Swift personal emergency help facilitated by the mobile cloud

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Abstract: Many emergency cases require the swiftest possible response from an appropriate medical service if they are not to become life-threatening. In the medical emergency field, response times to emergency cases are a major concern and gain a high degree of attention. Many of the systems proposed in the literature are either intended to replace the existing emergency system with a fully automated one, or build on unreliable or less efficient frameworks that are based on some sort of social media application, such as redirecting emergency requests to Facebook friends. We have designed a mobile cloud service that works side by side with the existing emergency system and is aimed at reducing the time spent waiting for emergency help to arrive, as well as making the best use of medical professionals who may be located in close proximity to the medical case. The experimental results show that the amount of time needed to find a medical professional and establish communication was between 4 and 25 seconds, depending on the communication method used. This result means that no extra time is added to the total medical response time and could enhance the chance of a better outcome.

Keywords: component; mobile; cloud; healthcare; medical emergency; help; doctors; nurses; SMS; medical response time.

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1 Introduction

Recent years have seen a significant increase in activity surrounding the adoption of information technology (IT) solutions in the healthcare sector (Jin and Chen, 2015; Talpur et al., 2015). These solutions are aimed at improving care services, as well as reducing the total cost of seeking/providing them. This integration has led to a new term in the healthcare field, 'm-health' (Medina et al., 2009). M-health stands for mobile health, which means providing health services to the public on the move.

Providing healthcare services to the public on an off-hospital basis reduces the pressure on health centres, whilst enabling people to continue managing their own health. The new mobile technologies have made a significant difference in emergency or special medical cases, such as heart-related incidents. If healthcare services can be made accessible through mobile devices, they can offer benefits such as health service provision anytime, anywhere. Furthermore, recent mobile devices can offer features such as a location service and wireless capability (Wi-Fi and Bluetooth).

However, mobile devices have limited resources, most importantly, limited battery life (Forman and Zahorjan, 1994). Mobile cloud computing (MCC) has recently been proposed as a solution to provide services to mobile devices (Fernando et al., 2013). The idea is to deploy the required services to the cloud, resulting in the shifting of resource-intensive and complex tasks to the cloud instead of executing them on the mobile devices themselves. MCC adds strong features to any system, such as high performance and reliability (Kumar et al., 2014). In practice, MCC has two definitions. First, deploying services in the cloud and making them accessible to mobile devices, where issues such as unstable storage and limited network resources can be dealt with (Dinh et al., 2013). Second, creating a cloud for mobile devices whereby these devices can benefit from sharing resources locally (Khalifa et al., 2014). For the purpose of our system, the first definition of MCC forms the basis of our system design.

In some cases, such as emergencies in which people can find themselves when they are on the move, the provision of healthcare services in the shortest possible period can be life-saving. A system that can support such a service requires unique features, such as availability, robustness, access to web/cloud information through different networking technologies (e.g., Wi-Fi and 3G), and the efficient management of mobile users.

As connectivity between users and a health service system is a key feature, in a previous paper (Alshareef and Grigoras, 2014), we introduced a mobile ad-hoc network (MANET) manager service hosted by the cloud that allows all mobile users to be reached, including those without cellular connectivity but who do have access to Wi-Fi. In a second paper (Alshareef and Grigoras, 2015a), we also proposed a robust management of active sessions between users who are connected to the same MANET to save mobile resources from being lost or misused. To ensure this, the progress of an active session is tracked and, as a result, if a break occurs, the session can be stored in the cloud and then resumed when the two users are active again. An example of such a session could be the sharing of a map file that includes directions for the nearest medical centre or an image that guides the user in how to deal with an emergency case.

In Alshareef and Grigoras (2015b), we introduced a novel system that provides healthcare services to people who are involved (either themselves or in helping others) in an emergency and are out of reach of home or office. These services are hosted in the cloud and can be accessed via mobile devices. The system consists of directories of medical practitioners: doctors, nurses, and medical organisations, such as emergency departments and medical centres, all of whom have volunteered to provide a first responder service. This service is based on availability and location, and aims at helping people in need as quickly as possible. This service is part of a larger system that has the goal of achieving an effective point-of-care system for people on the move (Alshareef, 2015).

This paper is an extended version of Alshareef and Grigoras (2015b) and offers the following new contributions:

1 Three examples of effective methods to seek help facilitated by the cloud are proposed to suit the requirements of each case, and include the smart detection of emergency medical situations using wearable medical devices.

2 An extension in the service evolution to capture the amount of time needed to establish communication between users and medical professionals using different communication methods. Further discussion is provided of the results collected, such as a comparison of the results with existing medical emergency systems.

3 A security enhancement for the proposed service.

The rest of the paper is organised as follows: Section 2 discusses research projects similar to this work; Section 3 presents some real-world scenarios and the paper's objective; Section 4 discusses the proposed system design and implementation; Section 5 discusses the security enhancement of our system; Section 6 outlines the experimental design; and Section 7 presents the experimental results and analysis. Finally, Section 8 presents our conclusions and future possibilities for research.

2 Background and related work

2.1 When cloud meets mobile devices to improve health services

The healthcare services can benefit of the cloud paradigm in many respects, such as on-demand self-service, ubiquitous network access, resource pooling, rapid elasticity, a pay-per-use model, and virtualisation (Chang et al., 2009; Bamiah et al., 2012; Pereira and Prata, 2015). Recently, cloud computing has been playing an important role in enhancing the development of healthcare information systems (Low and Chen, 2012). Furthermore, cloud-based health systems can provide easier access to medical data to reduce time and cost, as well as allow collaboration on and sharing of medical resources, information, and files.

When healthcare services are provided to mobile users, which is the main purpose of m-health, great benefits can be achieved, such as easy and quick access to medical resources (Medina et al., 2009). However, mobile devices have limited resources, such as battery lifetime, and suffer from a lack of reliability (Jemal et al., 2015). MCC can help deal with some of these limitations, by, for example, shifting heavy computational processes to the cloud (Barbera et al., 2013). Mobile devices can also store and access data in the cloud to improve reliability and storage capacity (Rahimi et al., 2014). Therefore, MCC has been found to be a suitable solution to known m-health shortcomings, such as small storage capacity and medical human error (Kopec et al., 2003).

2.2 *Similar projects and systems*

Some authors (Greer and Ngo, 2012) have discussed the design and integration of social networking applications with cloud computing and mobile technologies to provide a system that allows users to communicate during emergencies or disasters. A Facebook app is proposed in the paper to design a personal emergency preparedness plan (PEPP), which aims to allow users to collect geographical information, pictures and videos, along with any other data that may be useful in these kinds of situations. As shown in this paper, non-medical professionals (such as friends or family members) are connected to the user to provide help in emergency cases.

Elsewhere, a web service called CliniCloud (https://clinicloud.com) presents a medical kit that allows people to track their state of health using smartphones and store their data in the cloud. Users then have the ability to contact afterwards a service called ‘Doctor on Demand’ (http://www.doctorondemand.com). This service allows users on the move to start a video call with a doctor. This service is only available in the USA, and the system requires extra medical diagnostic equipment, which results in higher costs.

An Android-based emergency alarm and healthcare management system is presented by Du et al. (2011). The system aims to provide two main functions to users: a trigger alarm to friends or hospitals, and a life reminder feature to remind the user to take medicine on time. The authors discuss the benefits of integrating health systems on mobile phones, these advantages being portability, open operating systems, the use of the global positioning system (GPS) and the ability to detect events using a gravity sensor. The proposed system was tested on Android mobile phones and lab-based servers. However, this system only allows interactions with hospital-based medical staff, whereas ours benefits from the facility to interact with medical staff who are not on a hospital site, such as in a car or in a shopping centre. The system is also part of a hospital, whereas our idea is to implement a standalone system that allows interactions with all the parties who can be involved in an emergency.

A mobility management system for MCC M^2C^2 has been proposed in Mitra and Ahlund (2014). It aims to create a local cloud(s) in emergency locations to help emergency providers reach cloud services. This is similar to the idea of cloudlets (Satyanarayanan et al., 2009). Operations such as executing mobile-based applications, collecting sensors’ data, and submitting wearable device readings happen locally, via Wi-Fi or 3G links, at what is called an emergency response vehicle (ERV). This kind of vehicle offers functionality, such as low latency data processing, storage and access. This local cloud will then communicate with the public cloud on behalf of the users. According to the paper, more than one ERV can operate from the same emergency location and, therefore, a mechanism for selecting the most appropriate ERV in terms of networking and delay is tested and discussed by the authors. The authors claim that using their approach will benefit emergency services by reducing delays. Channelling activity through these emergency locations can be more than twice as fast as connecting directly to the public cloud. The M^2C^2 system differs from our approach in that it is mostly provided to professionals such as ambulance crews or firefighters, whereas, we aim to provide health services to normal users (i.e., the general public), as well as support to medical staff. It allows them to deliver the right medical treatment to those people who are experiencing an emergency.

A cloud-based system that can be installed in an ambulance to provide health support on the move has also been suggested in Muthaiyan et al. (2012). The proposed system offers video conversations over a cellular network between a first aid crew at the scene and doctors who are located in a hospital. Doctors can update/view patients’ medical records, retrieve the shortest path to the nearest hospital, and prepare the emergency department for what the patient needs based on information from the first aid crew. The authors claim that using this system will save lives by providing the right treatment at the right time and by taking into account mobility and road-traffic issues. However, using this system requires special equipment in ambulances. Furthermore, the selected specialists cannot provide any further help until the ambulance has arrived at the hospital if there are connection problems and a call cannot be made. Communication can also only be made with doctors who are present in the hospital, whereas our system makes use of doctors or any other medically qualified people who are within reach of an emergency location.

In Ma and Tang (2014), an online social mutual help system using the mobile cloud is designed and discussed. The main aim of this paper is to improve the feasibility of delivering help on a multi-tenant framework. The authors propose a helper recommendation algorithm that processes help requests, providing the best possible support based on user affinity and using data mining and machine learning to capture users’ behaviour. Once a recommendation is found, it will be pushed to or pulled by the user, depending on how active the user is. Interestingly, the proposed framework provides a RESTful web service API for better integration with third-party systems. The framework was built and evaluated on a physical machine and showed an improvement in the success rate of the mutual help process when the aforementioned algorithm was introduced.

2.3 *Section summary*

To sum up, to the best of our knowledge, most of the systems advanced in the literature propose either a system designed to replace the current emergency help available with a full IT system, or a system that uses a form of healthcare help that is provided by pre-defined and non-professional relatives and friends. Our model, however, provides a form of help that can be complementary to the existing emergency system (e.g., a two-way radio system or calling 999). Features such as looking for a medical professional who is an expert in a particular type of emergency are provided by taking into account the availability of the practitioners and the location of both parties.

3 Motivating scenarios

In this section, we present three different scenarios that would benefit from a system that could provide a first responder to the scene faster than the emergency services. The goal is to have response times to emergencies that are in the order of seconds and not minutes, whenever this is possible.

3.1 Crowded places

When a large number of people are present in the same place to perform the same activity, such as watching a football match or attending a concert or religious event, there is a high chance that emergency medical cases will occur. For example, in this paper, we consider Al-Hajj (pilgrimage to Mecca) as such an event. This is a religious duty whereby every able Muslim is obliged to perform a pilgrimage to Mecca at least once in his/her life (Müller, 2015). In this event, hundreds of thousands of people are present in the same area for a short period, performing virtually the same actions. There has been a review (Ahmed et al., 2006) of the most common health issues that occur during the Al-Hajj event. Some of these issues are related to the medical history of the pilgrims and others can occur because of the environment and the location of this event. Some researchers (Hameed, 2010) have analysed the difficulties and risks related to Al-Hajj in general and have designed a system to deal with some of these issues. Another paper (Mohandes, 2011) presents a mobile-based tracking service to help pilgrims in emergencies.

Imagine that a person who has a medical history, such as heart disease, requires healthcare urgently. In a crowded place, reaching such a person with regular emergency services will be difficult or, in some cases, might even be impossible. However, a doctor or nurse might be located in the crowd, not too far away from that person and, therefore, could immediately be available to help. Alternatively, the person in need, or someone around him/her, could use the mobile device to obtain directions to the nearest medical centre. Therefore, the kind of system able to link users who are looking for care with those who are able to provide it is potentially life-saving.

3.2 Shopping centres

Another scenario related to people’s daily activities is that of visiting shopping centres. Emergency cases might occur in such places, particularly in relation to children. For example, a child might lose his/her family or injure him/herself, prompting the need for an urgent response. Another example could be related to the failure of the electricity or lighting systems of these places, where a larger number of people may be involved and require help, such as directions to the nearest exit. In this scenario, a system that allows parents to track their children’s location in the case of losing them in the darkness and resulting confusion, as well as establishing a communication link between them, is required. Another feature that could be added to the system is propagating useful information, such as directions and instructions that would help emergency crews to rescue people who are in distress.

3.3 Residential areas

Emergencies can also occur in the home, from cases of people falling downstairs to serious fires that destroy a whole house. Suppose now that such an emergency has been detected in a home using a modern home-monitoring device. Generally, this will trigger an alert to one of the emergency departments, such as the ambulance and/or fire-fighting services. However, it might be that a professional in close proximity is available and could, therefore, provide help before an ambulance or fire engine arrives. Therefore, a multi-notification system is needed, one that automatically looks for doctors or nurses in the area of the emergency. It would also provide the shortest route to the location. This action would happen simultaneously to the triggering of an alert at an emergency centre.

3.4 Discussion

Our model discusses the kind of challenge that occurs when users have been in an emergency and are looking for appropriate and fast healthcare services. We introduce a cloud service that allows users to search for a professional who is available and, more importantly, located in close proximity to the person requesting help. We also develop different methods of reaching cloud services to enhance service availability, such as over the internet (directly or via a neighbouring link as reported in Alshareef and Grigoras, 2014) and by SMS. Furthermore, a directory service is hosted by the cloud and its entries are checked by the health authority to protect patients’ privacy, as well as to improve system trustworthiness.

Ultimately, the system presented in this paper will work side by side with current emergency systems (e.g., calling an emergency centre). Furthermore, it will offer a faster response by taking advantage of medical professionals who are located within reach of the scene of an emergency.

3.5 Research objective

The main objective of our project, presented in this paper, is to design a mobile cloud service which creates a directory of trusted and qualified medical professionals, as well as tracking their location and availability. As a result, the service will:

- Allow users to search the directory to facilitate a swift response to the requester's medical needs and reduce the total waiting time.
- Make the best use of medical professionals, registered in the system, who may be in a particular location, such as in a crowded area, and could assist the traditional emergency services (e.g., ambulance) by arriving faster on the scene and providing medical help until the emergency personnel arrive.

4 System design and implementation

This section presents our system design and implementation. The initial step is the registration of doctors, nurses and medical organisations with the cloud service. Only after that, the system is ready for users to send requests to the cloud service when looking for a professional to deal with the medical emergency/concern that he/she has.

4.1 Model overview

According to the high-level overview of our model presented in Figure 1, the proposed system consists of three main components:

1 *the cloud*, which plays the most important role by hosting services

2 *the users/potential patients* who might experience emergencies

3 *medical professionals*, such as doctors and nurses.

4.2 Registration of professionals

The central element of the cloud service is a directory that lists all the available volunteer medical professionals. Those who are able to provide medical care have to register their details, including personal information (name, gender, etc.), employment (ID, occupation, etc.) and contact (email and telephone number) details in the directory through their medical organisation before they begin providing a service (more details are provided in the section below on security). In addition, the details specifying the location and availability of each registered professional will be constantly updated. These details will play a major role in the 'look-up' operation.

4.3 Directory service in the cloud

The directory service allows users to alert professionals who match their medical needs. Only registered and authorised professionals are listed in this directory and are organised according to their role (doctor, nurse, etc.). In addition to the details that are provided in the registration operation, this service will track each professional's availability, such as whether he/she is connected, disconnected, busy, free, and current location. For reasons of fairness, the cloud will ensure that all professionals are treated equally based on the total number of cases assigned.

Figure 1 High-level overview of our model (see online version for colours)

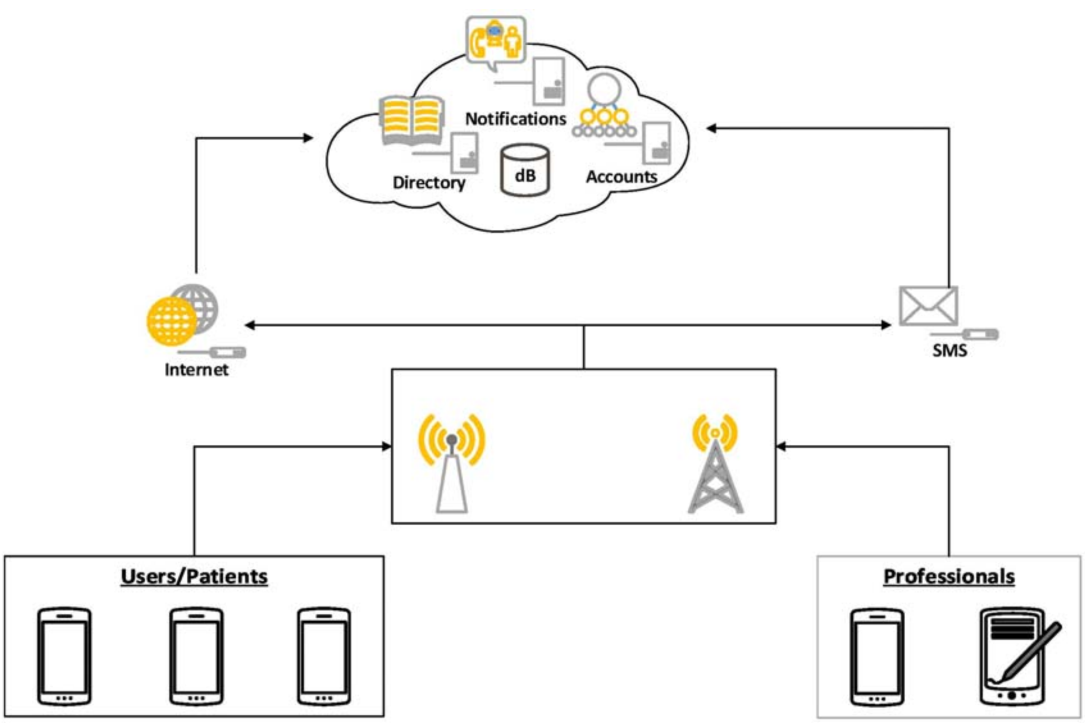
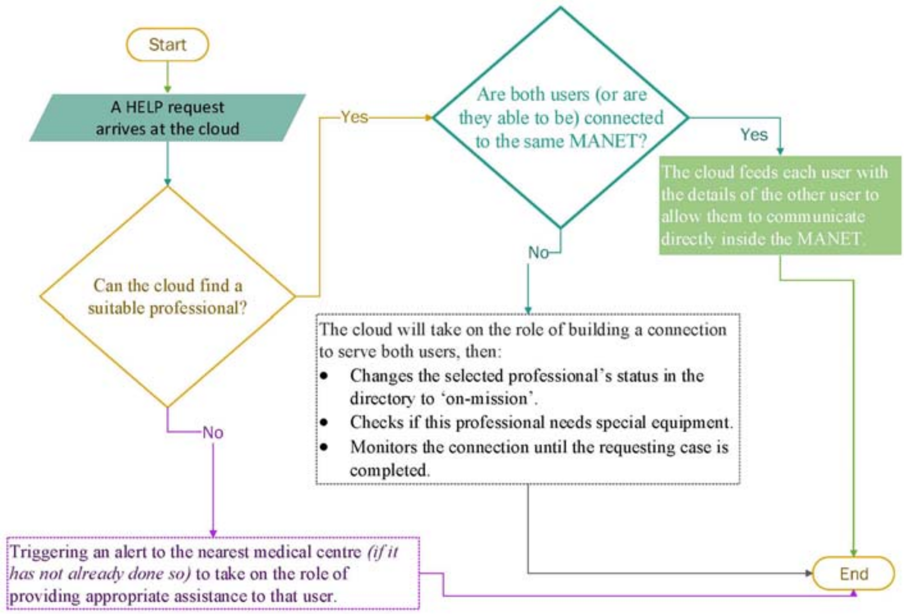


Figure 2 Responses from the cloud to a HELP request (see online version for colours)



4.4 Look-up operation

This operation is executed when a user sends a HELP request to the cloud looking for a medical professional to provide assistance. The request is redirected to the directory service to select the professional who most closely matches the needs of the patient making the request. Four attributes are considered here: status, availability, medical specialty and current location. Thus, only a professional who is both actively receiving jobs from the cloud and available, meaning that he/she is not treating another patient and is able to deal with the emergency case received, will be considered. Finally, he/she will be selected according to his/her proximity to the location of the emergency case. However, emergency services, such as the ambulance service, are also called when the look-up procedure starts. Figure 2 demonstrates the responses from the cloud to a HELP request.

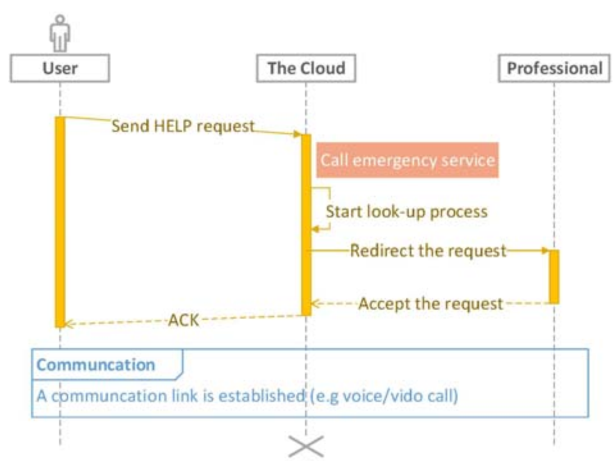
4.5 Notifying other people

Depending on the medical situation of the requesting user, another professional might be required to attend the emergency location; for example, a doctor in another specialty. A request is then simply sent to the cloud to notify this other professional. This kind of service is offered only to professionals who are on call. A communication link is then set up between the two professionals. In addition, directions to the emergency location are provided if required.

4.6 One-to-one communication protocol

Once a professional is selected to deal with the requesting case, a communication link is established between both users. The cloud is responsible for monitoring this link, as well as providing any support to the professional, such as notifying other professionals. Figure 3 shows a sequence diagram for establishing a link between a requesting user and a professional.

Figure 3 Sequence diagram for establishing a link between a requesting user and a selected professional (see online version for colours)



4.7 Help requests prototype

A user can use a mobile phone to send a HELP request to the cloud to look for a professional to discuss a medical concern with the ability to submit real-time information about this medical concern, such as answering questions that will help with diagnosis. However, a user might sometimes not be able, or not have time, to provide details of the emergency case but will at least be able to use a mobile device to request help. Similarly, someone could help another person who is in an emergency by requesting medical help on that person's behalf. Furthermore, a user might not be able to access conventional medical services at all, with nobody available to help him/her request appropriate help. Therefore, we provide three ways to ask for medical help from the cloud depending on the status of the emergency case. Furthermore, all these forms of help can be sent either over the internet or via SMS because it might be the case that users do not have an internet connection but have the ability to use a cellular network to make calls and send SMSs.

4.7.1 Completing a form

Any user who has an active account in the cloud can send a HELP request to look up a professional to discuss a medical case or to help another person who needs medical assistance (e.g., an injured child). This request has to include information explaining the user's medical situation, such as a keyword (e.g., 'heart', 'breathing' or 'fainted'), current location, and connectivity status to help the cloud select the most suitable professional from the directory service.

4.7.2 Clicking a button

Another way of requesting help can be by clicking a button that will trigger an alert to the cloud to help the user as soon as possible, taking into account that the requester is at high risk, thereby according this request higher priority. A user who intends to use this sort of help has to have pre-defined any allergies or special medical requirements. As a result, the cloud will redirect this information to a selected professional and emergency department to seek a swift and appropriate outcome.

We designed a simple electronic medical record (EMR) in the cloud that is linked to a user account. Each record includes a collection of electronic health information about each individual patient, such as medical history, medication, and allergies. The cloud also allows professionals to view/edit these EMRs, if required.

4.7.3 Detecting a medical case

The third way of seeking medical help is through wearable medical devices. First, a user can link a wearable device to his/her account in the cloud, which results in the cloud starting to monitor this device to detect an emergency situation without further input from the user. Then, when an emergency case is smartly detected (e.g., the heart activity is abnormal), a help request is automatically sent from this wearable device through a mobile device (or the internet if this device has the ability to connect to the internet directly) to the cloud to facilitate a look-up process and, at the same time, sends the user's information to an emergency department.

Detecting emergency cases using out-of-hospital schemes has been given a high level of attention in the literature. In one study (Romano and Cangiano, 2015), the authors claim that wearable technology is the 'next big thing' in tech industries, while others (Latré et al., 2011) provide a survey of wireless body area networks and highlight some applications with a special interest in patient monitoring. There are also a wide range of wearable devices and body sensors on the market that allow users to track their activity, monitoring such aspects as walking, running, sleeping, and heartbeat rate.

5 Security mechanisms

In this paper, we do not deal directly with the privacy and security issues involved in implementing cloud computing to the health field. However, we do provide some enhancements, as shown in the following subsections, to our proposed service to ensure a reasonable level of security.

5.1 Trustworthiness

To guarantee that the proposed system is trustworthy and that only medically qualified people are added to the directory service, the cloud sends the professional's details (such as name, registration ID and occupation) to the health authority (e.g., the Ministry of Health in Saudi Arabia) to verify that the person in the process of registration is qualified to provide healthcare services to the public. If the medical professional is validated, a new account is created and a message containing the result of this operation is sent to that professional. In addition, the details are added to the professional directory.

5.2 Privacy

Dealing with health data in cloud-based systems (i.e., storing, sharing and accessing) is one of the open issues in the integration of cloud computing to the healthcare sector (Chen and Zhao, 2012). A number of ideas have been proposed with the aim of providing high-level privacy for medical data, as well as ensuring the high-level protection of these data, such as using a private cloud (He et al., 2013) to provide a standard high level of protection. Others have used a hybrid cloud type (Lee et al., 2015), where data are stored in a public or private cloud depending on how sensitive the data are. In other words, the more sensitive the data, the more likely it is they will be processed and stored in a private cloud. With this in mind, we carried out the following actions to protect users' privacy:

1 *Access*: only users who have an active account in the cloud can access cloud services, including users' EMRs.

2 *Anonymity*: we refer to users and professionals using their IDs instead of their names.

3 *Sharing*: the cloud issues a new unique ID for each help request, then links this ID with the requester user's ID. This means that users' data can only be accessed through an active help request that is already assigned by the cloud to the particular professional who has resulted from the look-up process.

4 *Storage*: we intend to encrypt the users' data that are stored in the cloud using one of the well-known encryption protocols, such as the advanced encryption standard (AES) (Heron, 2009).

5.3 *Preventing malicious use of the service*

As mentioned previously, the first form of help requires the user to complete a form with brief medical information to help the cloud find a suitable professional. However, the cloud needs to ensure that a HELP request comes from a real user and is not being used as a method of attack (e.g., to slow down activities in the cloud). Therefore, we require the user to type a code that is generated randomly after completing the form, where the user has only three attempts to enter the correct code and thereby proceed with the request.

6 Experimental design and evaluation

To determine the feasibility of the proposed system, we extended our previous Android app (Alshareef and Grigoras, 2015b). We implemented the extended app on Android-based devices: one HTC and two Samsung S3 smartphones. The database and all the services were hosted by an Amazon Instance (AWS, http://aws.amazon.com). We also deployed an SMS gateway to the cloud using the Twilio (https://www.twilio.com/) web service API to allow SMS messaging.

The app provides two main interfaces, one for each type of user (professionals and ordinary people), including registration and login screens. For the sake of simplicity in this paper, a more detailed description of the verification step will be given in a future paper of ours.

6.1 *Forms of help*

As mentioned previously, we designed three ways of seeking help depending on the requesting user's medical status. First, users can send a HELP request to the cloud by completing a form using the Android app. Second, we created a blank activity that has only a 'HELP' button. Once this button is clicked, a request is sent to the cloud, which includes the user's ID and location. The cloud starts a look-up operation as well as sending the user's information to the nearest emergency centre. If a suitable professional is found, the cloud redirects the request to the professional selected, providing the location of that user. The cloud also allows the selected professional to access the requesting user's EMR record in the cloud. The cloud then waits for any update made by the professional to the user's status.

Coming to the third form of help, according to some researchers (Cabin and Henry, 1992), the normal heart rate among adults is approximately 70 beats a minute at rest, while one medical research group (Heart Rate: What's Normal?, http://www.mayoclinic.org) gives the normal resting heart rate for adults as ranging from 60 to 100 beats a minute (bpm). However, these rates are not the same for everyone, because it depends on a number of factors, such as weight, age, and general health. Therefore, we implemented a setting that when a heart rate is outside the 60–100 bpm range, an emergency case is detected. We developed a web-based app using a Tizen wearable SDK (Tizen Developer, https://developer.tizen.org/development/tools/download) and installed it in a Samsung Gears (http://www.samsung.com/global/microsite/gears/) smartwatch to monitor the user's heartbeat rate and send this to the paired mobile device. Transferring heartbeat data was done using the Samsung accessory protocol (SAP, http://developer.samsung.com). To avoid a false detection, a countdown (of five seconds) starts running with the option of cancelling the alert if an emergency case is not in progress. If no action is taken by the user, an alarm is triggered to draw any people who might be in the proximity and, at the same time, a HELP request is sent to the cloud marked as 'a high-risk case'. The cloud then notifies the emergency department, as well as starting a look-up operation.

6.2 *Chat application*

In the Android app, we offer a chat application feature with the help of the cloud service. This feature allows the requesting user and the selected professional to share text, photographs, and files after the look-up operation in the cloud has finished. Two scenarios are considered here, depending on the status of the connection of both users. If the two users are connected to the same MANET and can communicate directly, the chat application starts using their MANET IP addresses.

However, if they cannot communicate directly, then the chat application makes use of a notification-based format with the help of the Google cloud messaging (GCM, http://developer.android.com/google/gcm/gs.html). Therefore, when the user sends a message to the selected professional, it will be sent from that user to the cloud and then to the GCM platform responsible for delivering the message to the professional. Similarly, the response will travel all the way back to reach the sender over the cloud and the GCM. Therefore, after receiving a HELP request and a professional is selected at the end of the look-up operation, both users can start a chat session that is served by the cloud and GCM.

6.3 *Seeking medical help using the android app (via SMS)*

Mobile devices can use SMS as a supporting communication method to enhance the ways of communicating with other users/systems (Elton and Chung, 2015). For example, one possibility is updating current location (GPS coordinates) via SMS if the internet could not be reached.

Technically, sending and receiving SMSs in the Amazon cloud platform is provided only to US mobile numbers. Therefore, Twilio API was used in our system to allow the cloud to receive HELP requests via SMS, as well as to reach those (i.e., professionals or users) who do not have an internet connection. Put simply, in the background, the app constructs the HELP request as an SMS payload and sends it to the Twilio platform, which will then be responsible for redirecting the request to the cloud. An acknowledgement will be sent to notify the user that the cloud has received the message successfully. Then, a look-up operation will be started to select the most suitable professional. When one is found, a request is sent to that professional that includes the sender's contact information in order to start an SMS conversation. The cloud also feeds the selected professional's details to the requesting user.

7 Experimental results and analysis

The experiments were carried out 10 times to determine the time consumed in setting up the connection between the person in need and the first responder. Table 1 shows the round trip times (RTT) for a HELP request using different communication methods.

Table 1 Cost of setting up connection

Communication method		*RTT*	
Wi-Fi	Home broadband	4.077	Seconds
Cellular network	4G portable broadband	5.231	
	3 G	8.432	
	SMS	24.775	

The average time needed to set up a connection for help requests between a user and one of the professionals listed in the cloud directory was between 4 and 25 seconds, depending on the communication method used. During that time, the request is directed to a professional with the expertise appropriate to the medical situation, as well as being located within reach of the requester's location. In addition, the form of help had no effect on the amount of time that was taken here because we captured the delay from when the request was sent from the mobile devices until the acknowledgement (ACK) was received from the cloud stating that the professional had been selected and was engaging with the medical case.

7.1 Medical response time

The time needed to respond to medical emergency cases is an important factor in healthcare fields to evaluate the quality of emergency medical services (Kim et al., 2007). It is defined as the period between receiving an emergency call and the arrival of the rescue team (i.e., an ambulance) at the emergency location (Wilde, 2013; Mayer, 1979). This time has been standardised as follows: "Response times of four minutes for BLS [basic life support] first response and eight minutes for paramedics have become an international standard for urban EMS [emergency medical services] systems" (The American Ambulance, 1994). However, exceeding this time would not result in lower patient survival rates in all cases, according to real-world experiments presented elsewhere, and it is suggested that realistic response time standards should be developed that take into account the needs of each case (Pons and Markovchick, 2002).

However, our system achieved a response from a medical professional in a matter of seconds, as well as the system delivering details of an emergency case to the emergency services. This means that the amount of extra time involved will not affect the overall response time for this type of emergency case. This amount of time can increase, however, if the selected professional does not respond as soon as the request is received.

To avoid any delay that might result from the human factor, the cloud gives the selected professional one to three minutes to interact with the received request and, if there is no response, the request will be assigned to another professional. However, in some situations, this delay might not occur; for example, in the Al-Hajj scenario, there are usually a number of medical volunteers who are readily available to serve pilgrims.

7.2 Network issues

Another factor that might have an impact on the length of time involved is the quality of the communication links. As mentioned previously, we discussed the ability to use SMS messages as an alternative communication method. Here, the cloud or users can communicate via SMS messages to avoid low-quality internet connections.

Furthermore, in the case of a crowded environment or an inability to reach the cloud directly, a user could benefit from our previous solutions of creating/joining a MANET network that is managed by the cloud (Alshareef and Grigoras, 2014, 2015a). This means that a user can create or join a MANET network to submit details of his/her medical needs. The other member of this MANET can either be a medical professional who can provide help to the user or simply an ordinary user who acts as a bridge to allow communication between the user who needs assistance and the cloud.

7.3 Further analysis

To compare our idea with existing types of systems, such as calling the emergency help centre (e.g., 999) by phone, we have to understand the steps that are involved in the emergency operator processing a help request and the duration of each step. These steps have been defined as follows (Aboueljinane et al., 2012):

- *Regulation time*: the interval between the time the centre receives the call and the time the nearest available rescue team is notified. This includes the call handler's pre-analysis time, the medical evaluation time, and the time taken to pass the request to the original hospital in the case of less urgent emergency calls.

- *Preparation time*: the interval between the time the call handler notifies the care team and the time the care team leaves for the rescue.
- *On-site time*: the time interval between the care team arriving at the scene and the time it leaves the scene.
- *Diagnostic or therapeutic radiography (DTR) time*: the time interval between the care team arriving at the DTR medical service and the time it leaves this service.
- *Drop-off time*: the time interval between the care team arriving at the destination hospital and the time it leaves the hospital.

As our service does not conduct any real pre-analysis or perform most of the actions included in the regulation step above, we cannot compare our results with the amount of time taken during this stage. However, our service allows users to search for a medical professional, which results in the building of communication between the user who requested aid and the professional selected, as well as redirecting the emergency case to an available professional after pushing any available information to that professional to enable him/her to reach the requester. Therefore, it should be possible to compare our results with the time taken in the preparation step.

The paper provides the average real regulation and preparation time of 6,658 received calls in an emergency call centre in France for a period of 11 months from 1st October 2010 to 31st August 2011 (Table 2).

Table 2 Average emergency processing times (minutes)

Type of call	*Priority level*	*Average regulation time*	*Average preparation time*
Primary	1	6.5	3.3
	2	12.8	3.8
Secondary	1	22.8	4.9
	2	53.8	6

Source: Aboueljinane et al. (2012)

From Table 2, we can see that the lowest average for preparation time was 3.3 minutes, which is far higher than our preparation time of 25 seconds, taking into account that our service is sending the received request to the emergency department before taking any other action, such as the look-up operation. This is intended to deal with the issue of ‘no professional is found’ and ensure the request is redirected to the emergency department.

Furthermore, if we assume that the selected professional is located in the same location as the ambulance or rescue team, reducing the preparation time needed will lead to a reduction in the total waiting/response time from sending the request until arriving at the requester’s location.

As mentioned previously, our service is aimed at finding a medical professional who is available and, more importantly, located near the scene of the emergency. This means that there will be a high probability of finding a professional who can interact with the emergency case immediately and is located close enough to the emergency location, thus reducing the delay resulting from travelling to the emergency scene. As a result, the total response time will be improved and will, it is hoped, lead to a better outcome.

8 Conclusions and future work

This paper presented a mobile cloud service that offers people who are experiencing medical emergencies while on the move the possibility to ‘look up’ doctors or nurses who are located in their proximity and who can respond more quickly than the emergency services. Three main forms of help request were designed to serve as wide a range of emergencies as possible and to enhance system usability, including smart detection using a wearable device. Furthermore, details were established of a communication link that is managed by the cloud service, with the option to start a chat session to exchange text, photographs, and files. The SMS messaging ability is also provided as an alternative method for reaching the cloud services and seeking medical help in emergencies. The system benefits from using cloud features, such as high performance and availability and extended connectivity through MANETs, previously developed within this project. We designed and deployed the aforementioned service on real mobile devices and real cloud instances as a validation test. We also added a security enhancement to our system by implementing a verification scheme to ensure that requesters are real people who are looking for medical help.

The set-up time was less than 25 seconds using SMS and less than five seconds using the internet, which meets the initial time requirement of the system, as well as ensuring no extra delay was added to the total medical response time. On the contrary, it will make the best use of a medical professional who may be located just a few steps away from the medical case. Furthermore, comparing this amount of time with the time needed to prepare a care team with an ambulance using a traditional model (e.g., calling 999), we found that our mobile service could significantly reduce delays in responses by selecting a professional who is able to interact immediately with the emergency case. If the look-up process selects a professional who is located near enough to the requester’s location (e.g., a few steps away), this will also decrease the time needed to reach the emergency location, which will result in an increased chance of survival.

Our future work will develop an algorithm for better management of registered professionals’ activity to achieve fair and efficient outcome, including when they start/end dealing with emergency cases and how often they provide emergency support. We are also planning to extend experiments on smart detection (e.g., using different medical body sensors) to achieve better medical outcomes.

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References

Aboueljinane, L., Jemai, Z. and Sahin, E. (2012) 'Reducing ambulance response time using simulation: the case of Val-de-marne department emergency medical service', *Proceedings of the Winter Simulation Conference*, pp.1–12.

Ahmed, Q.A., Arabi, Y.M. and Memish, Z.A. (2006) 'Health risks at the Hajj', *The Lancet*, Vol. 367, No. 9515, pp.1008–1015.

Alshareef, H. (2015) 'Introducing mobile cloud technology into m-health to deliver better care/support in case of emergencies', *The Boolean*, pp.20–26.

Alshareef, H. and Grigoras, D. (2014) 'Mobile ad-hoc network management in the cloud', *The IEEE 13th International Symposium Parallel and Distributed Computing (ISPDC)*, pp.140–147.

Alshareef, H. and Grigoras, D. (2015a) 'Robust cloud management of MANET checkpoint sessions', *In 14th International Symposium on Parallel and Distributed Computing (ISPDC)*, pp.66–73.

Alshareef, H. and Grigoras, D. (2015b) 'First responder help facilitated by the mobile cloud', *International Conference on Cloud Technologies and Applications (CloudTech)*, IEEE, pp.1–8.

Amazon AWS Web Services (AWS) [online] http://aws.amazon.com (accessed 1 March 2016).

Bamiah, M., Brohi, S., Chuprat, S. and Manan, J-l.A. (2012) 'A study on significance of adopting cloud computing paradigm in healthcare sector', *Cloud Computing Technologies, Applications and Management (ICCCTAM), International Conference*, IEEE, pp.65–68.

Barbera, M., Kosta, S., Mei, A. and Stefa, J. (2013) 'To offload or not to offload? the bandwidth and energy costs of mobile cloud computing', *INFOCOM, Proceedings IEEE*, pp.1285–1293.

Cabin, H.S. and Henry, S. (1992) 'The heart and circulation', in *Yale University School of Medicine Heart Book*, Hearst Books, New York, p.5.

Chang, H.H., Chou, P.B. and Ramakrishnan, S. (2009) 'An ecosystem approach for healthcare services cloud', *IEEE International Conference on e-Business Engineering*, pp.608–612.

Chen, D. and Zhao, H. (2012) 'Data security and privacy protection issues in cloud computing', *International Conference on Computer Science and Electronics Engineering (ICCSEE)*, Vol. 1, pp.647–651.

CliniCloud [online] https://clinicloud.com (accessed 21 February 2015).

Dinh, H.T., Lee, C., Niyato, D. and Wang, P. (2013) 'A survey of mobile cloud computing: architecture, applications, and approaches', *Wireless Communications and Mobile Computing*, Vol. 13, No. 18, pp.1587–1611.

Doctor on Demand [online] http://www.doctorondemand.com (accessed 21 February 2015).

Du, Y., Chen, Y., Wang, D., Liu, J. and Lu, Y. (2011) 'An Android-based emergency alarm and healthcare management system', *IT in Medicine and Education (ITME), International Symposium*, IEEE, Vol. 1, pp.375–379.

Elton, J. and Chung, P. (2015) 'An integrated communications platform incorporating SMS and e-mail to support mobile applications', *Int. J. High Performance Computing and Networking*, Vol. 8, No. 1, pp.3–15.

Fernando, N., Loke, S.W. and Rahayu, W. (2013) 'Mobile cloud computing: a survey', *Future Generation Computer Systems*, Vol. 29, pp.84–106, Elsevier.

Forman, G. and Zahorjan, J. (1994) 'The challenges of mobile computing', *Computer*, Vol. 27, pp.38–47.

Google Cloud Messaging (GCM) [online] http://developer.android.com/google/gcm/gs.html (accessed 16 March 2016).

Greer Jr., M.B. and Ngo, J.W. (2012) 'Personal emergency preparedness plan (PEPP) Facebook app: using cloud computing, mobile technology, and social networking services to decompress traditional channels of communication during emergencies and disasters', in *IEEE Ninth International Conference on Services Computing (SCC)*, pp.494–498.

Hameed, S. (2010) 'ICT to serve Hajj: analytical study', *International Conference on Computer and Communication Engineering (ICCCE)*, pp.1–7.

He, C., Fan, X. and Li, Y. (2013) 'Toward ubiquitous healthcare services with a novel efficient cloud platform', *IEEE Transactions on Biomedical Engineering*, Vol. 60, No. 11, pp.230–234.

Heart Rate: What's Normal? [online] http://www.mayoclinic.org (accessed 2 September 2015).

Heron, S. (2009) 'Advanced encryption standard (AES)', *Network Security*, Vol. 2009, No. 12, pp.8–12.

Jemal, H., Kechaou, Z., Ayed, M.B. and Alimi, A.M. (2015) 'Mobile cloud computing in healthcare system', *Computational Collective Intelligence*, pp.408–417.

Jin, Z. and Chen, Y. (2015) 'Telemedicine in the cloud era: prospects and challenges', *Pervasive Computing*, Vol. 14, No. 1, pp.54–61.

Khalifa, A., Azab, M. and Eltoweissy, M. (2014) 'Towards a mobile ad-hoc cloud management platform', in *Proceedings of the IEEE/ACM 7th International Conference on Utility and Cloud Computing*, pp.427–434.

Kim, J.K., Sharman, R., Rao, H.R. and Upadhyaya, S. (2007) 'Efficiency of critical incident management systems: instrument development and validation', *Decision Support Systems*, Vol. 44, No. 1, pp.23–250.

Kopec, D., Kabir, M., Reinharth, D., Rothschild, O. and Castiglione, J. (2003) 'Human errors in medical practice: systematic classification and reduction with automated information systems', *Journal of Medical Systems*, Vol. 27, No. 4, pp.297–313.

Kumar, L., Malik, N., Agghi, G. and Anand, A. (2014) 'Mobile cloud computing', *IJRIT International Journal of Research in Information Technology*, September, Vol. 2, No. 9, pp.787–792.

Latré, B., Braem, B., Moerman, I., Blondia, C. and Demeester, P. (2011) 'A survey on wireless body area networks', *Wireless Networks*, Vol. 17, No. 1, pp.1–18.

Lee, Y.S., Bruce, N., Non, T., Alasaarela, E. and Lee, H. (2015) 'Hybrid cloud service based healthcare solutions', *IEEE 29th International Conference on Advanced Information Networking and Applications Workshops (WAINA)*, pp.25–30.

Low, C. and Chen, Y.H. (2012) 'Criteria for the evaluation of a cloud-based hospital information system outsourcing provider', *Journal of Medical Systems*, Vol. 36, No. 6, pp.3543–3553.

Ma, K. and Tang, Z. (2014) 'An online social mutual help architecture for multi-tenant mobile clouds', *International Journal of Intelligent Information and Database Systems*, Vol. 8, No. 4, pp.359–374.

Mayer, J.D. (1979) 'Emergency medical service: delays, response time and survival', *Medical care*, pp.818–827.

Medina, J.P., Villarruel, J.E.G. and Corona, B.T. (2009) 'Proposal for an m-health system', *Electronics*, *Robotics and Automotive Mechanics Conference*, *CERMA*, IEEE, pp.55–59.

Mitra, K. and Ahlund, C. (2014) 'A mobile cloud computing system for emergency management', *Cloud Computing*, *IEEE*, Vol. 1, pp.30–38.

Mohandes, M. (2011) 'Pilgrim tracking and identification using the mobile phone', in *IEEE 15th International Symposium on Consumer Electronics*, pp.196–199.

Müller, S. (2015) 'Spaces of rites and locations of risk: the great pilgrimage to Mecca', *The Changing World Religion Map*, pp.841–853.

Muthaiyan, M., Goel, N. and Prakash, D.S. (2012) 'Virtual e-medic: a cloud based medical aid', in *Proceedings of World Academy of Science*, *Engineering and Technology (WASET)*, p.1344.

Pereira, J. and Prata, P. (2015) 'Management of virtual machine images in heterogeneous clouds', *Int. J. Computational Science and Engineering*, Vol. 10, Nos. 1/2, pp.113–129.

Pons, P.T. and Markovchick, V.J. (2002) 'Eight minutes or less: does the ambulance response time guideline impact trauma patient outcome?', *The Journal of Emergency Medicine*, Vol. 23, pp.43–48, Elsevier.

Rahimi, M.R., Ren, J., Liu, C.H., Vasilakos, A.V. and Venkatasubramanian, N. (2014) 'Mobile cloud computing: a survey, state of art and future directions', *Mobile Networks and Applications*, Vol. 19, No. 2, pp.133–143.

Romano, Z. and Cangiano, S. (2015) 'Open sourcing wearables', *Empowering Users through Design*, pp.153–175.

Samsung Accessory Protocol (SAP) [online] http://developer.samsung.com (accessed 1 September 2015).

Samsung Gears [online] http://www.samsung.com/global/microsite/gears/ (accessed 1 September 2015).

Satyanarayanan, M., Bahl, P., Caceres, R. and Davies, N. (2009) 'The case for VM-based cloudlets in mobile computing', *Pervasive Computing*, Vol. 8, No. 4, pp.14–23.

Talpur, M., Bhuiyan, M. and Wang, G. (2015) 'Shared-node IoT network architecture with ubiquitous homomorphic encryption for healthcare monitoring', *Int. J. Embedded Systems*, Vol. 7, No. 1, pp.43–54.

The American Ambulance (1994) *Contracting for Emergency Ambulances Services*, The pp.15–8, American Ambulance, Sacramento, CA.

Tizen Developer [online] https://developer.tizen.org/development/tools/download (accessed 01 09 2015).

Twilio [online] https://www.twilio.com/ (accessed 2 February 2016).

Wilde, E.T. (2013) 'Do emergency medical system response times matter for health outcomes?', *Health Economics*, Vol. 22, No. 7, pp.790–806.