

Hybrid Approach for Disaster Recovery using P2P Communications in Android

Hakan Yekta Yatbaz*, Berkem Çınar*, Ali Gökdemir*, Enver Ever*,
Fadi Al-Turjman[§], Huan X. Nguyen[†] and Adnan Yazıcı[‡]

*Department of Computer Engineering, Middle East Technical University, Turkey

[†]Faculty of Science and Technology, Middlesex University London, United Kingdom

[‡]Computer Science, School of Science and Technology, Nazarbayev University

[§]Computer Engineering Department, Antalya Bilim University, Turkey

Abstract—Disaster recovery and rescuing are challenging tasks due to the unknown parameters related with the victims in disastrous situations. Existing surveillance systems have a degree of efficiency to inform the people through the use of various communication channels about disasters and their area of effect. However, the obscureness of the rescuing process has not been resolved in desirable levels, especially for the cases where the communication infrastructure can also be heavily damaged. Thanks to the prevalent use of mobile devices installed with variety of sensors, it is possible to aid the rescue process using the mobile hand sets. In this study, a framework which focuses on reducing the time spent to locate possible victims in a disastrous situation and to expedite the medical help is presented. For this purpose a system which introduces a proactive approach using Android, WiFi P2P technology, and local/central location database synchronization is proposed. In short, the system obtains the location of the users with fixed intervals to store in both local and centralized database for authorities to query for necessary information. The information related with the neighbouring mobile devices within a specific coverage area is also stored for the cases where only some of the devices are reachable due to disasters. With these features, it is possible to consider the system as a hybrid one where both reactive and proactive approaches are employed in order to reach the most up-to-date information available. This way, the probability of reaching up-to-date information about potential victims with no connection due to damaged infrastructure is increased, since each mobile node has information about the stations within its coverage area. In addition, the emergency medical information of the user are collected via a mobile application to accelerate the medical support time. Even though the system is designed to be used in any kind of disastrous situations, the case study included in this paper is for earthquakes only. Briefly, we developed a system that can enhance the rescuing and provide fast medical support by making use of the advancements in both mobile and wireless communication technologies.

Keywords—Disaster recovery, WiFi, peer-to-peer, Bluetooth, BLE, proactive victim tracking, Android

I. INTRODUCTION

Disasters are important problems for the world yet to provide counter measures in desirable levels. For example, in The Izmit Earthquake in Turkey, more than 17,000 people were killed and more than 500,000 people were left homeless [1]. As another important disaster in Japan in 11th of March 2011, an earthquake named Great Tohoku followed by a tsunami with a magnitude of 9.0 caused 230,000 casualties and \$10

billion damage [2]. A more recent earthquake in Nepal in 2015 with the magnitude of 7.8, affected approximately 8 million people and caused around 8,500 casualties [3]. Hurricanes and tropical storms are also causing as much heavy loss as those earthquakes. For example, in September 2017, a hurricane named as Irma, caused evacuation warning for 6.3 million people living in Florida [4]. To sum up the foregoing, according to The World Disaster Report of The International Federation of Red Cross and Red Crescent Societies (IFRC), there were roughly 1 million people died in disasters between 2004 and 2013 [5]. Thus, rescuing people is one of the most important parts of disaster recovery as the heaviest loss in such cases is human lives. However, rescuing process involves many obscure elements such as the location of the victims, total number of victims in an area, degree of injuries etc. Due to all these, many people can be trapped and suffer in disaster areas during the rescue process even though they are alive despite their condition, i.e. injured. In addition to these, people also face problems while getting medical help even after the rescue process is completed as the process of obtaining medical report of the people takes time. In some cases, certain procedures, such as safe blood transfusion protocol should also be followed in these situations [6]. In this study, we aim to present a framework that can be employed to aid these problems using the advancements in mobile device technology as well as wireless communication technology in a proactive manner. The proposed system mainly gather information from user in pre-disaster situations to overcome the problems stated; finding the victims, obtaining victims' medical information, finding nearby victims using the P2P connections to send the information to a centralized server.

More precisely, the system obtains user's location using two providers in Android based operating systems namely global positioning system (GPS), and Android location provider library [7]. Thanks to the P2P connection feature of WiFi Direct, it can also obtain the nearby devices' MAC addresses. Using this information, authorities can detect the possible victims of the disaster as well as their approximate location, which reduces the time spent for searching process of rescuing. In this study, we choose to focus on earthquakes due to their effects on both people and available infrastructures. Although the system can easily be configured to adapt any kind of

disasters, the focus in this paper is on earthquakes.

The main contribution of this framework is the fact that a hybrid approach is used when obtaining users' location data as well as presenting the P2P method to reach the devices nearby one another. In this hybrid approach, proactive approach obtaining the users' location before any disaster happens, and reactive approach, which is developed to be used right after a disaster, combined to enhance the recovery process by increasing the probability of finding the victims of a disaster. In proactive mode, the system collects data continuously with specific period so that even if the victim cannot reach to a base station using his/her phone after a disaster, location data collected before the disaster will play a key role to detect or to estimate victim's location to be able to take action. On the other hand, in reactive mode the users' device actively looks for the mobile stations to create P2P connections for data transfer. If any device is found during the process, the data is passed to that node and this process continues for the device which the data is passed to until a device with internet connection is found. When data is passed to a device that has the Internet connection, it is sent to the cloud for the authorities to see and take action.

The rest of this paper is organized as follows. Related works in the literature are discussed in Section II. Section III presents and explains our proposed framework. In Section IV, the operation of the designed system and some possible use cases are provided with explanations. Finally, Section V concludes the study and gives recommendations about some of future directions.

II. RELATED WORK

There exist a number of studies in the literature -that make use of mobile devices and the advancements in communication technologies to ease the disaster recovery process with variety of methods, such as evacuation, warning and safe-path finding systems. Moreover, many researchers focus on informing and warning the users for evacuation in case of a disaster. In particular, Rahman et al. proposes an early warning and evacuation application, Open Street Map, that obtains user location to inform them about disasters and to create a safe path out of the disaster zone [8]. Similarly, Jovilyn and Carlos, in their research, proposed a method using genetic algorithms for the people in need [9]. In their method, similar to traveling salesman problem, they find an optimal route on which most of the people can be helped in case of a disaster using the geolocation feature of Android. Even though warning the users and making evacuation process easier with these technologies are needed, both studies requires an active user interaction which may not be possible for people in disaster areas. On the other hand, Zongqing et al. proposed a system where user interaction is only needed for the rescue team members to check people in needs. Their application uses Wi-Fi Direct for creating P2P connections as in the proposed method in their paper for sending and receiving emergency messages between mobile devices for rescuing [10]. Although this system does not require any user interaction in order to get user's location;

it has some weaknesses. An example of these weaknesses can be the fact that someone from the rescue team is required to walk around the collapsed buildings in order to find people who are under the wreckage. This procedure obviously slows down the rescuing process and even few seconds can be important when it comes to rescuing people from a disaster. Another weakness of this procedure is the fact that it puts the rescue team member's life in danger, since someone from the rescue team is searching for people under wreckage. Mally and Kriz [11] propose an ad-hoc cloud solution with Android devices and LTE Direct technology which can be used for disaster recovery. Although the cloud system proposed is similar to the server side of our system, their main approach is reactive. In our proposed framework, all of these operations are handled in a more proactive fashion by continuously operating in the background to solve the shortcomings of the previous studies.

Even though the studies mentioned above are proposed for natural disasters such as hurricanes, earthquakes, floods, tornadoes and volcanic eruptions etc., the communication technologies and mobile applications are also used actively for epidemic disease cases. In their paper, Kok et al, propose an Android application where using the information gathered from authorities and information of the mobile devices, users are informed about the diseases which may be potentially dangerous for their location [12]. It is also quite important to use the location related information to accurately detect the people which may be affected from epidemic diseases. In this framework, thanks to the facilities provided for tracking nearby people, it is possible to detect victims who are potentially infected and then possibly avoid an outbreak. For example, instead of quarantine masses of people within a specific region, it is possible to use the location related information in order to establish the probability of a person to be infected by analyzing the neighbourhood related information from the local and central databases.

Another factor that affects the design of these applications is the selection of wireless interface. As seen in the previous paragraphs, the most popular one is WiFi Direct due to its availability on Android. However, there are other possible interfaces for use in mobile devices. For example, Near Field Communication (NFC) is used to develop mobile applications to buy e-ticket's via mobile device. However, NFC cannot be used in disaster recovery systems as its coverage area is limited to centimeters [13]. Another interface that can be used in such disaster recovery systems is Bluetooth technology, but the coverage area of Bluetooth is also limited considering the WiFi Direct's which makes WiFi Direct more suitable for proposed framework [14]. All in all, although there are several studies on this topic, very few of them use a proactive approach. Since the data stored in local as well as central databases can provide valuable information in events of disasters even for the cases where the infrastructure is destroyed, hybrid approach including the proactive and reactive approaches, proposed in this paper has the potential to improve the recovery process significantly.

III. THE PROPOSED FRAMEWORK

In general there are two ways to obtain the location related information when these systems are considered. The reactive approach and the proactive approach. The reactive approach is not suitable for all kinds of disasters since there may be some functionality related problems caused by the physical damage in the network after a disaster, and in such a case, it may not be possible for user to send data to the centralized system. In order to illustrate this, in a scenario where a heavy or moderate earthquake has occurred, it may not be possible for authorities to locate people and save them as the Internet providing units may be damaged or destroyed. Hence, instead of using a single approach, a hybrid approach is presented in our system to eliminate the disadvantages mentioned. In the proactive mode, the system gets some information from the user in specific time periods continuously and sends it to the centralized system in order to track the user without waiting for a disaster to occur. On the other hand, in case of a disaster, the reactive mode of the application is activated. In this mode, there are several possible scenarios based on the internet connection.

- 1) If the user has Internet connection, the mobile device gathers information from the nearby stations and sends the collected information including its own location to the centralized server.
- 2) If the user does not have connection due to some damage to existing infrastructure, it starts to store information in a local database as if it is in the proactive mode and passes the latest data to the nearby devices using D2D communication facilities. In case one of the neighbouring devices has reception, this information eventually reaches to the centralized database.

In short, the system enters ad-hoc networking mode to make the information reachable by the centralized server using the support of the WiFi Direct interface of mobile devices. The flowchart of the approach is shown in the Figure 1. Thus, even if the networking units of the area are damaged, an approximate information about users can be obtained via stored information in centralized database system.

To clarify the flow, when the app is launched, if the user is registered to the system, s/he enters the login credentials. If not, the user is forwarded to the signup page and enters the credentials to sign up. After the sign up process, s/he is forwarded to the main screen of the app where s/he needs to enter the login credentials. After entering the credentials, the system checks whether the credentials are correct or not. If not, an error is shown and user needs to re-enter them. If they are correct, the user is forwarded to the dashboard of the application where the system checks whether there is a disaster information. Regardless of the disaster information, the application starts to collect location information from the user and if the reactive mode is on which means there is a disaster; the application stores the information in the local database and continues to search for the nearby device information. If the reactive mode is off, then the app checks

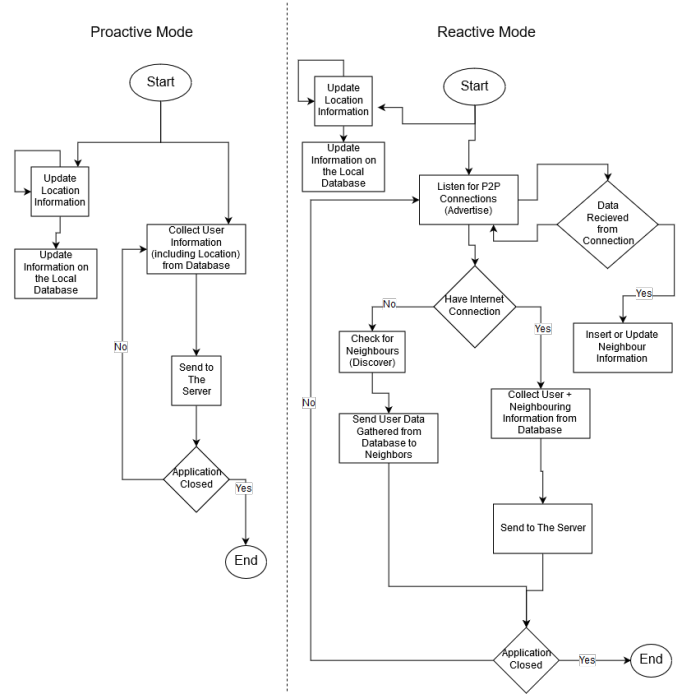


Fig. 1. Flow Chart of the Proposed System

whether there is an internet connection and if there is internet connection the system sends the location information to the centralized database; if not, it continues to retrieve location information. In the case of a disaster, locally stored data is sent to the devices which are in single hop coverage area. Their neighbourhood related information is also retrieved in turn. After updating the local database with the connection of the devices around, the application checks whether there is an internet connection or not; if yes, this data is to be sent to the centralized database and if not, the application continues gathering location information.

It is possible to provide the necessary ways of communication for the rescuing system framework presented by using emerging wireless communication technologies, i.e. LTE, LTE-A as enabling radio subsystems. The main target of the study presented in [15] is to show that in case the infrastructure employed for usual communications is not available, (i.e. there is loss of cellular coverage after an earthquake), D2D communication is still able to provide means of communication. Quantitative evaluation of a possible LTE D2D framework is presented in [15] and the simulation results for the proposed design show that efficient resource management for rescuing services is possible using multi-hop D2D communications.

IV. SYSTEM DESCRIPTION

The system considered in this study consists of two main parts.

- 1) Mobile Software Part
- 2) Backend Part

As shown in the Figure 2 there are four main components in the backend part and there is one component in the mobile

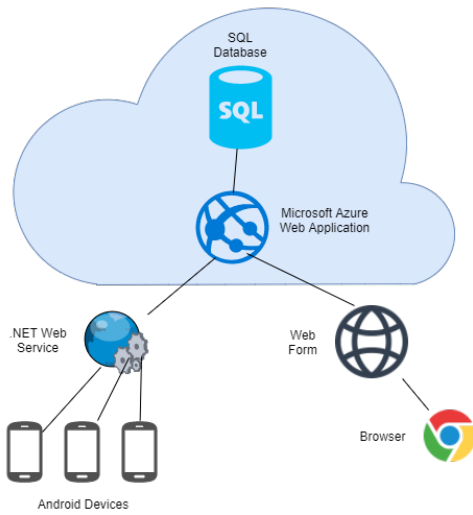


Fig. 2. Overall Design of the System

application side part which is the mobile application itself. In this section, the main parts of the application are explained.

A. Mobile Software Part

In order to benefit the prevalent use of mobile devices, a software that interacts with the mobile device is required. Hence, an Android application is developed with Java language. In the mobile application, the main focus is on the background services since the main aim of the application is to gather location and neighbourhood related information via sensors in the mobile device and to pass this information to the centralized database. Hence, two main tasks are determined and developed in a background service.

These are;

1) *Location Tracking*: To obtain location information, Android provides different sources such as GPS, Network and Passive Provider. Our application mainly uses network provider since it consumes less power compared to the GPS Provider. In addition, we did not choose GPS Provider although it has the highest accuracy in location tracking as it does not work well in indoor environments and environments such as cities where the population is quite high within large cellular areas. Moreover, interval of location retrieval is determined as one minute since the mobile users without a vehicle are not expected to change their location significantly. Thus, even if a disaster occurs and location information of users' is not updated, the admin(s) of the system will be able to control the users' approximate location by using the last obtained location. Lastly, information gathered is sent to the central database via web service by sending HTTPS request with a specified period.

2) *P2P Service Discovery*: To discover nearby devices, different interfaces can be used such as Bluetooth and Wi-Fi Direct. In our system we choose to use Wi-Fi Direct sensor as it has an API provided by Android. This API enables developers to discover peers and to connect to them. However,

when direct peer discovery is used, the mobile devices may collect data from non-mobile devices as well. Hence, we developed a service discovery where the background service only detects the peers who have the same application installed and running. Furthermore, by using the service discovery in Android, the application is able to obtain the Wi-Fi Direct MAC address of nearby devices. Thus, by obtaining and storing the MAC addresses of the nearby devices, the system is able to track who is nearby rather than only detecting the number of peers nearby.

As explained above, the system mainly runs in background and does not involve many user interactions. However, the application requires registration and login from user to be able to get some medical information, so that in case of rescuing, the medical teams may act in a faster manner. In addition, system assumes that all the entered information by the user is correct, and gives all the responsibility to the user. However, the medical data obtaining process is revisited in conclusion part. Hence, the information gathered from user in sign up can be explained as follows;

- 1) **E-mail**: To be able to identify users among each others in the server.
- 2) **Blood Type**: To act faster after rescuing a victim in case of hemorrhage as there are some procedures if the patient's blood type is unknown [6].
- 3) **Chronic Diseases**: To provide the required medicine for the victims depending on their disease.
- 4) **Drug Allergies**: To prevent side effects of drugs after rescuing or enhancing the intervention.

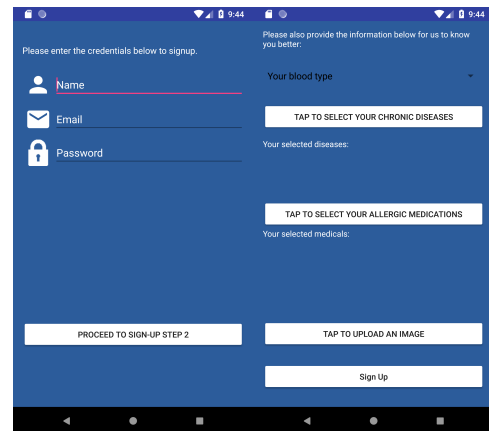


Fig. 3. Signup Page of the Mobile Application

To change this data, users can go to their profile pages and update every part of this data separately as shown in Figure 4.

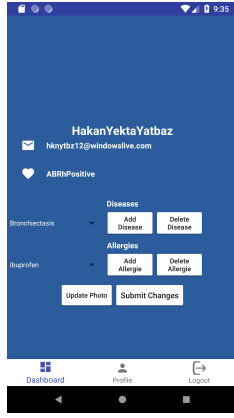


Fig. 4. Profile Page of the Mobile Application

Furthermore, MAC addresses of the devices are obtained every time a user logs in. The reason behind getting the MAC address of the devices is to limit each user to have only one device registered to the system as as registering multiple devices for the same person may cause consistency related problems in the databases employed. For example, one user may be seen at different locations depending on the location of their device which misdirects the rescue teams.

B. Backend Part

In the backend part of the overall system, there are four main components. Firstly, a web application that is deployed in a cloud with an SQL database which runs 24/7. Furthermore, to be able to pass the data from mobile devices to SQL database, a Simple Object Access Protocol (SOAP) web service was implemented with C in .NET. Hence, the communication between the web server and the devices are provided via a web service. In addition, as mentioned before, an admin panel is required to enable the authorities to query the database and to visualize the results.

1) *Admin Panel:* In admin panel, three main features are presented. These are;

- 1) **Result & Data Visualization:** These features are presented with support of the Google Map Interface and a result table. Furthermore, in Google Map, it puts a marker to the every user's location by indicating their username and the timestamp of location retrieval which can be seen in Figure 5 .

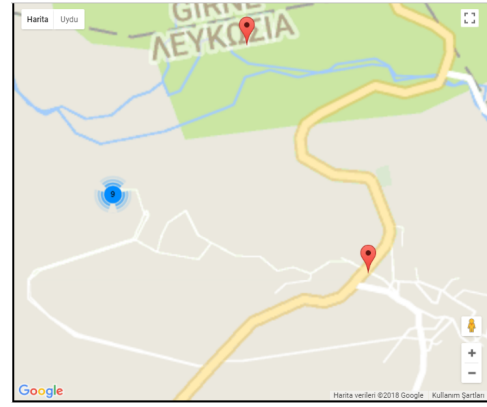


Fig. 5. Markers and Clustering on Google Map in Admin Panel

In addition, it clusters the markers and shows the total number of markers in an area if the admin user zooms out or if there are many markers in a small radius which can be shown in Figure 6.

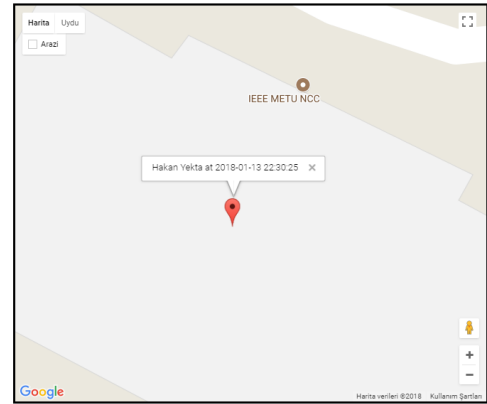


Fig. 6. Marker Information on Google Map in Admin Panel

Moreover, in the result table, admin users can see the results of their queries in a tabular format which is shown in Figure 7 .

Username	Email
Hakan Yekta	1@1.com
abdulrahman	abdulrahman@gmail.com
alejtest	alejtest@test.com
mehtmet	asd@gmail.com
selami	asclami@gmail.com
bbbb	asclndn@sh.com
Alan Turing	aturang@gmail.com
Berkem	berkem.cinar@kktcell.com
Mehmet C	oglanmehmet03@gmail.com
mHmur	cemce@mail.com
Berkem	cinar.berkem@gmail.com
ah	dag@dag.com
ali gokdemir	denizdev@mail.com
ali gokdemir	devdag@mail.com

Fig. 7. Result Table in Admin Panel

- 2) **Query Builder:** This feature is presented with a text box where the admin users can execute their own SQL select queries for different operations on NoSQL database. The attributes that can be selected are limited. All the results are shown in the result table.

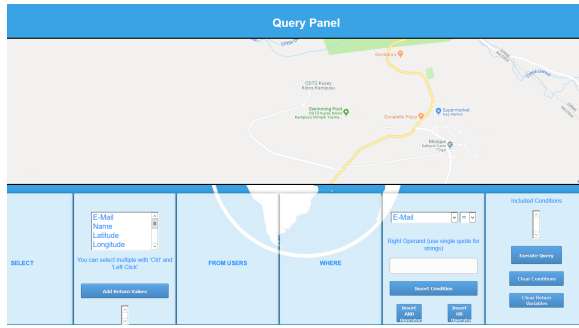


Fig. 8. Query Builder Page in Admin Panel

V. SECURITY

In order to keep track of the users, the system stores includes some sensitive information such as location, photograph, allergic medicals, and chronic diseases of the users. This information is sensitive because information of allergic medicals and chronic diseases are personal information which should be kept private and protected against exposures. Similarly the exposure of photographs with location information can be quite dangerous. Not only can photos be stolen and used by strangers, but also the current location related information would allow strangers to know exactly where people live, work, study etc , especially together with tags which reveal exactly where the photos are snapped. Hence, security of these information becomes essential.

Considering the security measures of such a system, it is inevitable to have several security levels to protect the sensitive data such as location, neighbour-related information etc.

Starting from the database itself, a firewall is introduced to have restrictions over the IP addresses that can connect to database. As all the connections(from both mobile application and admin panel) to database is established through the web service, the firewall only allows the web service to connect to the database, and allows no other IP addresses to make sure no one can access the database directly.

As for the mobile application part, sensitive user information, such as password, are kept encrypted with hash functions, as a common approach. Furthermore, requests that are sent to a web service from mobile application are also encrypted by using SSL to establish a secure connection and data transfer process from mobile application to web service.

Lastly, for the admin panel security, there is a token based authentication system for admins to authenticate themselves. When an admin enters his/her credentials, a token with expiry duration is sent to his/her e-mail address, and s/he is only able to login to admin panel once a valid token(that is not expired) is entered. Due to authentication system, redirecting to main page is also protected and unauthorized connections are not able to see main page.

Once an admin is logged in, s/he will be able to execute queries or stored procedures. However, to prevent the database injection, the database has a separate user for admins, and this user has restricted privileges so that the admin actions is also controlled. Moreover, as the login operation becomes

successful, a session for the logged in admin is created, giving an opportunity to track every move(executed queries or procedures) of the admins to have a history of actions for security reasons.

VI. CONCLUSION

Smart mobile devices entered our life and been taking more important roles as the technology advances. Today, more than two and a half billion people are using smart phones [16] and by developing these kind of public safety applications, the world can be a safer place. On the other hand, the population of the world is increasing day by day and because of this dramatic population increase [17], the cities are also affected inevitably which make the development of such applications a must in order not to have heavy loss around the world because of disasters. This paper introduces an application which can be used to save lives and ensure safety of the public after a disaster occurs. To the best of our knowledge, our proposed approach includes the first hybrid framework which harnesses proactive and reactive approaches in an attempt to reach the most useful information available. Introduced application makes the use of several Android features like location tracking and P2P communication as well as some other technologies like Microsoft Azure and .NET.

As future work, newly introduced technologies can be used to discover the devices nearby. Moreover, the optimal interval to retrieve users' location should be discussed further since the time interval that the data is being taken right now is based on a simple calculation. This time interval may cause high power consumption where the battery level of device has one of the most important parameters to reach to a user. Therefore, this feature's power consumption should be examined and enhanced for better performance. Lastly, the medical information of the user may be approved by the medical authorities for higher efficiency in post rescuing support. There is another level of security that can be employed, which is the physical security for D2D in disaster situation [18].

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