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Adhoc Networks for SOS Message in Natural Disaster Relief

Julio R. Ribón*, R. Martín Monroy and M. Plinio Puello

System Engineering Department, University of Cartagena, Colombia; jrodriguezr@unicartagena.edu.co, mmonroyr@unicartagena.edu.co, puellom@unicartagena.edu.co

Abstract

Background/Objectives: When disasters caused by nature occur, for example, floods or earthquakes, it is common for communications infrastructure to collapse, leaving people isolated; which can increase the risk of vulnerability after the disaster, due to ignorance of vital information to receive help. The objective of this work is to provide a mechanism to enable people affected during a disaster to have a communication channel to inform aid entities about their personal condition. **Methods:** The present work is based on a descriptive methodology that allows representing an architecture that makes it possible to send messages through an ad hoc network generated with mobile devices, which is based on the guides of the 4 + 1 views model. **Findings**: The work provides a guide that enables connectivity for communication during disaster situations, being of great help, for disaster response agencies, to quickly assist potential victims of disasters, who are in a vulnerable situation. **Application/Novelty**: The work has allowed us to generate a test scenario where the functionality of the architecture is validated. There has also been a simulated scenario where the behavior of the Ad hoc network is studied, which allows sending help messages in the moments after the occurrence of a natural disaster.

Keywords: Adhoc Network, Disaster Relief, Mobile Networks, SOS Messages

1. Introduction

A natural disaster is defined as an event of nature that threatens and jeopardizes the function and safety of the community. Natural disasters can be caused by rapid or slow events originated from geophysical, hydrological, climatological, meteorological or biological conditions[1].

When a natural disaster occurs the communications infrastructure usually collapses. This situation does not allow affected people to inform their families or disaster assistance organizations about their state of health or where they are located placing this population in a vulnerable state[2].

The lack of information and communication channels generates noise that increases the potential risk in people after a catastrophic situation has occurred. The above can aggravate the situation, creating confusion in the population, which generates uncertainty, chaos in the moments after the eventuality, problems distribution of resources, problems of public order, congestion in hospitals, saturation of security agencies, among others.

Situations such as those mentioned above have been experienced by the population victim of different recent natural disasters, such as the Armero tragedy in Colombia[3], the earthquake in Haiti[4], the earthquake in Mexico[5] among other serious incidents.

Technology becomes an important tool in timely attention after the occurrence of a disaster, especially mobile devices, since, despite the communications infrastructure is lost, these devices can be valuable to guide the population and the rescue units, store useful information such as photos, audio, videos, among others. There are several initiatives worldwide trying to use technological resources to support the population to mitigate the risk after the occurrence of a disaster.

**Author for correspondence*

The Ericsson Wider system - Wireless LAN in Disaster Emergency Response, allows the creation of wireless networks - Wifi[6], points for connection to the Internet or the distribution of mobile telephones for free calls through the Ericsson Response network; for this purpose, lightweight and easy-to-transport modules were designed with all the necessary tools for network deployment and connection. For more than 12 years, Ericsson Response has supported more than 40 relief activities in more than 30 countries. Although the system is efficient, the main function is to reestablish the communication system and the data network for the logistics operations of the humanitarian organizations existing in the area, which allow them to conduct their activities. However, it takes a few hours to reach the site with the equipment and deploy the services, wasting valuable time in disaster relief, which is when urgently requires knowing the status of potential disaster victims.

D2D[7] is an architecture designed for a device-to-device communication. It allows communicating one device to another without the use of a large infrastructure and also allows continuing operating the device in a normal way. One negative aspect is that it needs a server that functions as core of operations for the communication of different devices, causing the server device to be congested which is necessary to have certain hardware specifications. This architecture is currently being developed.

Sahana[8] was used in multiple natural disasters. Some examples are Hurricane Sandy in New York in 2012, along with the Earthquake and Tsunami in Japan 2011. Although this system shows good characteristics to collect and distribute information after disasters, it does not present functionalities for collecting and disseminating information in the early stages of an emergency where all possible information is vital to help people avoid the collateral damage of a disaster.

The present work shows an architecture that makes it possible to send SOS messages when an adhoc network is formed with mobile devices at a time after the occurrence of a disaster. This network is a weak infrastructure network, which must be optimized to the maximum to be used in an appropriate manner.

Initially, the architecture is described, and an operational prototype has been implemented in an experimental scenario of a possible natural disaster, small SOS messages are sent to locate a possible victim, then, a simulated scenario of sending SOS messages through of the Adhoc infrastructure network is carried out, and finally the conclusions of the study are obtained.

2. Materials and Methods

This work is supported in a descriptive methodology to distinguish and identify many aspects, dimensions and components of the phenomenon in search.

The diagrams used in the description of the architecture are based on UML as modeling language[9], considered as standard in the software development.

4 + 1[10] views are used as a guide to describe the architecture of the system. We chose 4 + 1 views, since multiple views are used which can address the interests of various actors in the system.

For the realization of the simulated scenario, where SOS messages are sent through the adhoc network formed with mobile phones after a natural disaster, the OMNet ++ Version 4.5[11] tool is used. This tool has been selected when evaluating various network simulators, due to the richness of its graphical environment to support the understanding of the simulation results.

3. Results and Discussion

Disaster risk management seeks to avoid, reduce or transfer the adverse effects of threats through various activities and prevention measures, mitigation and preparation, carrying out the systematic process of using administrative guidelines, organizations, skills and operational capabilities to execute policies and strengthen response capacity in order to reduce the adverse impact of natural hazards and the possibility that a disaster occurs[12].

In emergency situations where lives are at risk, all measures taken to rescue and save lives are valued; Keep calm and think clearly is the most important in these situations. Decision-making is vital, right decisions can save many lives and for this reason, appropriate information is important to defend oneself after a disaster. This is why communication is decisive in these eventualities; not having knowledge of the situation can lead to wrong decisions and thus waste time and valuable resources which can lead to the loss of human life.

For people who are in an emergency situation and cannot communicate through traditional means, it is very important to have the ability to send information about their health condition and position as this may facilitate their rescue; this information can be helpful for relief agencies because it allows them to save time and save many more victims. For organizations that handle an emergency keep maintaining the lines of communication with other organizations that support disaster response, facilitates the logistics and the effectiveness of their operations.

The present work provides a guide that enables connectivity for communication during disaster situations; specifically, in areas of disaster impact ("critical zone"), in which the communication infrastructure is lost due to the impact of the disaster, and a significant number of victims can also be presented. The communication network generated by mobile devices allows disaster response agencies to send information to victims for their help and allows victims to send information to these organizations for their location and rescue (Figure 1).

Figure 1. Sending SOS messages in an adhoc network - natural disaster scenario.

3.1 System Architecture

In this section, different views that constitute the proposed architecture are exposed; the 4 + 1 views are a set of views that describe the system from the perspective of different actors and members of software development[10].

3.1.1 System Requirements

In this section, the functional requirements of the system are described through the use cases (Figure 2).

The Actor "Victim" is the person directly or indirectly affected by the eventuality of a disaster, he / she needs to send SOS messages and receive messages with relevant information that allows him / her to stay safe. The "Interested" Actor is the person (s) that needs to know about the condition in which another person is, such as a relative or a loved one. The actor "Disaster Response Organization" is the agency that seeks the prompt attention to the victims in a disaster, provides relief, supports with humanitarian aid and maintain coordination with other entities during the emergency.

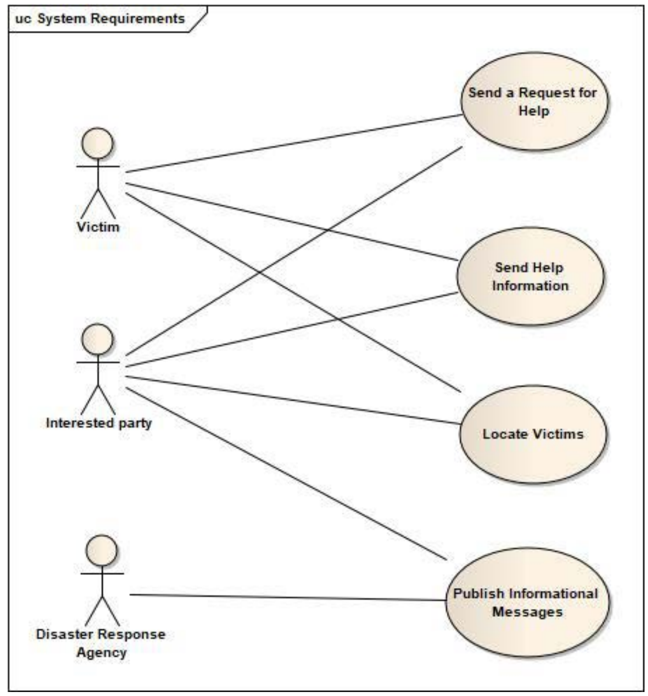

Figure 2. System requirements.

3.1.2 Logical view

This view represents the functionality that the system provides to the end users, that is, it must represent what the system must do, and the functions and services it offers[10]. The diagrams that we are using in the representation of this view are the class diagrams[9].

In Figure 3, we see three packages: *Model, Controllers y Router* where the *Model* stores the units involved in the system: *Device, User and Message* which represent the data device, the user information and the characteristics of the message to be sent. The *Controller* package represents the logic of the system responsible for the reception, storage and the sending of messages, all thanks to the *Router* package that together with its *Orchestrator* class decides how to send the message.

3.1.3 Process View

In this view (Figure 4), the processes developed in the system and the way how the actors communicate are shown; that is, it is represented from the perspective of a system integrator, the step-by-step workflow of business and operations of the components conforming the system[10].

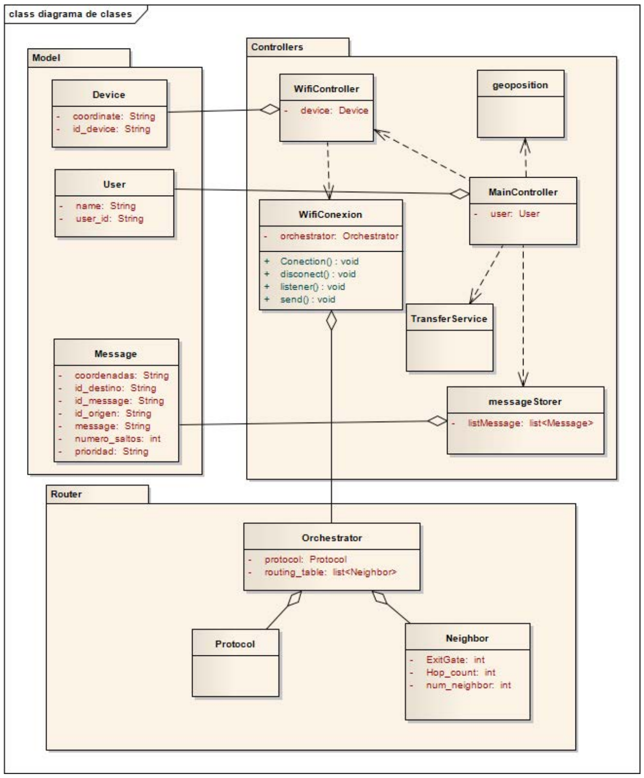

Figure 3. Logical view.

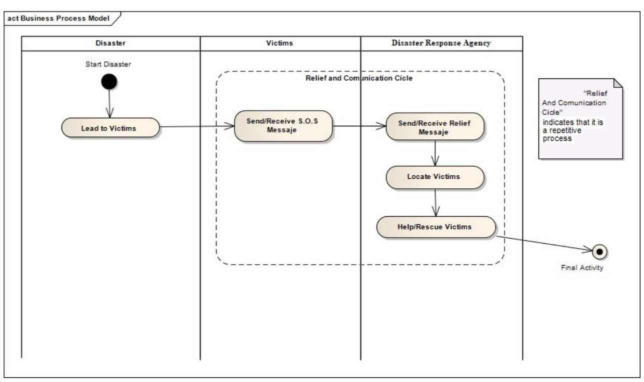

Figure 4. Process view.

3.2 Test Scenario: Sending of Help Messages Moments after a Natural Disaster has Occurred

In this scenario, the occurrence of a natural disaster is considered. People get trapped inside the disaster zone. Moments after the disaster, the survivors try to make distress calls through their mobile phone, but unfortunately, they cannot do it so because the communications infrastructure has collapsed and their mobile devices are at that time on emergency mode.

The survivors or possible victims are in a vulnerable condition because they cannot notify their relatives about their condition or location. They also do not have information about zones to a shelter or victim assistance; for example, zones for medical attention, safe areas and provisions zones.

A minimum viable prototype has been developed that can be used in mobile devices, which uses Wi-Fi Direct, a regulation that allows Android devices to connect with each other using Wi-Fi connection, allowing the possible victim through the mobile device to attend the following use cases (Figure 5).

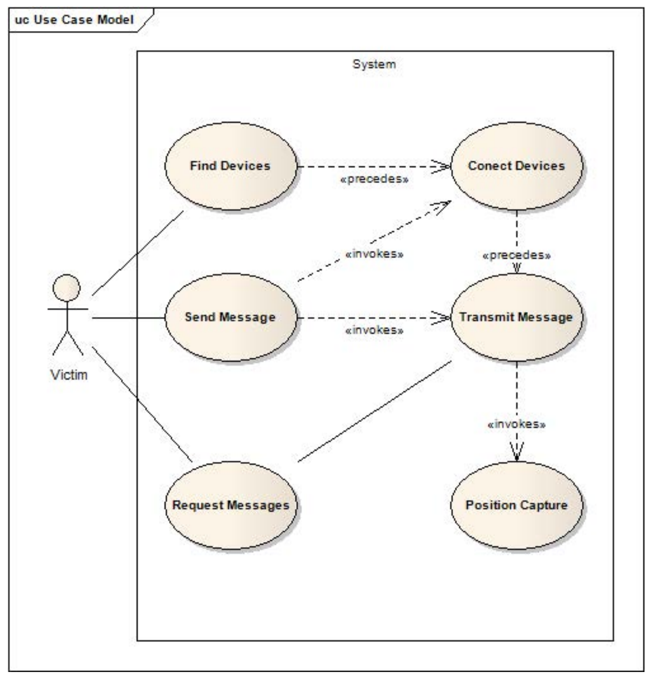

Figure 5. Uses case – test scenario.

When establishing communication via Wi-Fi, the devices establish a mesh network of low infrastructure, which allows creating a communication channel for sending small messages. The Victims send an emergency message requesting assistance to the disaster assistance agencies with their own coordinates (Figure 6).

The message is sent through the created Information Channel and the information travels to the next available device (Figure 7). This new device evaluates if this is the recipient. If this is the recipient, it shows the SOS message sent by the victim's mobile device (Figure 6); If this is not the recipient, the message is sent to another new device.

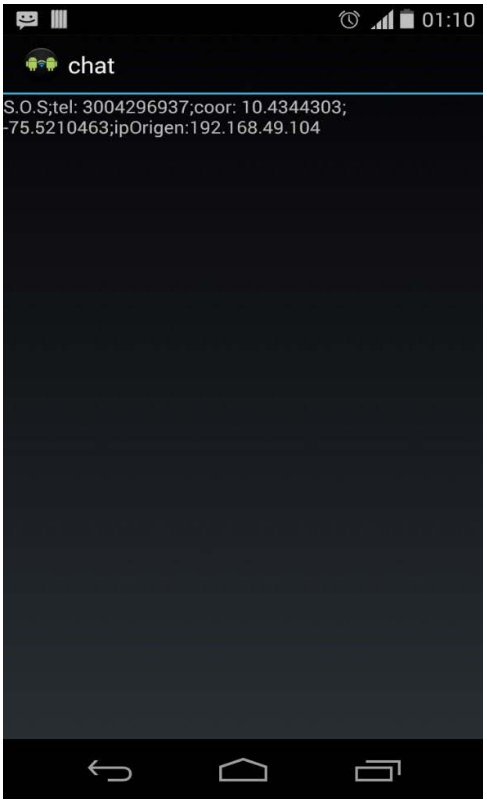

Figure 6. SOS message.

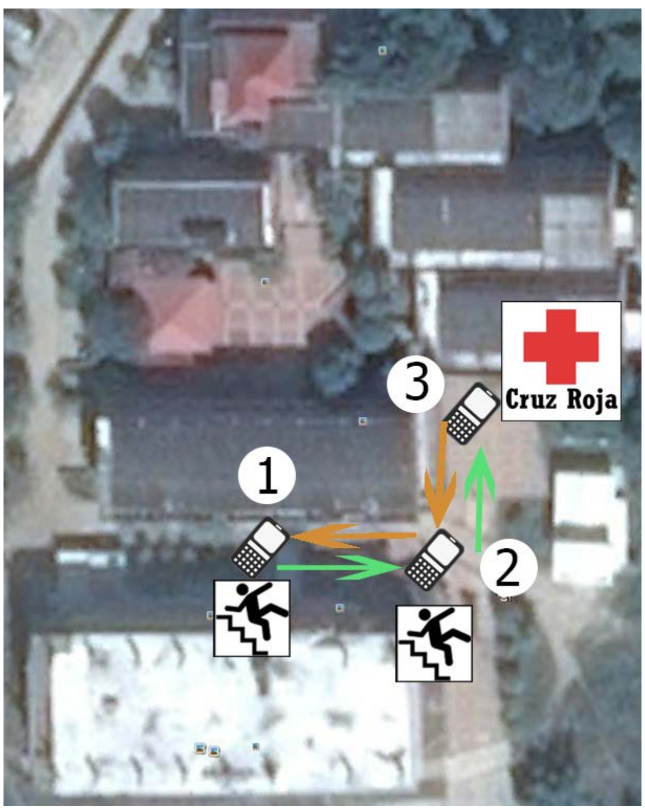

Figure 7. Test scenario.

The test scenario was carried out using two Motorola G cell phones that the victims had at the time of the natural disaster; 1 cell phone Samsung Galaxy S4 that the disaster relief organization "Red Cross" has. In this scenario, victim 1 (Figure 6) is out of range from the ¨Red Cross¨, as shown in Figure 6 as number 3; The green lines represent the flow of the "emergency message requesting help" from the victim. The orange lines represent the flow of the "Relief Message" from the disaster response agency.

As a result of this test, the implementation of the architecture through the minimum viable prototype has allowed the sending and receiving of messages; these were sent from one device to another. This observation confirms the ability to create channels of communication between the actors within a disaster situation proposed in the architecture.

The message travels from one device to another (Neighbor), using the proposed protocol, this is evidenced since the victim possessing the mobile device, number 1, is out of range from the ¨Red Cross¨; also a communication channel was created using a mobile device of an intermediary person, number 2; managing to send a message from number 1 to number 3 (Figure 6), thus allowing the victim with mobile device number 1 to get communicated and be rescued.

The observations in the test scenario were: connection failures in the communication range of the devices, as well as failure in message transmission at a distance of 65 meters, since messages were sent from a greater distance and the devices did not have good connection.

3.3 Simulation of the Behavior of the Adhoc Network in a Possible Scenario for Sending SOS Messages

After the minimum viable prototype has been made, the question of how the behavior of multiple victims trying to send SOS messages after the occurrence of a natural disaster has been raised. To assess the above, a simulated scenario is performed in which it is assumed that there are 99 potential victims and an agency ready to support the victims and locate them.

Figure 8 illustrates 100 virtual devices that represent 99 potential victims within a disaster area. 1 mobile device represents disaster response agencies moving through the affected area looking for SOS messages.

It is assumed that a natural disaster occurs and users with mobile phones within the disaster zone turn on their devices in emergency mode. The devices send messages to all devices within reach (making a Broadcast). The devices that receive the message evaluate if they are the recipient. If it is the recipient, he/she responds with an acknowledgment receipt. If not, the recipient sends the message to all devices within reach. Any device that sends the message receives the acknowledgment of receipt.

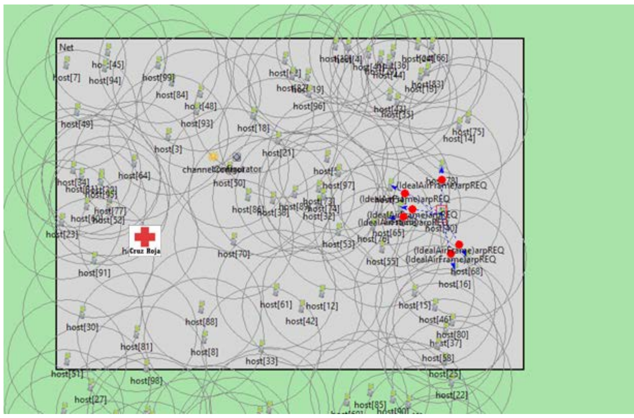

Figure 8. Behavior of the adhoc network.

The simulation has been done using the OMNeT ++ tool in version 4.58. This tool was selected after exploring multiple available simulators, some of these were NS2, NS3, GNS3, OPNET, ANSiM and NetSim; OMNeT ++ is selected for the ease and for being user-friendly in the graphical environment that allows to configure the simulation characteristics with high effectiveness; Virtual devices are configured for the Ad hoc communication, this scenario is performed to observe the behavior of the network and seeks to establish a communication according to what is described in the architecture.

In the simulation (Figure 8) the possible victims, represented by devices 1-99 (host [1-99]), send messages requesting help to the disaster assistance agencies, represented by the logo of the red cross (host [0]), this is an example of what would happen in a real environment, where people caught in a disaster situation want to be assisted.

At the end of the simulation you can observe the data of sending and receiving messages (Table 1).

It is observed that the transmission of data in this scenario is quite variable because the possible victims that are away from the rest do not manage to send their messages to a greater number of devices, this is a case of the people identified with id 14 and 75 (Table 1); these victims are out of reach and fail to send their SOS messages to the disaster response agencies.

Table 1. Simulation data

Device	% Lost Messages	round-trip time (min/avg/max ms)	Deviation (ms)
Host[14]	100	0/0/0	N/A
Host[15]	46.1538	1.69805/20.7519/1012.87	135.013
Host[32]	23.8095	1.69819/1.8875/4.04322	0.480512
Host[45]	4.71698	1.69811/2.65716/6.37791	1.30844
Host[75]	100	0/0/0	N/A

The results of the simulation show that it is possible to establish communication between many devices despite the loss of messages, many victims manage to communicate with disaster assistance agencies and receive help information.

There is great loss of messages due to the fact that the transmission is done through Broadcast; this type of transmission is characterized by causing great congestion within the network when it is used by multiple devices. To solve this problem in the proposed architecture. a routing, which allows the messages of people to travel from device to device, looking increasingly closer to the target device.

4. Conclusion

The importance of this work lies in the fact that it allows providing a form of alternative communication for victims in a natural disaster situation and save their lives; this can become a valuable tool for disaster response agencies when seeking victims and helping them, as well as a useful tool to meet communication needs in cases where conventional communication methods do not work

The test scenarios indicate that it is possible to create communication channels independent of the infrastructure that currently exists in a certain area, so that victims can rely on their mobile devices in a disaster situation.

In addition, the above mentioned, some aspects that may affect the sending help messages through the adhoc network generated have been evidenced; among these aspects there are: the characteristics of the devices, the software version, the hardware specifications, the limited scope of the signal; although they are technical factors it is expected that as time goes by and the advance of the technology they do not become limiting to send help messages in an appropriate way; notwithstanding the aforementioned, in the proposed scenario, the system works properly, it helps people to communicate in emergency situations.

There is the possibility of generating a new channel of communication when the conventional infrastructure collapses during a natural disaster, the potential risk in which people find themselves decreases after the catastrophic situation. The above can avoid confusion in the population, reducing uncertainty and chaos in the moments after the eventuality, having the possibility to disaster relief organizations to save their lives quickly and reduce the possibility of collateral damages normally generated in these situations.

5. Acknowledgement

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