Satellite-Enabled eHealth Applications in Disaster Management-Experience from a Readiness Exercise

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Abstract

Despite progress in information and communication technologies (ICT), communication is still a bottleneck for health early warning and response systems. Satellite communications combined with a local WiFi network promise rapid deployment and facilitate coordinated response and optimal adjustment of resources for disaster management. In this paper, we present experiences with extending eHealth applications to support disaster medicine over an emergency hybrid satellite-WiFi infrastructure. The prehospital health emergency information system (PHEIS) of Crete was extended to provide mobile access to volunteer rescue workers and enable triage on the field. Moreover, an Electronic Health Record (EHR) system was extended for rapid entry of chronic diseases and medication needs, as well as epidemiology protocols through the SAFE system. Operational validation in a 2-day earthquake readiness exercise confirmed the effectiveness of PHEIS, while asserting the need for disaster-specific EHR workflows.

1. Introduction

Natural disasters, terrorist attacks, wars, and epidemics stress the health care system and the telecommunications infrastructure, at a time when coordinated response and optimal resource allocation are imperative. An overwhelming number of emergency calls further disrupts the operation of emergency services, response is delayed, and many calls for help remain unanswered. Satellite communications combined with a local WiFi network can be rapidly deployed to augment the stressed telecommunication infrastructure and facilitate the use of information technology [1]. Indeed, disaster situations can benefit from information technology and customized workflows that facilitated optimal adjustment of resources. Furthermore, relevant literature suggests that chronic conditions and cardiovascular programs are aggravated by stress and anxiety induced by the disaster [2-9]. Allegra et al. [2] report that 0-60 days after the 911 attack in the World Trade Center, the number of OEM admission to New York hospitals increased by 49%. Sato et al. [3] reported that after the Mid-Niigata earthquake (6.8R, 2004), emotional stress triggered increased incidence of "Tokotsoubo" cardiomyopathy to elderly women living near the epicentre. Furthermore, Vest et al. [9] note that health assessment is important for preparedness in situations where shelters host displaced individuals to identify their immediate needs, to record the scope of chronic conditions that need to be managed, and to provide critical information regarding health planning to the authorities.

The objective of this work is to assess the added value of eHealth applications enabled by hybrid satellite-WiFi networks for disaster medicine and to identify areas where further research work is needed. This paper investigates two specific eHealth application areas, emergency medical services and public health assessment. Specific emergency and health assessment workflows were designed, implemented, and validated in the readiness exercise. Firstly, the PHEIS at the emergency coordination center of Crete was extended to support triage by volunteers of the Hellenic Red Cross on the field. Secondly, a primary care EHR system was extended to support rapid health assessment on Personal Digital Assistants (PDA), and to create automatic reports on the health condition of its residents requesting the needed pharmaceutical supplies. The situational scenarios of the exercise simulated the events following a destructive earthquake addressing not only search & rescue operations in the acute phase (0-48 hours after the earthquake), but also public health assessment as well as an epidemiological crisis in a camp of displaced refugees.

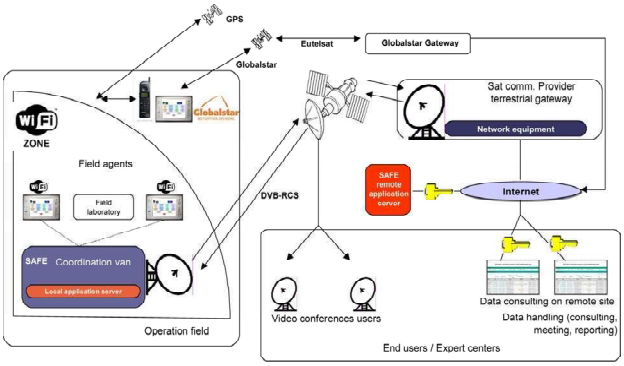

Figure 1. Overall SAFE architecture [10].

2. Methods

The emergency satellite-WiFi network infrastructure was provided by SAFE [10-11]. A coordination van equipped with DVB-RCS terminal and Internet access for communication with decision makers and expert centers, assumed the role of the local coordination centre. Communication between the local coordinator and the mobile teams on the field was ensured via a local WiFi network and satellite phones outside the WiFi coverage. A mobile field laboratory equipped with biological and biomedical equipment identified microbial agents responsible for the threats enabling in-situ analyses (see Figure 2). The SAFE epidemiological surveillance system offered data collection and geo-localisation capabilities to visualize the evolution of the epidemic and monitor the alarm levels associated with different geographical regions.

Figure 2. Emergency satellite-WiFi communication by SAFE.

The SAFE data collection system is the central component in managing the outbreak. It is based on open standards and can be interoperable with specific health information systems in the local health IT infrastructure, through specifically designed interfaces. In this way, it can facilitate monitoring of indicators and other measures potentially useful in modeling the transmission patterns. An interface was designed between the EHR system and SAFE to track suspicious cases and communicate information on raising alarm levels, to enable health early warning.

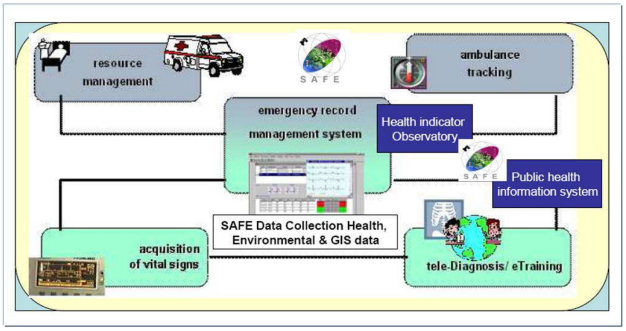

Figure 3. Overview of workflows incorporating emergency, public health assessment, and epidemiology.

2.1. Emergency workflow

The medical emergency coordination center of Crete is supported by PHEIS that offers online ambulance tracking, acquisition and transfer of vital signs en-route to the hospital and resource management (Figure 3). Telephone operators responding to 166 have two screens in front of them. The left screen shows triage protocols and the current episode card, while the right one shows the location of all ambulances on a map. The telephone operator answers the phone and following appropriate triage protocols fills in the emergency incident card and dispatches appropriate type of ambulances (see Figure 4).

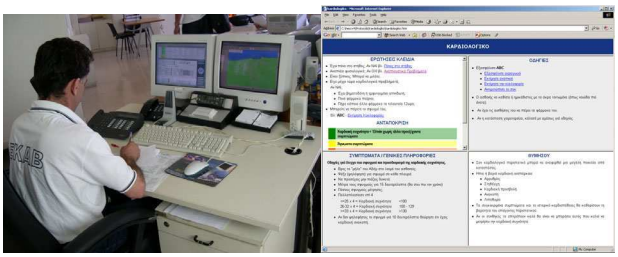

Figure 4. Telephone operators at the coordination center.

However, in disaster situations or other multi-victim accidents, this workflow is not effective. Thus, we designed a special front-end to the PHEIS, through which after initial confirmation, volunteers may enter episode triage information directly, assisting the telephone operators. This functionality is particularly important as it does not use the telephone network, but an emergency satellite network that does not depend on the telecommunication infrastructure (landlines or mobiles).

A second interface was created for the main hospitals to provide the emergency ward with information on the episodes that are currently en-route to the hospital for improved preparedness and resource management. The interface was implemented with web technologies and presented a summary view of currently dispatched episodes in a web page shown on a mounted monitor.

2.2. Health assessment workflow

Chronic health conditions may be triggered by stress or be aggravated by the disaster due to lack of prescription medicine, missed treatments due to shortage of trained physicians, etc. Moreover, the outbreak of an epidemic is quite likely due to suboptimal living conditions and damages in the infrastructure (e.g. water system/sewage). The EHR system was linked to a special PDA application for rapid health assessment, through the Person Identification Service of OMG [12]. The health assessment applications facilitated data entry of symptoms, common chronic diseases and medication needs, using standard coding systems (e.g. ICPC, ICD, etc). Upon request, an automated report was created reporting the cumulative needs of the camp to the health authorities, by email [13].

3. Results

The operational earthquake readiness exercise was carried out on November 5-6, 2007 with participation of more than 20 organizations and around 300 volunteers. The 1st day of the exercise dealt with the acute phase, while the 2nd day addressed issues of post disaster health management [14]. Figure 5 below shows the main scenarios and actors involved in 1st day of the exercise.

3.1. Acute phase: search & rescue

According to the scenario of the first day, following an earthquake 6,8R extensive damage is reported in the area of Heraklion, and the Central Coordination Body (CCB) is summoned at the Operations Center of the Civil Protection with representatives of the Regional Government of Crete (Civil Protection), the Prefecture, the Port Authority, the Fire Department & its Special Unit of Disaster Management, the Police Department, the Pre-Hospital Emergency Services, the Municipalities of Heraklion and Gazi, and the Hellenic Red Cross.

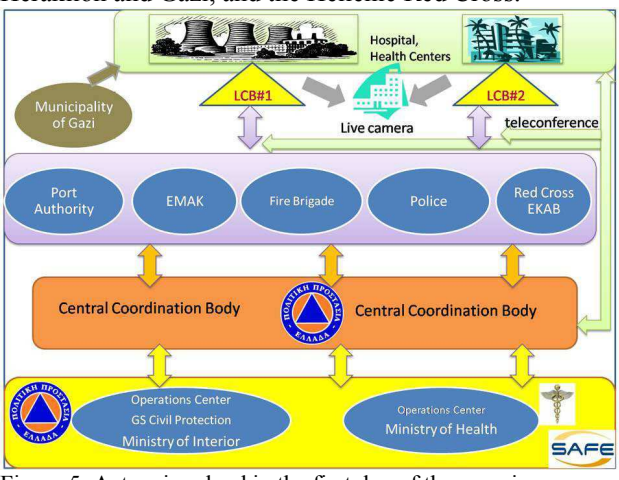

Figure 5. Actors involved in the first day of the exercise.

Power plant: As a result of the earthquake, there is explosion in an oil tank at the main power plant, followed by fire, an oil leak to the sea, and high environmental risk. Through coordinated efforts, volunteers assist the authorities to extinguish the fire, rescue the injured, and prevent potential environmental pollution. The CCB communicates with field agents via the coordination van. Volunteers of the Hellenic Red Cross and the Disaster Management unit engage in search & rescue operations. They use PDAs to perform triage and report the condition of the injured to the emergency services (see Figure 6). Vital signs of the injured are reported to medical experts, who offer remote guidance. The emergency satellite infrastructure provides connectivity to the coordination center and the emergency services via satellite terminals, bypassing the overloaded telecommunication network. The episodes entered on the PDAs by the volunteers of the Hellenic Red Cross, were processed by the operators at the emergency coordination center, and the central hospital was promptly notified of the pending arrivals.

Figure 6. Use of PDAs to perform on-line triage on the field.

Hotel: Later on the same day, in a large touristy hotel the scenario dictated fire, extensive damage in a hotel wing, activation of the evacuation plan, search & rescue operations. Volunteer fire-fighters put out the fire and the disaster unit of the fire brigade performed search & rescue. Once again emergency workers successfully performed triage using their PDAs. Expert centers supported the volunteers in clinical decision making by video-conferencing and in the case of a heavily wounded episode, the experts after reviewing her vital signs, suggested air evacuation that was promptly carried out.

3.2. Recording the needs of the population

On the 2nd day, an earthquake settlement is organized in the supporting facilities of the Pancretan Stadium by the Prefecture of Heraklion, the Hellenic Red Cross, the Regional Health Authority and the Municipality of Heraklion. The health needs of the population in the settlement are assessed using the EHR system and communicated to health authorities. Epidemiological

surveillance and health early warning used the SAFE system, while biological and environmental samples were analyzed in the mobile laboratory. A group of 10 volunteers reporting to the Head of the settlement, performed health assessment of the population. They used PDAs to collect demographics and health needs (chronic problems, medication) for all persons in the settlement, and emailed an automatically generated summary report to the health authorities.

Data collection on the PDAs was successful. However, data entry took longer than expected. Initially, coordination of the data collection team with the personnel at the entry point was not easy. On several occasions the management reverted to paper as the personnel was more comfortable with it. Automatic creation of the report to be transmitted to the OCCP was successful, but again delayed.

Integration with EHR system through PIDS was not stable, due to network fluctuation and latency problems. Clearly the applications were not configured for intermittent connectivity. Security measures in the WiFi network delayed the process of data entry. The application did not offer the option of disconnected operation and that was a significant disadvantage, compared to the SAFE data collection facility.

4. Discussion and conclusions

In the context of a 2-day earthquake readiness exercise in Crete Greece, the added value of satellite-enabled eHealth services was demonstrated revealing strengths and weaknesses of emergency IT services. The evaluation by the users was very positive. Vital signs and information on emergency episodes along with sights and sounds of the crisis were successfully transmitted to the coordination center of civil protection. However, the use of the EHR system over a hybrid satellite-WiFi network turned out to be challenging. Recording of health needs in PDAs took longer than expected. Disconnected operation, security and privacy, as well as usability of the relevant eHealth service needs to revisited.

The operation of information systems in disaster or post disaster situations needs to plan for intermittent connectivity taking into account in the design of the system, the delay induced by the satellite network. Thus, the main lesson for software engineers working to deliver systems suitable for disaster situations is that they have to design with resilience and robustness in mind. Simplicity is the key to user adoption, while power awareness and disconnected operation are critical features for disaster management systems.

Acknowledgements

The authors would like to thank the partners of the SAFE project, the volunteers that contributed to the success of this exercise, and the observers who provided valuable feedback.

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