharing between entities and agents or between agents-agents. The Occurrence Data is a set of data composed by GIS data, Agents Location, SitPo data sent and Agents Status.

GIS data consists in Geographic Information inserted by the entities when they are not on duty. Geographic Information supports the agents on the field, providing useful information about available points of interest in the locality of the occurrence. The information can be water spots (hydrants), available roads access, hospitals coordinates, firefighters department's coordinates, and the path taken by the first agent to reach the local of the emergency or Operations Theater (OT). The functionality that provides the path taken by the first agent that reaches the OT, is extremely important in support to the agents, who come from other localities, because most of these agents have no geographic knowledge of other locations than their own, often leading to a delay in their arrival, contributing in this way to a decrease in the effectiveness of the initial response of the agents in OT.

Agents location, as the name implies, consists in a set of agents location information or geographic coordinates, that are shared to their entities and to the other agents in the OT. This data set, is composed by agent coordinates, last update timestamp to inform the system about the availability of the agent in the moment, velocity and orientation.

SitPo Data Set, this data set, consists in processed information that are created by the agents in the OT, such type of information describes the Situation Point (SitPo) at a given time of the evolution of the emergency, this information must be processed, in order to provide to the entities and agents, a set of graphical and text information that describes in the

moment, the evolution of the emergency (SitPo), or in other words, what the agent can see in the field.

Agent Status, this information allows the entities and the Local Commander of Relief Operations of the OT (LCRO) determine their agents status. There are several agent status available: In the local, Available, On the way to the hospital, On the way to the OT, SitPo sent, Hospital Green line requested, Local Commander of Relief Operations (LCRO) status, and for last Offline status.

The communication between the agents and entities is executed by two different webservices. One oriented to the agents and another oriented to the entities. The agent oriented REST webservices, applies cipher algorithms in all requests and responses.

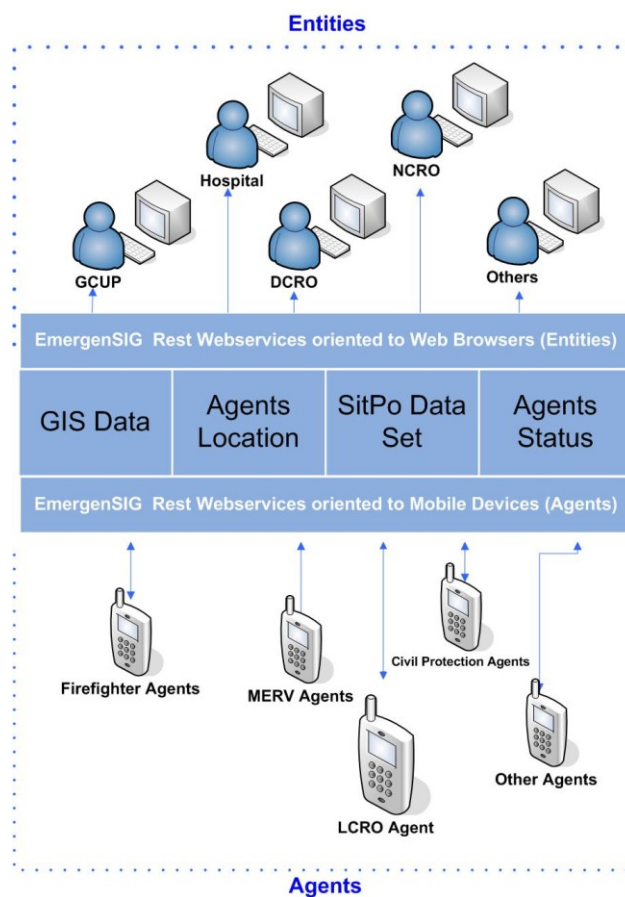


Figure 17 - Relation Agents-Entities that shows the Occurrence Data shared between the Agent and Entities.

The EmergenSIG system, create a new approach on this context, which is based on the agent and respective entities relationship, has well the relation between the different entities mostly involved in any emergency response process, and it is extremely important, because allow the constant support of the agents on the field, by their own entity on decision making in almost real-time.

4.6 Security

EmergenSIG provides a channel for transmission of sensitive and confidential information between agents and their entities. So it is necessary to protect the privacy of the data sent. Once the EmergenSIG is a platform that provides a set of real-time data, it is necessary simple and fast processing algorithms, to provide appropriate response times to the innumerable requests performed by the mobile and web applications. Therefore the system, must be, capable to encrypt data, with minimal of computational resources, ensuring this way the data security and fast responses by the REST Web Services. In Silva et al [60], is presented a comparison between symmetric encryption algorithm, where the AES 128 bits key encryption was the most efficient algorithm when handling with both small and large amounts of data. For this reason the EmergenSIG system, uses symmetric encryption algorithm only between the mobile devices and REST Webservices, using the request format:

128 bits AES encryption(SESSION_ID # TIMESTAMP # ID_USER # REQUEST_DATA)

The request is encrypted, and is composed by the session id (SESSION_ID) of the user login, the time stamp (TIMESTAMP) of the request, user id (ID_USER) and the message sent to the system (REQUEST_DATA).In the request, is necessary to insert the SESSION_ID of the login, in order to ensure only one active session for the user at the time. The TIMESTAMP,

allow the system, to detect repetitive messages. in order to block them, only the first is accepted. By the ID_USER information, the system confirms the identity of the user, with the proprietary credentials of the SESSION_ID, if the identification is confirmed, the system process the REQUEST_DATA. In the REQUEST_DATA describes the type of the request, and all data necessary to complete the order. The REQUEST_DATA are composed by JSON data format. Furthermore the EmergenSIG web application, can be used by HTTPS or HTTP protocol.

4.7 Entities and Agents Privacy

One of important topics in the area of civil protection is the conservation of the privacy of the different organisms involved in such type of operations. Normally in such operations are involved different types of entities, with different types of responsibility. The same is applied to the agents in the OT, but with a difference, the LCRO agent is the only agent in the field, independently of the different type of agent, that must know everything that occur in his OT, in other words all the information transacted in the field is sent to the LCRO mandatorily.

In Figure 18 is exemplified the different levels of privacy in one Operations Theater. In Entities section, the national department or national command center of one determined entity, have the privileges to receive of all activities related to all active occurrences in national range. The District/Region Department view, have knowledge about the active occurrences in their region or district area. The Department view, only have knowledge of active occurrences operations in entity location range under its responsibility. The Public Service, was applied more restricted data filter, once its oriented to the public users, the information provided must be resumed and useful. This public service only shows basic

information about the occurrences near user location and the hazards inherent to the emergency event. In agents side, the simple agent only knows the location of the occurrence, the epicenter of the occurrence, graphical information of the SitPo sent by all agents, the SitPo's description submitted the LCRO Agent, meaning, that the agent have no knowledge about the other agent location, besides the LCRO. This measure was based, by the hierarchical organization principles that prevail in emergency response process. The LCRO is only the one view, which has privileges to see all the activity related to the emergency response process in their OT. The LCRO agent can also have access, to all the activities and events information, resulted by the emergency response procedures performed by agents under another entities tutelage, that are operating in same LCRO OT.

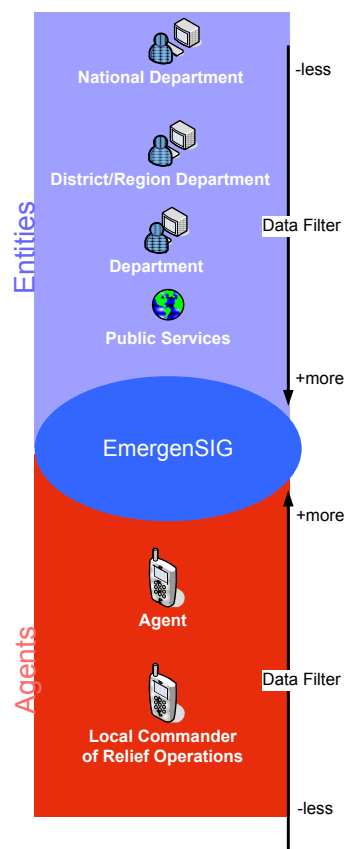


Figure 18 - Entities and Agents Privacy.

4.8 Functionalities

In this section, is presented in

Table 1. It resumes the EmergenSIG provided functionalities and their user targets. In the table, is possible to observe, the Hospital View. The view, have less functionalities than the others actors, due to the occurrence data privacy applied, which respects the limits of the entities responsibility on the civil protection. Furthermore, the view is defined only to follow the patient health state, since the agent defined the hospital, as the patient health care destination. Thus, the hospital only receives specific agent locations and their status, after the agents are on the way to the hospital facilities. This view, also receives occurrence information such as estimated time for the agent arrival and all SitPo's sent during the patient transportation.

The general entity view, receives the location and the status changes of the agents under their tutelage, receives their own inserted interest points, specific occurrence information, inserted geographic interest points. It is also provided a set of management functionalities allowing to the entity final user to insert, edit, delete operational data, such vehicles, agents accounts and devices permissions.

Furthermore, the entities have all access to the occurrence events history functionality, that begins on the territory under their responsibility and have at least one of their agent operating. This functionalities, is designed to allow the entities control the agents locations and actions over the duration of the emergency response process. The information retrieved can also be oriented to academic and research purposes.

The agents are allowed to send SitPo's, their operational status, their updated location, and LCRO status requests. It also receives the LCRO agent location, receive the path to the OT epicenter, receive geographic

interest points and operational data. In this view, the operational data consists, on the list of the operational vehicles available in the moment (for the agent selection).

The LCRO agent, is the only view that are allowed to receive LCRO requests, and having privileges to answer them. The LCRO agent can send an general SitPo, their operational status, and their updated location. It also receives, other agents (same OT) locations and their status changes, geographic interest points, operational data inserted by their own entity, and all the occurrence information provided by all agents in the OT.

Functionalities	Actors			
	LCRO	Agent	Entity	Hospital
Receive LCRO request	✓			
Send OT Situation Point (SitPo)	✓	✓		
Send Agent Status Data	✓	✓		
Send Agent Location	✓	✓		
Receive Specific Agent Locations	✓	✓	✓	✓
Receive Tracking Paths		✓		
Receive Specific Agent Status Data	✓	✓	✓	✓
Receive Specific Geographic Interest Points	✓	✓	✓	
Receive Specific Occurrence Information	✓	✓	✓	✓
Insert Geographic Interest Points			✓	
Receive Operational Data	✓	✓		
Insert Operational Data			✓	
Send LCRO request		✓		
OT History			✓	

Table 1 - Functionalities and their actors.

5. System Demonstration

This chapter focuses on the application functionalities demonstration using print screens of the windows that make up the EmergenSIG mobile application, through the Android activities screens and system functionalities demonstration.

5.1 EmergenSIG Mobile Application

The EmergenSIG Mobile Application targets mobile devices running Android platform, but can be easily reproduced to other mobile operating system, such as iOS, Windows Phone, etc. This solution was also designed to support more modules of emergencies, other than the two modules explained and described in this thesis, wildfire and health emergencies. The emergency modules or SitPo modules are independent parts of the algorithm, which can be deployed in any time in the mobile application, through a self-update functionality, without having the necessity to change the application base structure, in order to apply new SitPo features. For this motive, the EmergenSIG system is considered as framework.

The EmergenSIG user interface is simple, uses large buttons, includes appropriated size for fingers use, and is customized according to the sizes of different screen devices. An arm accessory sustains the mobile device providing an excellent position for information access and interaction. Figure 19 presents a firefighter agent using the EmergenSIG application.



Figure 19- Example of an agent using the EmergenSIG mobile application.

The application requires user authentication. Credentials are created by the EmergenSIG Web application (entity view) and shared only with the proper agent. This procedure allows entities to control improper actions from their agents, allowing to block agents devices(Figure 10) After the procedures, the mobile application communicates with the EmergenSIG web service, with the credentials provided by the entity. After the positive validation, the system returns an Hash token similar as the Universally Unique Identifier (UUID) [61]. Thereafter, the system record the hash token in the system. The hash only can be readable by the EmergenSIG mobile application. In every login procedure the EmergenSIG system checks the validity of the recorded hash, and determine whether the device is blocked or not.

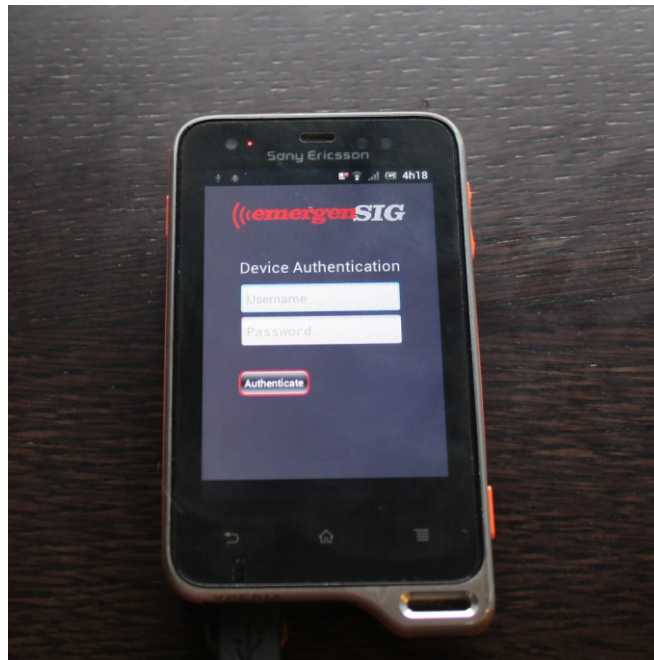


Figure 20 - Device Authentication functionality.

Login activity (Figure 21) allows a registered agent to access into the EmergenSIG mobile application. After a successful login, the EmergenSIG process a temporarily hash token, that allow the system to have only one active session every time, in other words, the system do not allow two simultaneous active sessions of one user (agent). In order to achieve the maximum simplicity on the login procedure, the EmergenSIG allows the user to use simple username and passwords tokens, in order to promote quick credentials submission and validation. This method is only possible by a submission of the recorded device hash token plus the user credentials trough the web service, allowing the recognition of the entity of the device and the agent entity. The system only needs to find the user in the list of all agent of the respective entity and not in the list of all agents of the EmergenSIG system, resulting in short username and passwords to the agents credentials validation, maintaining the security of those.



Figure 21 - Login Functionality.

The operational methodologies of the entities that represents the civil protection in any country, is constantly changing over the years. Then, any system that supports operations in the field must adapt and always be updated. For this reason, a self-update tool was developed. Figure 22 shows the steps of the self-update functionality. On the right the application, recognizes a new version available and request to the user if he wants to update the application in that moment. After the agent accepting, the application performs a quick download (in normal conditions 2-3 seconds), and asks the user, if he wants to update the application (in the right). This self-update, have mandatory character, to prevent future mismatches of information in the system, thus causing misunderstand between agents during the operations.



Figure 22 - Application Self-Update Functionality.

Afterwards the agent must select a vehicle, as shown on Figure 23. This activity presents only the vehicles of their department that are available at that moment. This activity, requested by the web service, presents the list of the vehicles available in every 2 seconds, that can hold a significant data transaction during the time when the agent are choosing the vehicle. However, normally, this activity is realized in the agent base, where the mobile application can have Wi-Fi connection, minimizing this way the costs of data transaction by the GSM module.

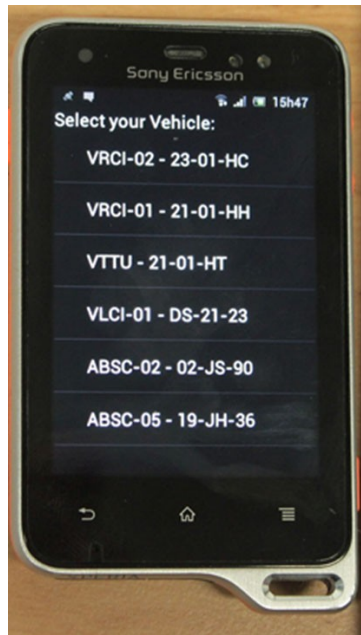


Figure 23- Selection of the Vehicle functionality.

After vehicle selection, the agent must select if wants to create a new occurrence or select a active occurrence that was created by another agent of the same entity through EmergenSIG mobile application (Figure 24 on the left), furthermore is available other functionality "*last occurrence selected*" that allows the user to recover the last active state of the agent. This functionality was thought to provide a quick solution to the agent recover in cases that the mobile application suffers as unexpected shutdown or when the agent is logged in other device and want to restore his last active state. The Figure 24 (on the right) illustrates the functionality that allows to the agent, select the emergency occurrence type, which want to create. The list of available occurrences types is provided by the SitPo module taking into account their availability. After the selection of the Emergency type the agent must insert the occurrence ID, provided by the DCRO's or by the GCUP's response centers.

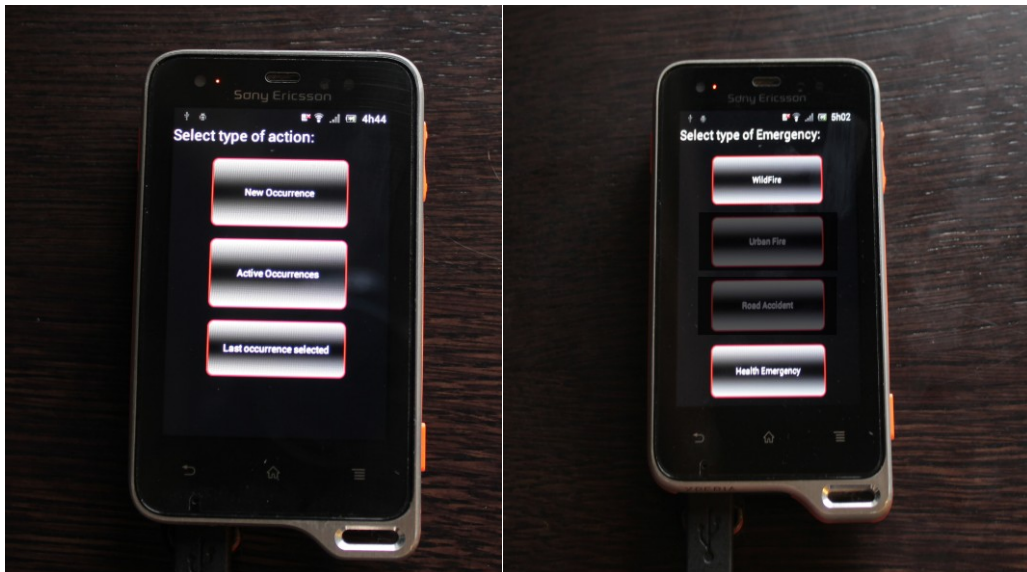


Figure 24 - On the left the selection of the type of action interface, and on the right the selection of the type of the emergency interface.

The Figure 25 shows the activity that enables the agent to select the current incident, this operation is synced with the server, every 2 seconds. The occurrences listed, are the occurrences that are created by the agents of the same entity, also enables the agent to have the option to insert the occurrence ID (GCUP or DCRO), allowing to the user, selection of an occurrence created by agents of different entities. The ID is the identification number of the occurrence, and their selection is only available when the occurrence is still active. This functionality can aggregate every agent in the EmergenSIG system, in one selected occurrence, allowing this way the collaboration between the agents of different entities.

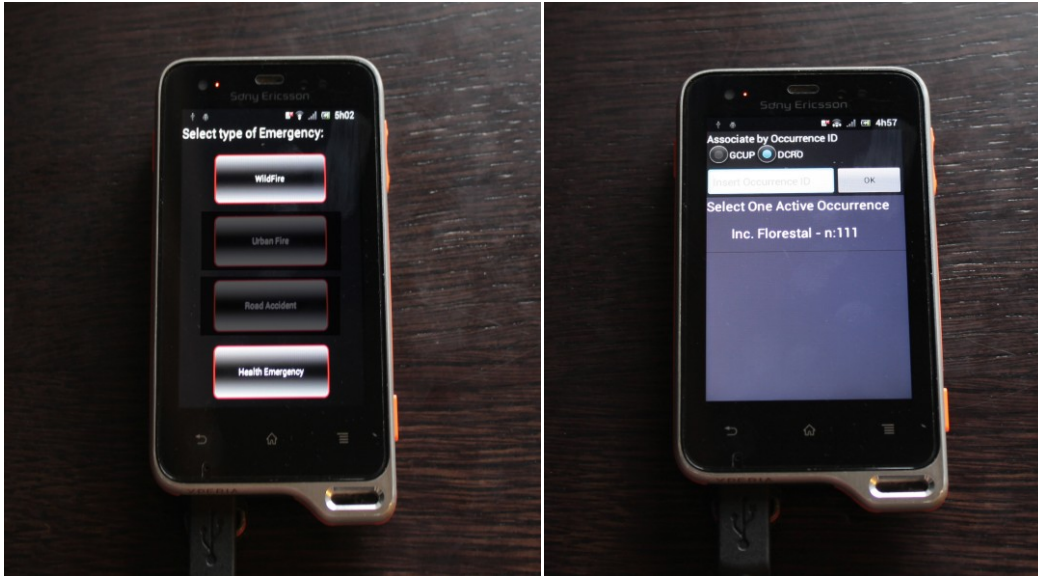


Figure 25 - Select Active Occurrence Functionality.

In Figure 26 - Operational Interface. Figure 26, shows the operational Interface oriented to the agents. The interface provides current map, with different zoom levels and different view angles. Also provides two menus, one on the top of the interface and other on the bottom, keeping this way a simple interface and user friendly. On the top, there are disposed the most useful operational functions oriented to the agent operations. On the bottom is available the agent status functionalities and the SitPo functionality with large button.

Top menu:

LCRO request, provides to the agent, the possibility to send LCRO request to the current LCRO agent. Occurrence Info, provides to the agent, all the information about the OT, according the agent current privileges. OT path, allow the agent, to receive the path to the epicenter of the OT. Economic mode, represented by I/O (activated/deactivated). This mode, when activated, reduces the data transmission over GSM, by blocking all the requests responsible to receive data, about others vehicles and occurrence. This mode only send the location of the vehicle, every 10 meters traveled by the agent.

Bottom menu:

Green line request- Allow the agent to send the green line alarm to the hospital, when the patient is on the way to the selected hospital. Available, send available status to the system, in order to inform their entity and the LCRO agent, that the agent exit from the occurrence and he is available. Way to hospital, this functionality, allow the agent to specify the hospital so that the agent is directed. In local, send the "In local" status, due to inform the LCRO and respective entities, of that agent arrived to the OT. Send Situation Point (SitPo), allow the agent to send precise information about the evolution of the occurrence, in order to inform the LCRO and respective entities. Additionally, is presented the current velocity of the agent, bellow the superior menu. To activate any these functions, the agent must confirm their action, preventing this way, any accidental action.

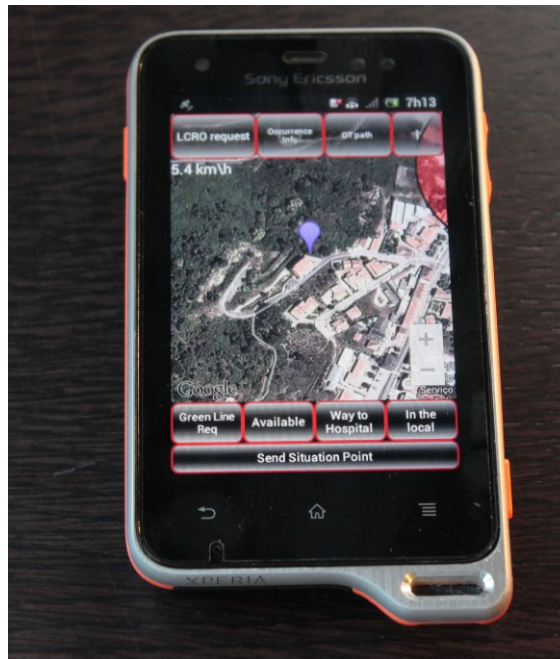
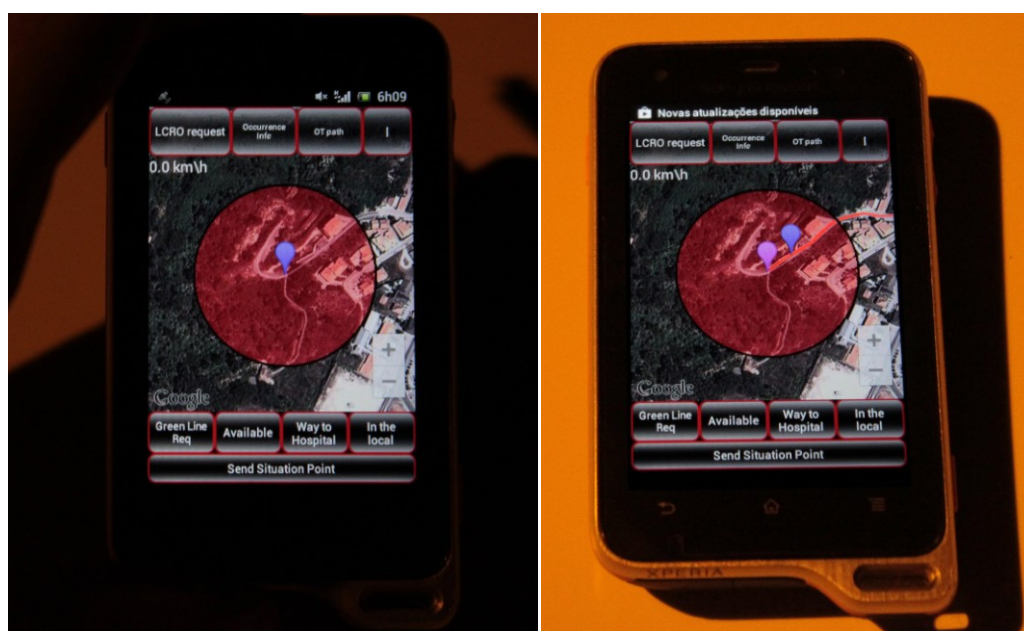


Figure 26 - Operational Interface

In Figure 27, shows the location of the epicenter and danger zone of an occurrence. This red circle is drawn by taking into account the position of the agent, after submit the "In local" status. The red circle represents the danger zone and is showed to other units in the same OT, to the LCRO agent and the respective entities. In the right of the Figure 27, is shown the path of the first unit that traveled to reach the epicenter of the OT, in order to inform others agents, about one possible path to reach the epicenter of the OT. The path is drawn after the agent pushes the "OT path" button in superior menu.



a)

b)

Figure 27 - Operational Interface showing the epicenter of the danger zone (a) and the path (red line) to the epicenter of the OT (b).

Figure 28 shows the different views for three agents into same OT. On the middle is shown the LCRO view, where is represented all operational agents in the respective OT, represented in red markers. In this figure are shown the different positions of the agents in the OT. Every agents without LCRO privileges (left and right devices in Figure 28), only

can see the LCRO position (red marker), in order to inform all units where is the LCRO location. This way, all agents have the possibility to move to LCRO position, for making face-to-face meeting, if necessary. In the red marker, is represented the other agents location, in blue marker the own current position in the map. After click in any red marker is shown in the dialog (above the marker) the designation of the agent and their entity. (e.g., VLCI-01 B.V Belmonte, VLCI-02 B.V Belmonte and VTTU-01 B.V Belmonte). These functionalities also have the ability to detect police and medical/nurse staff in the occurrence, by highlight the location of them with personalized markers. If one police agent is present on the occurrence, the application set the marker into blue color with a "star" shape, and if one vehicle transport, medical/nurse agent, the application, represents the vehicle location with a yellow color, same color of INEM vehicles, in order to quick identification of the medic or nurse agent.



Figure 28 - Different views for three agents into same OT. In the middle shows the LCRO agent.

In Figure 29, is figured the two different types of SitPo, currently available on the EmergenSIG mobile application, the Wildfire SitPo form (Figure 29 on the right) and the health emergency SitPo form (Figure 29 on the left). The SitPo forms, provides to the agent a very quick and effective method to send information about what the agent is seeing, describing this way the current situation of the occurrence.

In the **Wildfire Emergency SitPo** form, is possible to describe the wildfire situation, trough the information:

- **Current State of the Occurrence** - Describe the current state of the occurrence, by selecting one of these several options: In progress (Active), in resolution (Dominated), in conclusion (Aftermath) or Finalized (Extinct).
- **Intensity of the fire** - Describe the intensity of the fire, by selecting one of these options: Low Intensity or High Intensity.
- **Type of fuel** - Describe the type of fuel, by selecting one of these options: Pine Forest, Bush, Agriculture, Mixture, or Eucalyptal.
- **Geography of the terrain**- Describe the type of geography, the options: Smooth slope, Sharp slope, Moderate slope and Flat terrain.
- **Access condition** - Describe the access condition of the OT, the listed options: Good, Difficult, Asphalted road, Dirt roads, Without access and Rough terrain.
- **Sensitive infrastructures** - Describe sensitive and threatened infrastructures, the available options: None, Habitations, Commercial, Industry and Mixed.
- **Flank** -Describe operational location of the agent, by selecting the defined flank, the options: A, B, C, etc.
- **Temperature** - Describe the Ambient temperature.
- **Wind Velocity** -Describe an interval of the wind velocity (Min-Max).

- **I'm doing** - Describe the current procedure adopted by the agent, the available options Head Attack, Cooling, Flank Attack and Sensitive point defense.
- **Require-** Allow the user to require more support units, **by inserting the quantity of:** Combat brigades, Aerial Vehicles and Combat group.
- **Orientation** - The orientation is collected by the internal sensor (compass) of the mobile device. In order to send the Wildfire SitPo. The agent, must target the top of mobile device to the orientation of the evolution of the fire, while the agent is submitting the SitPo data.

The **Health Emergency SitPo** form is composed by:

- **Name** - Input form designed to identify the patient
- **Age** - Age of the patient
- **Sex** - Specify the sex of the patient, by selecting one of these option: Male or Female.
- **Saturation** - Depict Level of oxygen in the patient blood
- **Glycemia** -Describes the Glucose concentration in the blood
- **Temperature** -Describes the patient body temperature.
- **Pulse** - Information about the patient heart rhythm
- **Blood Pressure** - Describes the patient blood pressure by inserting two parameters: Systolic and Diastolic values.
- **State of consciousness** - Describes the state of the patient by selecting one of the two options available: Conscious or Unconscious
- **Breath** -Inform if the patient is breathing, by selecting yes or no options.
- **Pupils** - Describes the pupil's reaction of the patient, by selecting one of the two options available: Contracted or Dilated.
- **Procedures** - Describes the procedures performed by the agent, until the moment.

- **Complaints** - Describes the patient complaints.
- **Skin** - Describes the patient skin state.
- **Shock** - Confirm if the patient is in shock or not.
- **Type of lesion** - Form designed to describe the patient lesions. The agent must insert the anatomical location of the different lesions. They are: Open Wounds, closed Wounds, burns, fractures and bleedings.

Figure 29 - The SitPo forms. On the left SitPo forms oriented to Health Emergencies, on the right the SitPo form oriented to WildFires.

In the EmergenSIG mobile application, all agents that are operating in the same OT must have general and singular knowledge about the

current reality of emergency OT and their evolution. In Figure 30, is possible to view the Occurrence Information interface, divided by three different tabs. The first (Car Symbol), shows all the vehicles and agents, who are involved into the emergency operations, grouped by the Agents/Vehicles, who are on the way and the Agents/Vehicles currently in the OT. The second tab (Info Symbol) shows the timeline of information related to the occurrence, which will be filtered according the privileges of each agent. The information can be about the occurrence, LCRO agent and SitPo's data sent by other agents. The third tab (Satellite Symbol), show the current information about the state of device GPS module, such as latitude, longitude, velocity, altitude and precision of the coordinates calculation.

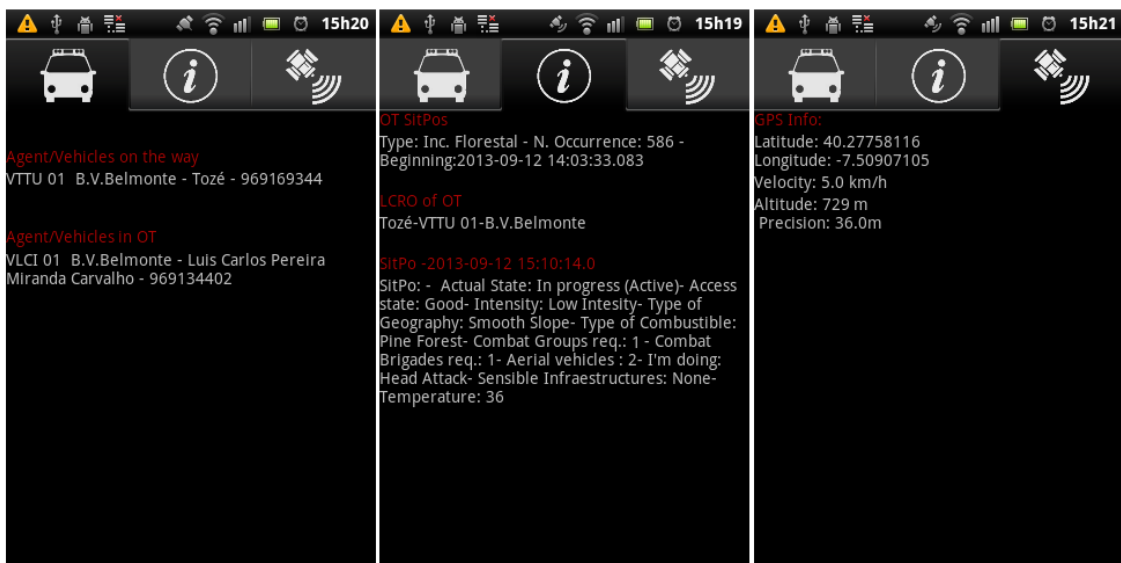


Figure 30 - Occurrence Information interface.

Figure 31 demonstrates the level of detail of information received by LCRO. Only the LCRO of the OT and the respective entities, can view and record the vehicles/agents status, as well all SitPo data submitted by other agents in the OT, unlike the simple agents, that only have privileges to view SitPo data sent by the LCROs agents, view the OT information and LCRO information, as shown on the center of the Figure 30.



Figure 31 - LCRO view of the occurrence information interface.

In Figure 32, show the LCRO status request dialog in the LCRO agent view. The dialog is triggered when any agent submits the request, by clicking the LCRO request button in the superior menu. Furthermore, the dialog is shown to the current LCRO agent, allowing to the LCRO agent, accept or denied the status transfer. This functionality was developed, by taking into account the real procedures in the real emergency scenario operations, wherein this operation is made by face-to-face, by the involved agents. After the LCRO accept the request the agent requester becomes the new LCRO of the OT, and .the old LCRO becomes simple agent. To achieve the simplicity of this procedure, the LCRO must be informed about

the name of the agent requester, the graduation and the agent entity, in order to identify the requester.

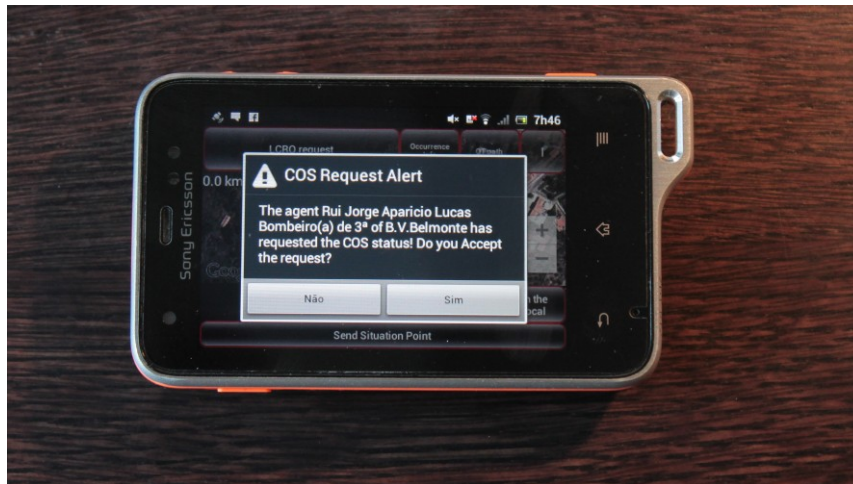


Figure 32 - LCRO status request dialog.

In Figure 33, shows the interface of the "Way to hospital" functionality. This functionality shows the ten more nearest hospitals of the current agent location. After the agent, selected the addressee hospital, is sent to system the new agent status. This functionality is important, due to define the addressee hospital, of the green line request functionality, which the hospital in question is informed about the alarm. Therefore, the "green line request" functionality is only available after the addressee hospital selection. The distance calculation is madden by using the Euclidean distance equation.

$$dist((x, y), (a, b)) = \sqrt{(x - a)^2 + (y - b)^2} \quad (1)$$

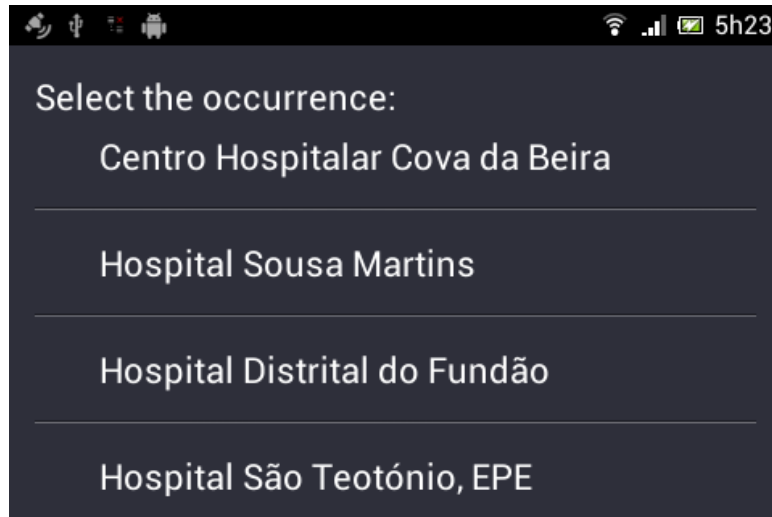


Figure 33 - Way to hospital functionality.

Figure 34 shows the SitPo functionality oriented to Wildfires emergencies, which consist on one of the main contributions presented in this dissertation. In such type of emergencies, is important to locate, and inform to other agents on the ground the evolution of the fire, preventing this way, the possibility of the agents being blocked by the fire during the operations. This allows the agent, to gather more geographical knowledge about the progression of the wildfire, and determine the future hazards by the possible progression of the fire, e.g. habitations, commercial buildings, industrial buildings, governmental buildings, etc. To show the SitPo forms, the mobile application, drawn triangle shapes over the map, indicating to the agent, the location of the SitPo sent and their orientation.



Figure 34 - SitPo handler module functionality.

The orientation of the triangle shapes is provided by the SitPo handler module, which process the SitPo's forms submitted by the agents. The length of the triangle shapes are drawn according the Wildfire Progression Velocity estimations in Table 2 [62], where is possible to calculate the estimation of the fire progression distance by taking the wind velocity by the Wildfire SitPo submitted. For example, in fires with winds of 15 km/h, the fire in one hour can reach a extension of 450 meters. This graphical information is targeted to all agents that are operating in any wildfire OT. Other approaches to calculate more efficiently the fire progression, was been taken account such [63], [64] and [65], although not been applied, due to two factors. These type of algorithms must have more process capabilities than the smartphones, in order to grant quick and effective responses. For the implementation of these algorithms the agents must have strong knowledge of the numerous different types of fuel, most of them, practically difficult to distinguish timely. Other reason, concerns

the fact, that the EmergenSIG system, was developed by adopting the User-Centered design, whereby the system must adopt the typical procedures associated to the pre-defined agents emergency response protocols.

WildFire Progression Velocity		
Wind Velocity	Vel. WildFire	Distance Militar Map 1/25000
(km/hour)	(m/hour)	(cm)
5	150	0,6
10	300	1,2
15	450	1,8
20	600	2,4
25	750	3
30	900	3,6
35	1050	4,2
40	1200	4,8
45	1350	5,4
50	1500	6
55	1650	6,6
60	1800	7,2
65	1950	7,8
70	2100	8,4

Table 2 - Wildfire Progression Velocity estimations[62].

In Figure 35, shows the location of Interest Point (Hydrants Spots), inserted by the entities of the district of the occurrence location, drawn over the map, in order to advertise the agents about interest points for their emergency response operations.

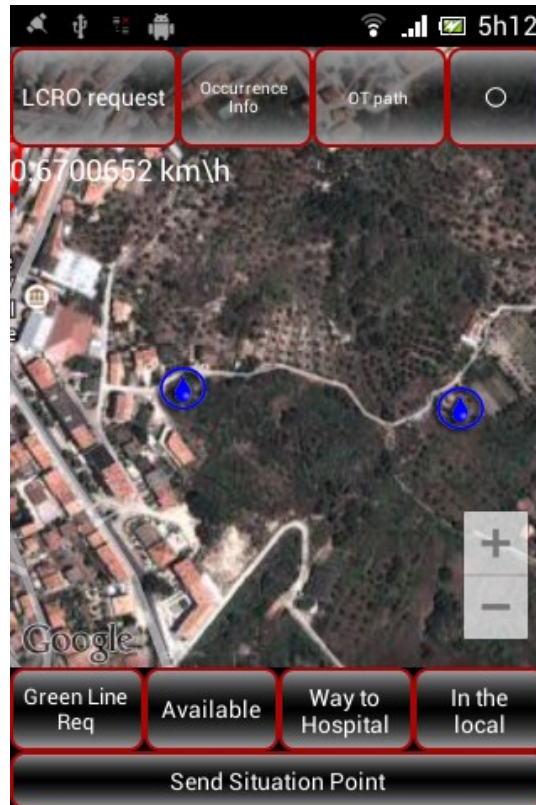


Figure 35 -Point of Interest example.

The available status is sent by clicking the "Available" button on inferior menu. After clicking the button, the system is aware, that the agent is available and is on the way to their base. For this reason, after the status submission, the application, blocks all functions, showing, only one dialog with "Ok" button, as figured on Figure 36. At the time, the agent arrive to its base, should press the "Ok" button, informing the system about his arrival. After the new status have been sent, the EmergenSIG mobile application, shuts down the occurrence for that agent.



Figure 36 - Available functionality.

5.2 EmergenSIG Web application

The web application EmergenSIG, was developed for entities responsible for the different agents present in current OT. As target, this interface proposed to provide to entities a collection of information that allows controlling and managing the agents in the OT. Resulting in a reduction of data transmission via radio. Consequently turn the communication between agents and entities more effective. In addition, the web application provides a set of management tools and other features, such as, devices registration, add vehicles, block devices, register agents, add interest points and record all events of the OT. The general interface (figured in Figure 37) is composed by four different sections. One represented on the top of the interface, assigned to welcome the user and provide a tool that allows the user to perform search for locations on the

map or logout the session. The interface items or menus are designed to be movable, ensuring the user-friendly interface when a lot of information is displayed in the interface. This functionality allows the user to move any section (less the top menu), in order to display all graphical operation data without any obstruction. It allows also the user to move the sections to other screen, in cases where the users have more than two screens. This interface is the same for all entities, such as NCRO, DCRO's, GCUP's and other entities, but with differences regarding to the information received. The NCRO interface receives all active occurrences at the national wide. The DCRO only receives the active occurrence at the district wide and in relation to fire departments. Moreover they only receive data from active occurrences in which at least one firefighter department is in operation in such occurrence or was created by. In its beginning, this interface triggers multiple request to the EmergenSIG REST web service (oriented to web browsers). These requests have intervals of 2 seconds, in order to take active occurrences in almost real-time. When the web application detects an active occurrence, the browser plays a characteristic sound to alert the user of a new occurrence that was just created by at least one agent. After the selection of one active occurrence, the system requests every 1 second new data about the occurrence. It also requests the current location of all agents in that OT, new SitPo's sent, new graphical information available, how many different vehicles are in the OT, how many vehicles are on the way, how many vehicles are available and the LCRO of the Occurrence. The web application has the capability to distinguish new information minimizing unnecessary computational resources and granting this way an interface more fluid and more intuitive. Otherwise, the web application would have to update all the different interface components giving the user a sense of data updating. Moreover under certain network velocities it can *froze* the interface due to the delay of asynchronous requests madden by AJAX (http requests). Preventing this problem ensures a more fluid interface to the user.

Figure 37 shows firefighters department interface with three active occurrences at the moment, with one Wildfire Emergency occurrence selected. This occurrence is displays two triangles shapes of two SitPo sent by the agent, represented in the red marker (Agent VLCO1- B.V. Belmonte).

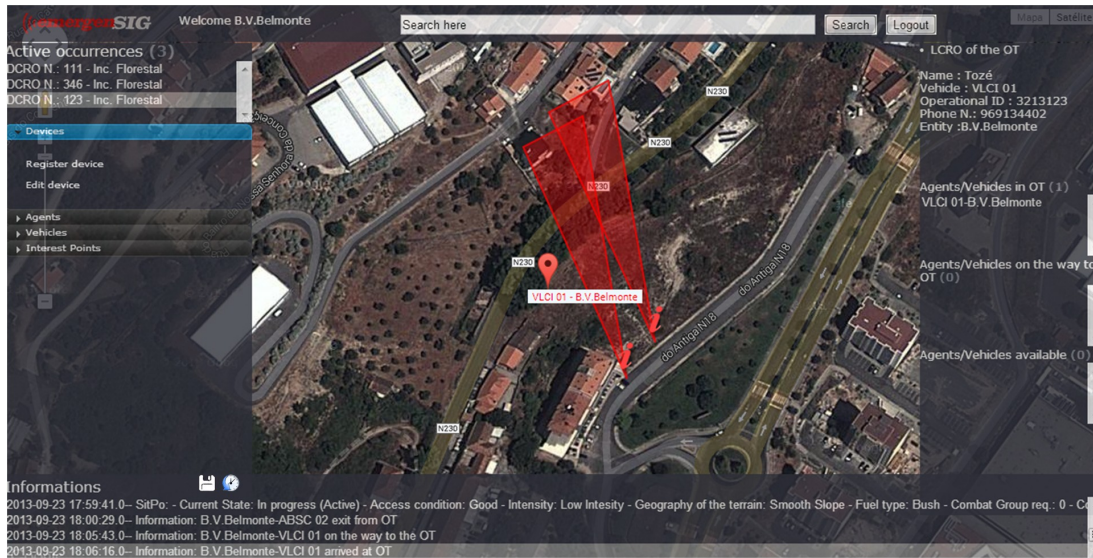


Figure 37 - Web application general interface.

Figure 38 presents a close up of the general interface left and right elements. The general interface left side menu disposed one section that lists all active occurrences, designated to the entity. This section allows the occurrence selection showing all related data. The section of the left menu is designed to provide to the entity user a set of functionalities such as, assign/edit/block/delete Devices, create/edit/block Agents, insert/edit/delete Entity Vehicles and Add/Delete Interest Points. On the right side of Figure 38, is shown the right side menu, designed to inform the entity about the number of agents involved in the selected active occurrence. The information is separated and listed by the different agent status at the moment, which are the agents/vehicles in the OT, the Agents/Vehicles on the way to the OT and, the agents/vehicles available. Such information, is composed by three different lists, where the agents

and their respective status are listed informing the entity about who they are and the quantity of agents with the specific status. After clicking the agent designation, the web application moves the "camera" of Google Maps API to the clicked agent location. On the top of right side menu is displayed the crucial information about the current LCRO Agent in the selected active occurrence (OT), such as the name, vehicle, phone number and their entity designation.

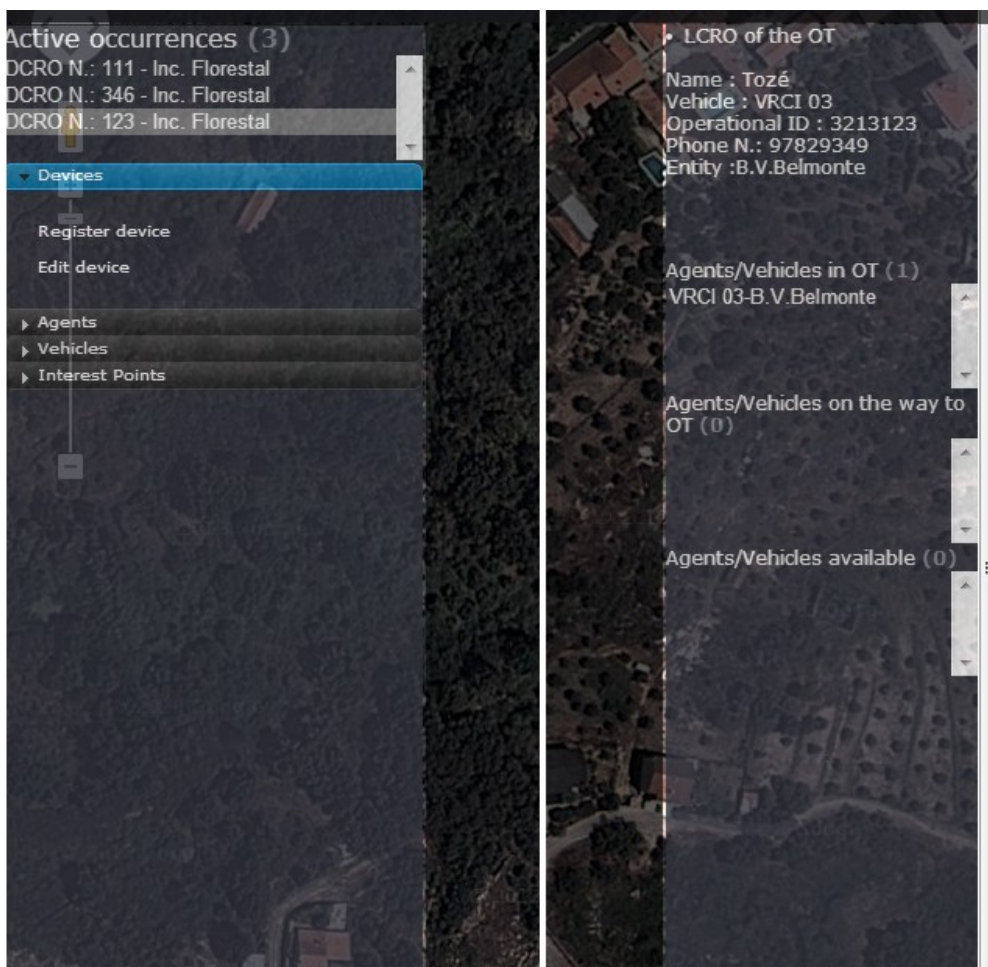


Figure 38 - Left menu and Right menu(respectively).

The bottom menu figured in Figure 39, is designed to list every event occurred in the selected active occurrence, thus creating an historic of all occurred events. The events listed can be agent's status changes and SitPo

forms submitted by the agents in the OT. The bottom menu (information), have two buttons on the top, the "floppy disk" icon and an "historic" icon.

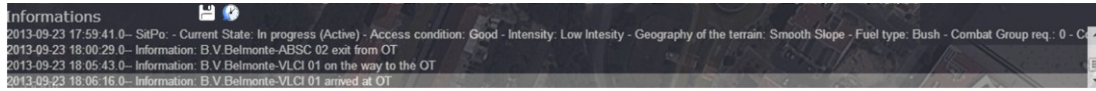


Figure 39- Bottom menu of general web interface.

The "floppy disk" icon, allow the user to save all OT history information about the occurrence in a .txt file (Figure 40).

```

2013-09-22 15:39:46.0-- Information: B.V.Belmonte-VLCI 01 on the way to the OT
2013-09-22 15:40:26.0-- Information: B.V.Belmonte-ABSC 02 on the way to the OT
2013-09-22 15:40:46.0-- Information: B.V.Belmonte-VRCI 03 on the way to the OT
2013-09-22 15:43:28.0-- Information: B.V.Belmonte-VLCI 01 arrived at OT
2013-09-22 15:44:08.0-- SitPo: Agent:B.V.Belmonte-VLCI 01 - Current State: In progress (Active)
- Access condition: Asphalted road - Intensity: High Intesity - Geography of the terrain: Smooth Slope
- Fuel type: Pine Forest - Combat Brigades req.: 1 - I'm doing: Head Attack - Sensitive infrastructures: None - Temperature: 36
2013-09-22 15:44:32.0-- Information: B.V.Belmonte-VRCI 03 arrived at OT
2013-09-22 16:01:21.0-- Information: B.V.Belmonte-ABSC 02 arrived at OT
2013-09-22 16:55:21.0-- SitPo: Agent:B.V.Belmonte-VLCI 01 - Current State: In progress (Active)
- Access condition: Good - Intensity: High Intesity - Geography of the terrain: Smooth Slope
- Fuel type: Pine Forest - I'm doing: Head Attack - Sensitive infrastructures: None
2013-09-22 04:46:32.0-- SitPo: Agent:B.V.Belmonte-VLCI 01 - Current State: In progress (Active)
- Access condition: Good - Intensity: Low Intesity - Geography of the terrain: Smooth Slope
- Fuel type: Pine Forest - I'm doing: Head Attack - Sensitive infrastructures: None
2013-09-22 06:02:24.0-- Information: B.V.Belmonte-ABSC 02 is available
2013-09-22 14:58:14.0-- Information: B.V.Belmonte-VLCI 01 is available
2013-09-22 06:02:24.0-- Information: B.V.Belmonte-ABSC 02 exit from OT
2013-09-22 14:58:14.0-- Information: B.V.Belmonte-VLCI 01 exit from OT
2013-09-23 04:18:05.0-- Information: B.V.Belmonte-VLCI 01 on the way to the OT
2013-09-23 04:22:39.0-- Information: B.V.Belmonte-ABSC 02 on the way to the OT
2013-09-23 04:46:49.0-- SitPo: Agent:B.V.Belmonte-VLCI 03 - Current State: In progress (Active)
- Access condition: Good - Intensity: Low Intesity - Geography of the terrain: Smooth Slope
- Fuel type: Pine Forest - I'm doing: Head Attack - Sensitive infrastructures: None
2013-09-23 04:47:26.0-- SitPo: Agent:B.V.Belmonte-VLCI 03 - Current State: In progress (Active)
- Access condition: Good - Intensity: Low Intesity - Geography of the terrain: Smooth Slope
- Fuel type: Pine Forest - I'm doing: Head Attack - Sensitive infrastructures: None
2013-09-23 05:44:32.0-- Information: B.V.Belmonte-ABSC 02 arrived at OT
2013-09-23 05:01:21.0-- Information: B.V.Belmonte-VLCI 01 arrived at OT

```

Figure 40 - Example of an OT history data in plain text.

The "historic" button allows the entity user to trigger the "OT history" timeline. This functionality shown in Figure 41 provides the entity user a view of all previous vehicles or agents' locations. Therefore is possible to record agent's locations during the period of emergency response. Providing this way important tools for research or investigation purposes, by giving important data of the evolution of the fire and the consequences of the measures taken in the emergency response process. When activated, this functionality shuts down the requests madden by AJAX. AJAX is responsible to refresh the current location of the vehicles and make a simple request to the Server. This request (presented in Figure 41, above the bottom menu) retrieves the location of vehicles on the

selected time defined by users, by selection of the time in the horizontal scrollbar presented in Figure 41 (above the bottom menu).

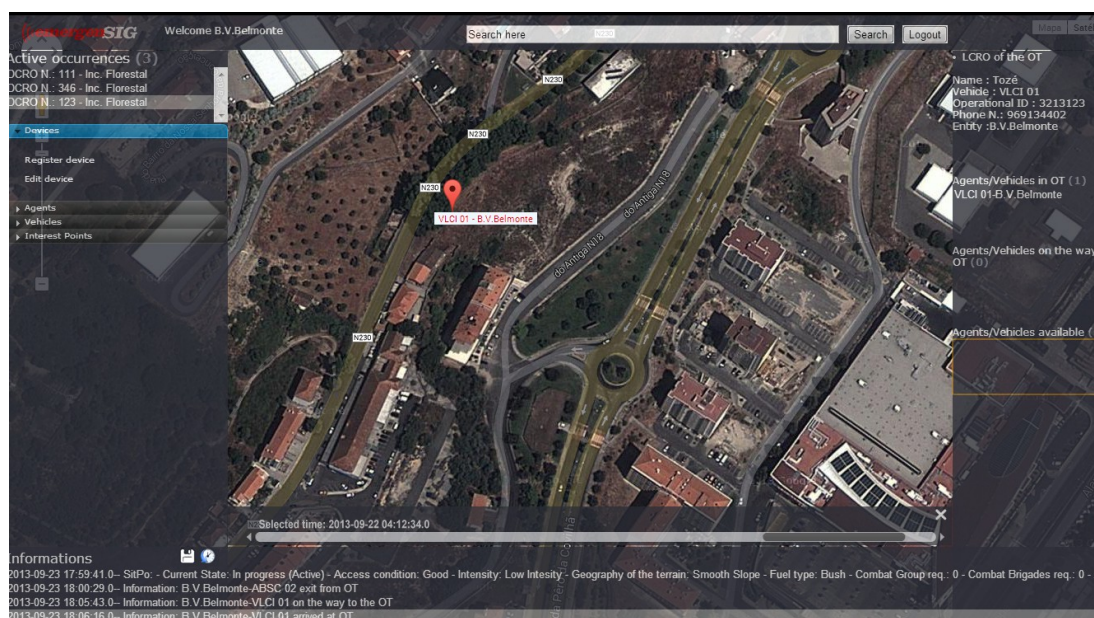


Figure 41 - OT History functionality.

The EmergenSIG Web application also provides content information about all graphical objects represented on the map. Figure 42 shows two triangle shapes, which represents the SitPo sent by the agents. Clicking above the shape triggers one info window, with all useful information for the entity. This information contains the coordinates of the SitPo, the information of the issuing agent and the data content of the SitPo, the orientation and the location of the submission. Other objects represented on the map, such as agent marker, also are clickable presenting the agent basic information.



Figure 42 - Example of the info window.

5.3 EmergenSIG Public Service

The EmergenSIG system also provides public services oriented to the general public. These services provide useful information about active occurrences in particular locations. This web service provides a JSON data, (show in Figure 43), where is listed two different active occurrences, a Wildfire emergency and a Medical emergency. This web service, receives two parameters, a district initial (E.g., District Castelo Branco is CB) and county initials (E.g., County Covilhã is CVL). The http url is defined for example by:

`http://localhost:30005/Emergensig_geral/webresources/com.emergen.occurrence/public_serv/CB,CVL? ,` Returning the JSON data shown in Figure 43.

The data returned contains information about the quantity of active occurrences in the location submitted such the occurrence location, the time that occurrence began, the designation of the occurrence, the quantity of vehicles involved, vehicles identification, SitPo of the occurrence and the information about the LCRO agent in the OT. In Medical

Emergencies, is not transmitted any SitPo information, due to the data privacy rights of the patient.

```
[
  {
    "longitude": "-7.35183904",
    "latitude": "40.35757017",
    "begin": "2013-09-23 14:30:25.0",
    "idOccurrence": 99,
    "design": "wildfire",
    "data": {
      "vehicles": [
        {
          "design": "VLCI 01",
          "entity": "B.V.Belmonte"
        },
        {
          "design": "VRCI 02",
          "entity": "B.V.Belmonte"
        },
        {
          "design": "VRCI 03",
          "entity": "B.V.Belmonte"
        }
      ]
    },
    "SitPo": [
      {
        "Type": "wildFire",
        "Keytime": "2013-09-23 15:40:26.0",
        "POSIT": {
          "Access": "Good",
          "direc": 211.84295654296875,
          "Fuel": "PineForest",
          "Sensible_Infraestructures": "None",
          "Intesity": "LowIntesity",
          "State": "Inprogress(Active)",
          "Geography": "Smoothslope",
          "wind_veloc": "12-20",
          "Doing": "HeadAttack"
        }
      }
    ],
    "LCRO": {
      "category": "Bombeiro(a)de3ª",
      "vehicle": "VLCI01",
      "name": "Tozé",
      "lcro_entity": "B.V.Belmonte"
    }
  },
  {
    "longitude": "-7.35173636",
    "latitude": "40.35827087",
    "idOccurrence": 111,
    "design": "Health Emergency",
    "begin": "2013-09-23 17:00:12.0",
    "data": {
      "vehicles": [
        {
          "design": "ABSC02",
          "entity": "B.V.Belmonte"
        }
      ]
    },
    "LCRO": {
      "category": "Bombeiro(a)de3ª",
      "vehicle": "VLCI01",
      "name": "LuisCarvalho",
      "lcro_entity": "B.V.Belmonte"
    }
  }
]
```

Figure 43 - Example of JSON data of an active occurrence.

This JSON data allows the public users to develop mini apps, that consumes the JSON data to provide to the public information, active occurrences near their location. Furthermore to aware the people of what it is happening on their location and also inform about the dangers relatives to the emergency scenario evolution.

5.4 EmergenSIG Web Interface for Medical Emergencies

The main goal of the Web application is to provide a set of tools that enables the control of agents in a mobility environment. Figure 44 presents the user's interface of the EmergenSIG Web application for Medical emergencies. This view informs the medical staff through visual and beep sound alarms who requested the green line and how long the ambulance takes to arrive at the hospital. Furthermore, it points the current geographic ambulance position and provides information, such as the patient state condition. At the bottom of the screen is shown the SitPo data and the patient health records submitted by the agent. The *green line* alarm dialog is triggered by any agent request. This dialog describes the information about the request and the vehicle that transports the patient.

Furthermore, it provides the direct link to more information about the patient health status, the agent, and the estimated time for the hospital arrival. Red dialog inform the medical staff, about who is the agent that send the green line alarm. Above the red dialog, is shown an dialog with the SitPo information, which describe the patient condition. This dialog appears after the click of the user in the SitPo information listed on the bottom menu of the interface.

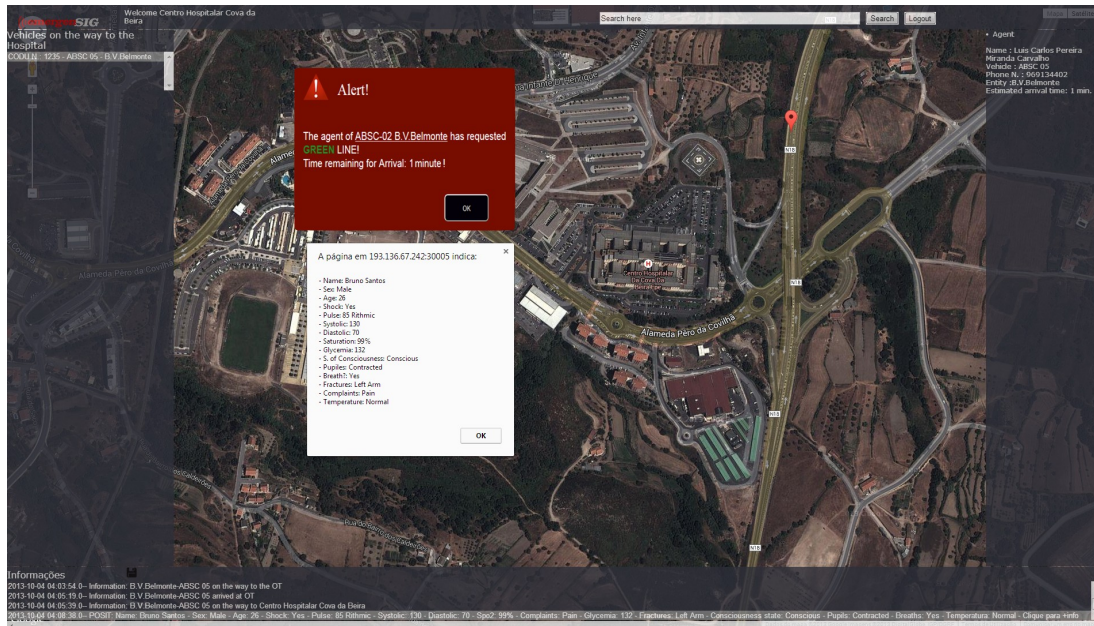


Figure 44 - EmergenSIG Web Interface for Medical Emergencies.

6. System Validation

This chapter focuses on the performance validation of EmergenSIG framework. Firstly it presents simulated cases scenarios, through simulated scenarios with real agents, in order to collect real operational data and simultaneously evaluating the system performance. Afterwards, the results of the EmergenSIG users surveys, accessing the user experience, are presented.

6.1 Simulated Cases Demonstration

This simulated case scenario, is a wildfire emergency and a Medical emergency scenario, involving real agents in duty. On all exercises it was possible to verify good integration of the EmergenSIG system with the agents.

6.1.1 Wildfire emergency response process with use of EmergenSIG system

The simulation begins with a phone call from the respective DCRO to the Firefighters department communications operator agent. The operator describes a wildfire occurrence in evolution, including its location and number identification. In that moment, is given the order to VRCI-01(vehicle) and their agents to move to the wildfire ignition location. One agent of VRCI-01 executes the login in EmergenSIG mobile application, selecting their vehicle and inserting the occurrence number. Automatically creating a new occurrence with the number inserted. The communication

operator is warned with buzz sound played by the EmergenSIG web application, warning that new occurrence was created by one of their Dpt. agents. While the agent is on the way to the emergency OT, the communications operator can see VRCI-01's real location on the web application's map. Few minutes after, the agent sends to the system the status "*In the local*". Immediately the EmergenSIG system defines the agent, as the OT's LCRO. The firefighters department is informed of the agent arrival on the OT. After the agent reached the site and sent a SitPo of the occurrence, it is requested more vehicles to support the emergency response process on the field. The DRCO and the firefighters department are informed about the actual situation of the wildfire evolution and the deflagration orientation (provided by the SitPo handlers). Immediately, it orders are given to VRCI-02 to proceed to the emergency site. One of the VRCI-02 agents did the login procedures, selected their vehicle on the list provided by the system, and selected the respective active occurrence of their Dpt., listed in the mobile application. Afterwards, DRCO, Firefighters Department and the new LCRO agent (agent of VRCI 01) were warned that the VRCI 02 was on the way to the occurrence to support VRCI 01. Through the mobile application, VRCI 02 agent requests the path made by VRCI-01 agent to reach the OT epicentre, in order to know how to reach the site. After following the "*red line*" path, the agent reaches the OT epicentre and presses the status "*In the local*". Firefighters department, DCRO and LCRO are informed about the new status sent by VRCI 02 agent. VRCI 02 agent submitted the LCRO request functionality; in that moment, VRCI 01 agent (current LCRO) is warned by the request with beeping sounds and vibrations and accepts the request. Simultaneously, the system changes the LCRO agent status of VRCI 02 agent, submitting a new occurrence SitPo. Firefighters Dpt. and DRCO are warned about the new occurrence SitPo sent. VRCI 01 agent are also informed, but only through "*Occurrence Info*" functionality, where it is only possible to see the last SitPo sent by the last LCRO agent. In SitPo form, it is described that the occurrence is dominated. VRCI 01 pressed status button "*Available*", and the system

informed DCRO, Firefighters Dpt. and LCRO that the agent are available and on the way to their operational base and on exit process of the OT. Afterwards, VRCI 02 sends an available status and the system close the wildfire occurrence playing the buzz sound in the entities view of EmergenSIG Web Application.

All the tasks in this demonstration have been performed with 100% of efficiency, with some communications delays, due to the beta edition of the EmergenSIG system.

6.1.2 Medical Emergency response process with use of EmergenSIG system

The exercise begins with a call made from GCUP to firefighters Dpt. informing a sudden illness situation in the region under responsibility of the firefighters Dpt. The GCUP informs the patient location and the occurrence identification number. The communication operator informs the personnel to attend to the patient location. Immediately, firefighters login in the EmergenSIG system, selecting the ambulance and creating the Health/Medical Emergency with the occurrence number provided by the GCUP. After that, firefighters Dpt. and GCUP are informed that the agent in the ambulance is "*on the way*" to the occurrence location. Moments later, the ambulance reached the patient location and the agent submitted the status "*in local*", informing GCUP and firefighters Dpt. of the new status submitted. After the patient health conditions evaluation has been made, the agent submitted the SitPo describing the patient health condition. It was possible to determine an anomaly in the cardiac rhythm and in the blood pressure. The firefighters Dpt. and the GCUP were informed about the patient health condition. The agent was ordered by GCUP to transport the patient to the nearest hospital facilities. The agent selected in the

EmergenSIG mobile app the nearest hospital of his location. After, was listed in ascending order the most five nearest hospitals from the agent location. After the hospital selection, firefighters Dpt. and GCUP were informed of the destination of the patient. The hospital was also informed about an ambulance of B.V. Belmonte, with one patient, was coming on the way to the hospital, and reported that it took 15 minutes to reach the hospital facilities. After 13 minutes, the patient health condition was unstable and suffers cardio-respiratory arrest.

The agent have submitted immediately the "*green line*" alert which triggers the alarm in the hospital's urgent care unit view, by an buzz beep sound play, and informed that the ambulance take two minutes to reach the facilities, giving enough time to the medical urgency professionals prepare the advanced life support room. After 2 minutes the ambulance reached the hospital facilities and the patient was transported to the advance life support room. Afterwards, the agent have submitted the status "*available*", immediately the hospital EmergenSIG web view close the occurrence, staying only active to the firefighters Dpt. and for GCUP view. The entities followed the path taken by the ambulance to their base until the ambulance reached their base, and the agent have pressed button "*Ok*" of the status functionality "*available*". Immediately, the occurrence is closed.

In these simulated scenarios, the hospital, GCUP, and the DCRO entities have been simulated by others agents with experience in order to make these exercises possible and reliable.

6.2 User Survey

The surveys where made in SurveyMonkey.com which provides free online questionnaire and survey software.

EmergenSIG Web and Mobile application have been deployed, configured, and was publicly accessible. A total of 38 firefighters of

Bombeiros Voluntários de Belmonte, Bombeiros Voluntários da Covilhã and Bombeiros Voluntários do Entroncamento have answered the survey questions. They have used the system for their own initiative and after approximately ten minutes of training for each one. The questions are shown in Table 3.

In Figure 45 and Table 4 it can be seen that the majority strongly agree that platform is useful for their purposes, the environment is user friendly intuitive and easy to use, text blocks are compact and with useful information, fonts are easy to read, the application help to understand the geographically reality of the occurrence and its evolution, and the application help the LCRO agent in the initial emergency response process.

Furthermore, in Figure 45, it is also possible to verify low ratings on questions 7 and 9. After all survey submissions, it has been made a quick briefing in order to record the reasons for the low ratings in the highlighted questions in above. For the low ratings in the Question 7, some users related that was due to some data communication delays issues caused by weak GSM signal in some locations, where the mobile application was tested. In Question 9, users considered that the actual operational protocols in tactical levels and the response capacity are well implemented by the Portuguese National Authority. Although the majority of users, classifies, that the EmergenSIG system helps in tactical procedures on the emergency initial response cases and in large scale emergencies with a large number of agents and entities involved.

Q1	Is the application useful for their purposes?
Q2	Is the application easy to use?
Q3	Does the application help the LCRO agent in the initial emergency response process?
Q4	Is the application environment user friendly and intuitive?
Q5	Text blocks are written in minimalist style. Are they compact and useful?
Q6	Are Fonts(style, color saturation) easy to read in screen?
Q7	Is the feedback and response time of the application fast enough?
Q8	Does the application help to understand the geographically reality of the occurrence and its evolution?
Q9	Does the application help in tactical procedures?

Table 3 - EmergenSIG Survey Questions

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9
Strongly agree	29	33	33	32	29	34	18	35	19
Agree	9	5	5	4	7	4	12	2	13
Tend to agree	0	0	0	2	2	0	7	1	6
Undecided	0	0	0	0	0	0	1	0	0
Tend to disagree	0	0	0	0	0	0	0	0	0
Disagree	0	0	0	0	0	0	0	0	0
Strongly disagree	0	0	0	0	0	0	0	0	0

Table 4 - EmergenSIG Survey Results

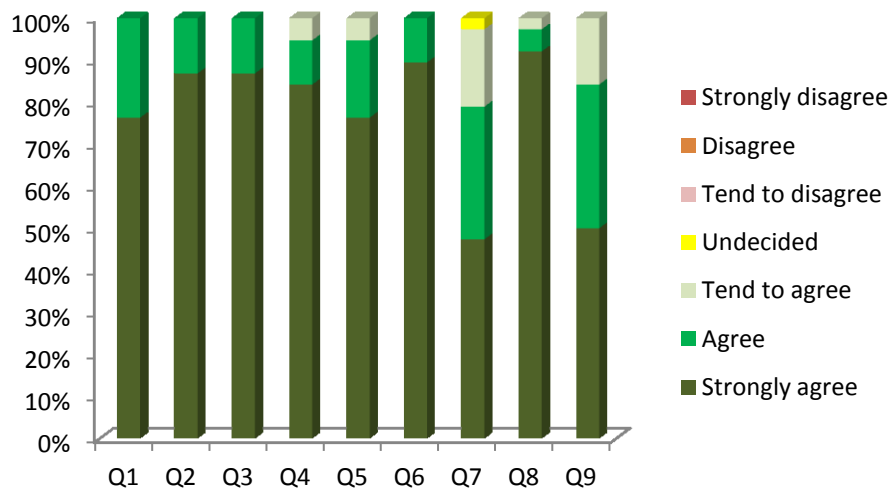


Figure 45 -Graph of EmergenSIG Survey Results

7. Conclusions and Future Work

This Chapter presents a synthesis of the main achievements and points several directions for future works.

7.1 Conclusions

This dissertation proposed the development of a ubiquitous solution of emergency management and location-aware system that promote the integration and cooperation of different types of agents and entities mobilized to an emergency scenario called EmergenSIG. This proposal presents two different modules, a Web application oriented to entities and a mobile application. Furthermore, it provides to field agents and other agent's location in almost real time, a collection of detailed data of the occurrence through the wildfire situation points and medical emergency SitPo. A useful solution oriented to the general public in order to provide useful information about the hazards, caused by the emergencies events, close the citizen locations was also presented.

Simulated emergency case studies with real agents on the ground were performed and presented. In these exercises the results were obtained with 100% efficiency with no messages lost. It was also possible to verify good integration of the application with the agents. A survey to evaluate the user experience was also applied to 38 users. The survey results are very positives concluding that EmergenSIG system helps on the

initial emergency response process. It is easy to use, user friendly and intuitive, and helps agents (LCRO) to understand the geographically reality of the occurrence in large-scale emergencies. Therefore, all the proposed objectives were successfully accomplished.

7.2 Future work

To conclude this dissertation, there are some suggestions for further research works:

- Extending the mobile application to other mobile operating systems.
- The algorithm development of the device accelerometer to motion detection on vehicles, in order to save energy expended on the continuous use of the GPS, due to the constant distance calculation.
- Development of solutions for EmergenSIG mobile application, in order to prevent connection failures in areas not covered by GSM networks.
- Development, of low cost self-update tool for offline mobile maps API, with current satellites images.
- The development, of algorithms to provide dynamic rate of data retrieving, to prevent unnecessary data refreshing cycles.

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Appendix



Welcome Centro Hospitalar Cova da Beira
 Vehicles on the way to the Hospital
 CODUM: 7235 - ABSC 05 - B.V.Belmonte

Search here Search Logout

Agent:
 Name: Luis Carlos Pereira
 Miranda Carvalho
 Vehicle: ABSC 05
 ID: 1330005
 EMB: B.V. Belmonte
 Estimated arrival time: 1 min.

Alert!
 The agent of ABSC-02 B.V.Belmonte has requested GREEN LINE!
 Time remaining for Arrival: 1 minute!

A página em 193.136.67.242:30005 indica:
 - Name: Bruno Santos
 - Sex: Male
 - Age: 26
 - Pulse: 85 Rhythmic
 - Systolic: 130
 - Diastolic: 70
 - Saturation: 95%
 - SpO2: 98%
 - GCS: Conscious: Conscious
 - Pupils: Contracted
 - Breath: Yes
 - Fractures: Left Arm
 - Complaints: Pain
 - Temperature: Normal

Informações
 2013-10-04 04:03:54.0 - Information: B.V.Belmonte-ABSC 05 on the way to the OT
 2013-10-04 04:05:19.0 - Information: B.V.Belmonte-ABSC 05 arrived at OT
 2013-10-04 04:05:39.0 - Information: B.V.Belmonte-ABSC 05 on the way to Centro Hospitalar Cova da Beira
 2013-10-04 04:08:38.0 - POSSIT: Name: Bruno Santos - Sex: Male - Age: 26 - Shock: Yes - Pulse: 85 Rhythmic - Systolic: 130 - Diastolic: 70 - SpO2: 98% - Complaints: Pain - Glycemia: 132 - Fractures: Left Arm - Consciousness state: Conscious - Pupils: Contracted - Breaths: Yes - Temperature: Normal - Clique para info