NESA
Neighborhood Emergency Support Application

By

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Abstract of Project Presented to the Graduate School
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NESA: Neighborhood Emergency Support Application

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2013

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Weather inclement and natural disasters, such as hurricanes, tornados, earthquakes and fires, can affect communities adversely and people might suffer damages on their homes and goods. As a result, countless situations and needs may arise and sometimes individuals could need help from the authorities, as well as from other residents. Communications are essential to coordinate help and support on these situations. The phone, text messages, social networks and emails are communication mediums that are used during emergencies of this nature. Nevertheless, most of them depend on the Internet or network service providers, thus they could be affected during these events making the recovery process more difficult. In order to provide an additional communication mechanism, this project introduces a new communication system based on Android devices using a backup network that will be deployed on affected areas after a major disaster. This system will make possible the communication of information between residents and the government authorities even if regular phone systems have failed.

This project consists of an Android application through which residents can get in contact with their neighbors or the authorities in case of an emergency. The devices will be connected using a backup emergency network deployed after a major disaster allowing other residents, friends, family members, volunteers, and emergency personnel to be contacted using a text messaging system (chat). The connection required will not depend on any network service provider; instead the devices will be directly connected through the emergency network (peer-to-peer). The authorities will be able to use this medium to send information and alerts to the citizens through a notification mechanism and the user will be able to search for nearby shelters. Furthermore, the authorities will be able to receive formal help requests from the residents for situations that may require their intervention.

Resumen de Proyecto Presentado a Escuela Graduada
de la Universidad de Puerto Rico como requisito parcial de los
Requerimientos para el grado de Maestría en Ingeniería

NESA: Aplicación para manejo de emergencias en la comunidad

Por:
Víctor J. Vázquez López
2013

Presidente: Néstor Rodríguez
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Las inclemencias del tiempo y los desastres naturales suelen causar daños a las comunidades y afectar adversamente los bienes y viviendas de las personas ubicadas en las áreas afectadas. Como resultado de las innumerables situaciones y necesidades que pueden surgir, los individuos pueden requerir ayuda de las autoridades, como también de otros residentes. Los medios de comunicación, como las llamadas, los mensajes de texto, redes sociales y los correos electrónicos, son esenciales para coordinar la ayuda y el apoyo en estas situaciones. Sin embargo, la mayoría de estos medios dependen de la internet o del servicio telefónico, por lo tanto podrían verse afectadas durante una emergencia. Este hecho puede provocar que el proceso de recuperación sea más difícil.

Por esta razón, este proyecto introduce un mecanismo de comunicación adicional en casos de emergencia. Este sistema, diseñado para dispositivos Android, permite a los residentes ponerse en contacto con sus vecinos o las autoridades a través de un sistema de mensajería (chat). Los dispositivos se conectan a una red de respaldo, la cual es activada luego de un desastre de gran magnitud. La conexión requerida, no depende de ningún proveedor de servicios de red, sino que los dispositivos se comunican entre sí directamente a través de la red de emergencia (peer-to-peer). Las autoridades pueden enviar información a los ciudadanos a través de un mecanismo de notificaciones. Además, las diferentes agencias para el manejo de emergencias podrán recibir solicitudes de ayuda formales por parte de los residentes. De la misma manera, la aplicación permite que los(as) usuarios(as) puedan buscar refugios cercanos a donde puedan acudir en caso de ser necesario.

ACKNOWLEDGEMENTS

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DEDICATION

This project is dedicated first of all to God for giving me the opportunity of being how I am, for providing me health, wisdom, intellect, determination and allowing me to complete this project successfully. I would like to dedicate this project also to my family specially my father Víctor M. Vázquez, my mother Migdalia Lopez and my brother Emmanuel Vázquez, as well as my second family Marinés Chaparro, Gabriel Miranda, Neftalí Chaparro and María Acevedo, for their support during hard times and for being part of my good times. To my advisor, Dr. Néstor Rodríguez, and to the members of my committee Dr. Kejie Lu and Dr. José Borges for the confidence they have always had in my work and for giving me the opportunity and their support to develop this project. Finally, to all my friends that like a family, have always stayed with me no matter the circumstances.

TABLE OF CONTENTS

LIST OF FIGURES AND TABLES

Figures **Page**

Tables **Page**

CHAPTER 1

1 INTRODUCTION

1.1 Motivation

Natural disasters such as hurricanes, tornados, earthquakes and fires, can affect communities adversely and people might suffer damages on their homes and goods. As a result, countless situations and needs may arise and sometimes, individuals could need help from the authorities, as well as from other residents. Communications are essential to coordinate help and support on these situations. The phone, text messages, social networks and e-mails are communication mediums that are used during emergencies of this nature. Since most of these communication mediums depend on the Internet or network service providers, they could be affected during natural disasters, making the recovery process more difficult. Recently this fact was demonstrated after the pass of Hurricane Sandy through the east coast of the United States. Millions of customers experienced outages in all communication services including wireless and cable based services, mostly due to power failures throughout the area that was affected by the hurricane (CBS 2012). Appendix II presents more situations that show the need of alternate communication systems after a major disaster.

1.2 Contributions

This project provides a system that will add an alternate communication medium in areas affected by a major disaster. Using a cellphone application, users will be able to communicate with other residents promoting the support between citizens. The developed system will also make the authorities able to receive the feelings and requests directly from the community and send notifications to them. The main benefit of this system is that users could use their own phones as a communication medium even if their service provider is not available. This is done using a Wireless Mesh Network framework known as Versatile Service Oriented Mesh Network (VESO-Mesh) that is been developed by the University of Puerto Rico at Mayaguez (Chaparro-Acevedo, et al. 2011). VESO-Mesh is a distributed network that will be deployed after major disasters have occurred and one of it purposes is to provide a backup network during emergencies even when the conventional network services are not available due to the disaster event. It can be self-sustained by using solar panels to acquire required power and the connection between nodes is performed wirelessly. For this reason, it does not require installation of hardware links (fiber optics or copper) and with a set of these devices the affected areas can be covered. The mobility, versatility and capability of this system, provides the capabilities needed to operate in rough environments during emergency situations where the access and resources are limited. The application takes advantage of this component and its benefits making NESA cheaper than other emergency communication systems in the market (e.g. the satellite communication systems implemented in Chile (Aetecno 2011)). There are more technologies in the market for emergency management, but several situations demonstrate that there was space for improvement. The next chapter will provide an overview of some of these technologies, applications and services that can be used as communication medium during disaster events.

1.3 Document Organization

The organization of the rest of the document is as follows: the next chapter presents a literature review of available emergency management applications, their approaches and their limitations. Chapter 3 provides an overview of the project including objectives, a general description of the system, and the relation of the developed application with the emergency management agencies of Puerto Rico. Chapter 4 presents the methodologies that were used to develop the application including the project schedule, development cycle and the tools that were used to implement this project. Chapter 5 describes the interface of the application among with screenshots, and a description of the functionalities provided by each screen. Chapter 6 address important aspects of the development of the application including the implementation of the user interfaces, communication methodologies and data management. Chapter 7 presents the results of the heuristic evaluation that was conducted to the application as well as the improvements that were performed to the application taking in consideration the results of the heuristic evaluation. Chapter 8 describes a test bed configured to verify the functionalities of the developed system on different realistic scenarios. Finally, Chapter 9 presents some conclusions based on the results of the project and improvements for future work.

CHAPTER 2

2 RELATED WORK

Mobile devices in general, especially cellphone devices, are broadly used after an emergency event. Applications such as Facebook, Twitter and Google+, among others, play an important role to provide an alternative to conventional telephony voice services (Google 2012). On the cellphone applications market, there are applications that allow users to perform tasks similar to those provided by the system described in this document. Their benefits and limitations will be discussed in the next sections.

2.1 Text Messaging

During catastrophic events, conventional telephony services get saturated and eventually end in a system collapse, unable to handle the demand of customers. Trying to avoid these problems, authorities recommend (FEMA 2012) the use of text messages as a communication medium instead of voice phone calls (voice) because text messages require less bandwidth and computing resources for processing and transmission over the network. One minute of a voice call is equivalent to send 10 text messages (Hrepich 2010). Using this method, the amount of information that can be sent and managed during peaks situations can be increased. Text messages provide an effective way to send short messages with information that can be useful during critical moments. The disadvantage is that it relays on conventional cellphone systems that are susceptible to the traffic problems addressed previously and depends on the availability of these systems during catastrophic events. In addition, it requires the phone number of the person that needs to be contacted, which makes difficult to contact other people on the same area that could provide necessary help during an emergency.

2.2 Kik Messenger

This application allows users to chat (text) with other people and share pictures, videos, locations, and sketches, among other social media. Conversations can be performed 1-to-1 between two users or different groups can be created where all of it members can participate of the conversation (Kik 2012). Users can be contacted importing address books from different email accounts or searching them using their Kik ID or name. This application is available for all major cellphone platform including iOS, Android, Windows Phone, Ovi, and Blackberry. Conversations can be performed regardless the platform, so for example Android users can chat with iOS users. Since this application was implemented using a server side support to synchronize messages and share media, as well as for user authentication, it requires an active connection to the Internet. Other applications, such as Facebook Messenger and WhatsApp Messenger, provide similar functionalities (Google 2012).

2.3 NTT DoCoMo i-mode Disaster Message Board Service

NTT DoCoMo, one of the major communication service providers in Japan, added a Disaster Message Board Service to their i-mode[1] platform to reduce the overflow of phone calls and data managed by their systems after a major disaster and reduce it effects in network performance (NTT DoCoMo 2004). With this system, like a bulletin board, subscribers can communicate with their relatives during these events by posting messages that eventually can be received by their family or friends to let them know their safety, locations or any other information. Using the phone application "Disaster Kit", also developed by DoCoMo, users can record up to 10 messages as voice or text and specify the phone numbers or emails of recipients (recipients do not have to be DoCoMo subscribers). These registered addresses will receive a notification when a new message has been posted and they can access it using the application, using a telephone or using their web portal before the message expire 72 hours after it has been posted. This service is activated only during major disaster events on the affected areas; it is subject to network connectivity and is limited to DoCoMo subscribers in Japan. As DoCoMo, other communication providers in Japan provide "Disasters Message Exchange Services" dialing 171 from any phone (Kumamoto JET 2010).

[1] I-mode is a mobile Internet platform developed by DoCoMo to provide web browsing, multimedia support, mail, gaming and other Internet services on i-mode compatible phones.

CHAPTER 3

3 PROJECT DESCRIPTION

In order to provide an additional communication mechanism, this project creates a new communication system based on multiple Android devices that are connected using a backup network that will be deployed and activated after a general emergency event. This system will make possible the communication of information between residents and the government authorities even if regular phone systems have failed.

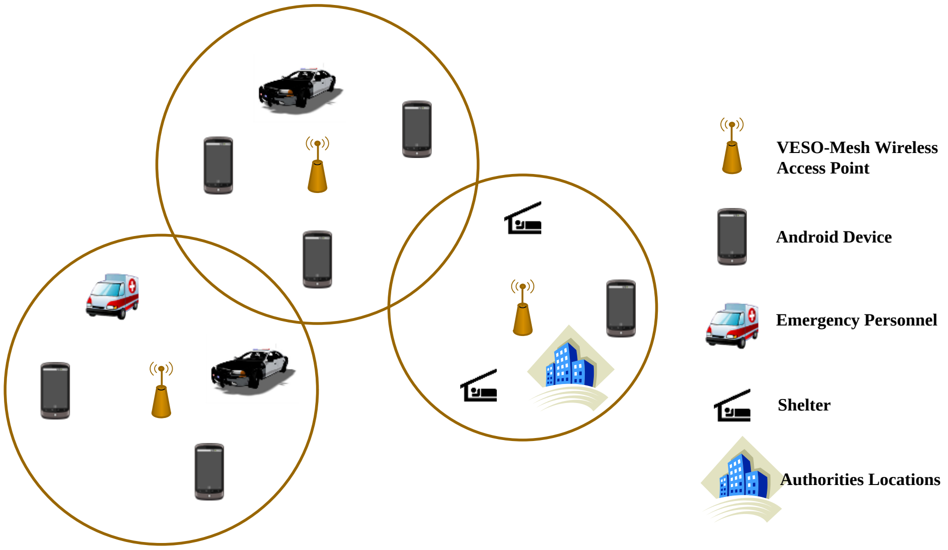


Figure 1 System Topology

This project consists of an Android application through which residents will be able to get in contact with their neighbors or the authorities in case of an emergency. As shown in Figure 1 System Topology, the Android devices will be connected using a backup emergency wireless network provided by VESO-Mesh (Chaparro-Acevedo, et al. 2011) that will allow other residents, volunteers, and emergency personnel, to receive messages and, if it is possible, provide the corresponding help. The connection required will not depend on any major network service provider; instead the devices will be directly connected through the emergency network, peer-to-peer, without requiring any server side support. This network will consist of a series of nodes, in this case routers, that will be connected to each other wirelessly implementing VESO-Mesh and it will be deployed on the affected area after the event has happened. The users of this system will connect to this network using their Android devices and the application, which will makes them able to contact other users using a messaging system (chat), allowing neighbors, family members, friends and authority officers to get in contact with each other. The authorities can use this method to send information and alerts to the citizens as well as send information of the shelters that are open in the area. They can send notifications to the users that are connected to the network about weather conditions, actions to be taken, alerts (Tsunami, floods, winds, etc.), or any other information that might be needed. In addition, they will receive requests from people and coordinate the necessary help actions regarding situations that require their intervention.

Figure 2 presents the structure of the emergency management agencies in Puerto Rico. When a citizen needs help from the authorities he/she can contact the 911 or contact a state or municipality emergency management agency directly. With the exception of 911 that can only be reached by phone, these agencies can be reached also by fax, email or visiting one of the locations. Designated personnel often call as dispatchers, receive the request and introduced it on the "Computer Aid Dispatch" (CAD) which is a system used to track the resolution of all help requests. This request can be forwarded or delegated through different levels on the hierarchy and even be assigned to other agency but always tracking the situation until it is resolved. The state emergency management agencies do not necessary provides direct service to the citizen; on the other hand they are coordinator agents. They work with the police, fire departments, municipality agencies and other supporting agencies to provide a service to the community and manage the situations (refer to Appendix I for more information).

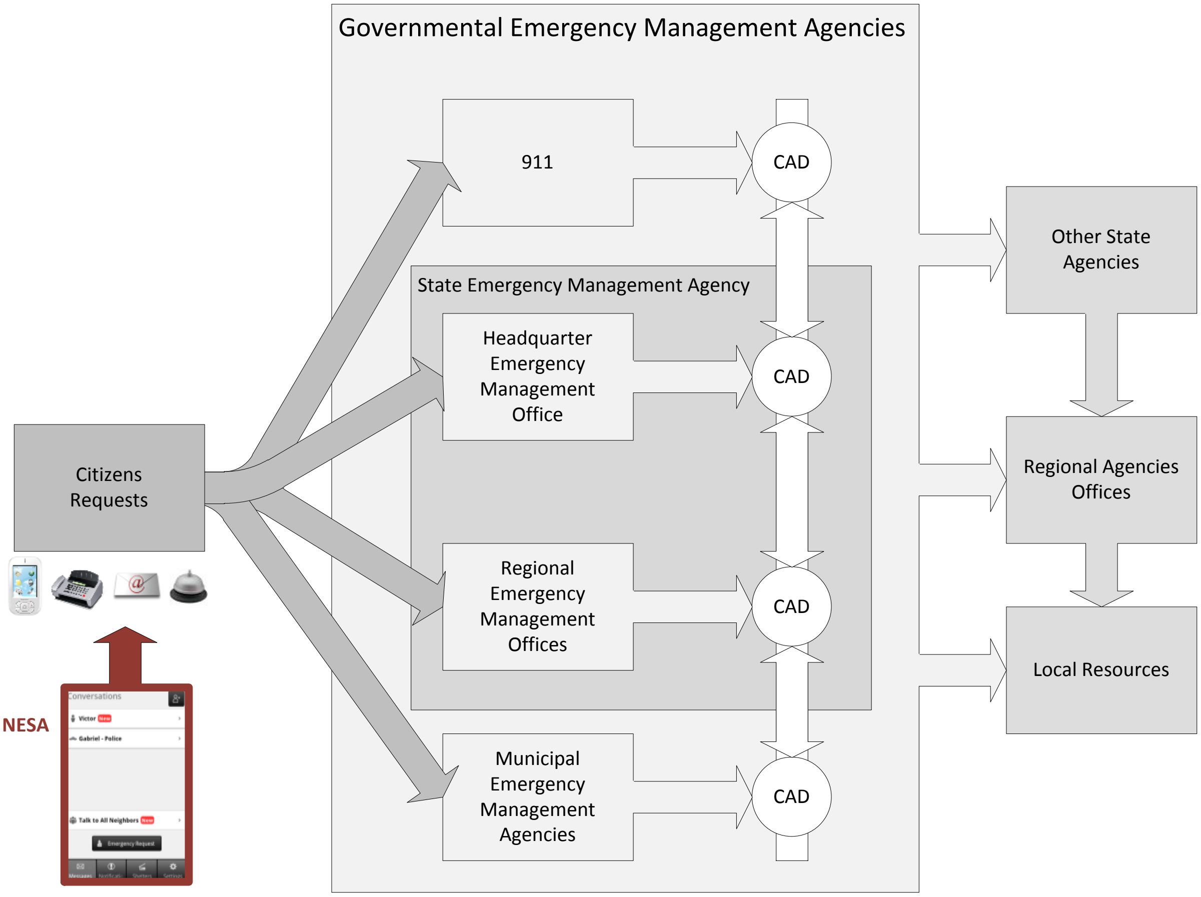

Governmental Emergency Management Agencies
911
CAD
State Emergency Management Agency
Headquarter Emergency Management Office
CAD
Regional Emergency Management Offices
CAD
Municipal Emergency Management Agencies
CAD
Citizens Requests
NESA
Conversations
Victor New
Gabriel - Police
Talk to All Neighbors New
Emergency Request
Messages
Notificati
Shelters
Settings
Other State Agencies
Regional Agencies Offices
Local Resources

Figure 2 Puerto Rico Emergency Management Agencies

The communication between citizens and emergency management agencies may be affected by major disasters. Using this system, authorities will be able to provide the same services even though the regular communication mediums are not available. The help requests received from this application will be managed by the dispatcher and entered into CAD to manage the situation like it would be a phone call on a future integration.

CHAPTER 4

4 METHODOLOGY

Following a software life cycle schema, the development of this project was divided in several stages distributed throughout the last academic semester as specified in Table 1.

Table 1 Project Time Frame

Stage	Month 1	Month 2	Month 3	Month 4	Month 5
Design	■	■	■		
Task Analysis	■	■	■		
Implementation		■	■	■	
Usability Testing			■	■	
Implementation Testing			■	■	■

The design stage started with the design of the Graphic User Interfaces. Use cases diagrams and mocks interfaces were created applying the corresponding usability principles. Once this process was completed, the design of the core elements of the application was performed including the structure of the program applying necessary design patterns as well as the design of the database schema. As part of this phase, a literature review was conducted to obtain any skills and knowledge that might be needed including topics in disaster management. The design also included the communication schema between devices and the authorities.

During the task analysis, emergency management experts were interviewed to obtain important aspects to be considered during an emergency to identify requirements for this project and potential areas of improvement (refer to Chapter 3 and Appendix I). These interviews included two meetings with personnel of the Puerto Rico Emergency Management Agency, one from the central office in San Juan and another from the regional office in Carolina. Other two meetings included personnel of the Emergency Management and Disaster Administration Department of Carolina. The most relevant aspects obtained from the task analysis are addressed on Chapter 3. The interviews performed during this stage were approved by the University of Puerto Rico Institutional Committee for the Protection of Human Beings in Research (CIPSHI - Comité Institucional para la Protección de los Seres Humanos en la Investigación). The authorization letter is available on the Appendix III. Since approval of the interviews required additional time as well as the interviews and the reporting of the task analysis, the design stage and important tasks of the implementation were started in parallel to not delay the project. Eventually the design and implantation were modified to comply with the findings of the task analysis.

The implementation stage started coding the application for the neighbors, followed by an integration process were multiple instances of this application were able to communicate with each other. Once the system was able to perform these actions, the next step was implementing the emulator of the services provided by the government in this system. For the neighbor’s application, a horizontal prototype was developed first, which included an implementation of all functionalities of the applications only in terms of the visual interface, not the internal implementation (IEEE Computer Society 2004). The reason for this order was to conduct a preliminary heuristic evaluation of the user interface early in the development process so that necessary fixes could be performed at an early stage. At the end of the implementation, a final and formal heuristic evaluation was performed (refer to Chapter 7 for the results of this evaluation). The design and development process of this system including any information used for these stages were documented progressively to facilitate the writing process of the final report and eventually the final presentation. Unitary and integration testing were performed along the implementation stage. In addition, once the implementation stage was completed a final test was conducted to verify the functionalities of the project on a more realistic scenario (Chapter 8).

The resources required for the implementation of this project are shown as follow:

- Hardware
    - Three wireless routers
    - Two Android Devices
    - Laptop Computer
- Software
    - Eclipse - Android SDK
    - Adobe Photoshop
    - Microsoft Office
    - SQLite Database Browser

The Android platform used for this project was Android 2.3.3 but the application supports Android 2.1 onward to maintain compatibility with as many Android devices as possible. The application was coded using Java language, for this purpose, Eclipse Software Development Kit (SDK) version 4.2.1 was installed. This SDK provides a good environment to program in Java, including a real time debugger. The Android SDK includes additional tools to code for Android including the plug-in for Eclipse, phone drivers and the emulator. This emulator provides the functionalities of a phone without having it physically. This emulator runs Android and is very helpful for applications debugging before installing them into the real devices. However, physical devices were needed for testing the communication between devices because the emulator does not provide network connectivity. The Android SDK plug-in for Eclipse also provides the Dalvik Debug Monitor Server (DDMS), which was used to retrieve data from the emulator and the phone, and to see the application's Log, which is very useful for debugging (Android Developers 2011). With this tool, the file that contains the internal database can be extracted for inspection or edition. For this purpose the SQLite Database Browser was used. With this application the database can be queried using any SQLite supported query and it has a table viewer that shows the results. The documentation of the code was done using Javadoc. This standard requires the documentation of each class and method, including parameters and returned values.

CHAPTER 5

5 APPLICATION GRAPHIC USER INTERFACES

This chapter presents a description of each interface provided in the application. It includes screen shots and descriptions of the functionalities and graphic components included on each screen[2].

5.1 Messages Interface

The messages interface is the first screen presented to the user when the application starts. As shown in Figure 3, from this screen the user has access to all the people that have been contacted, as well as a conversation with all neighbors, and a mechanism to contact the authority's headquarters.

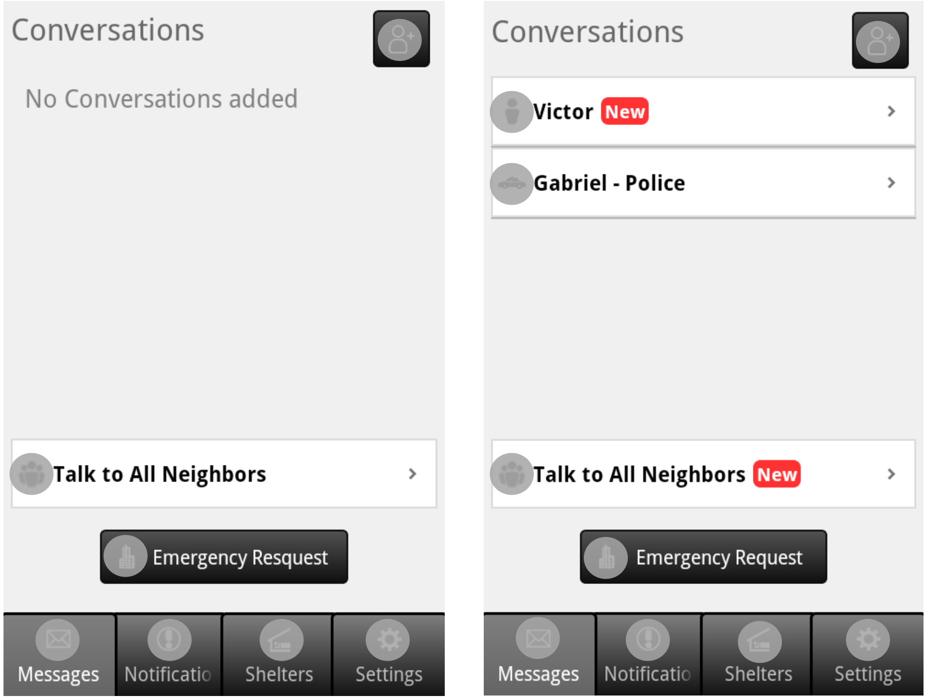


Figure 3 Messages Screen
(a) No conversations added (b) Conversations with new messages

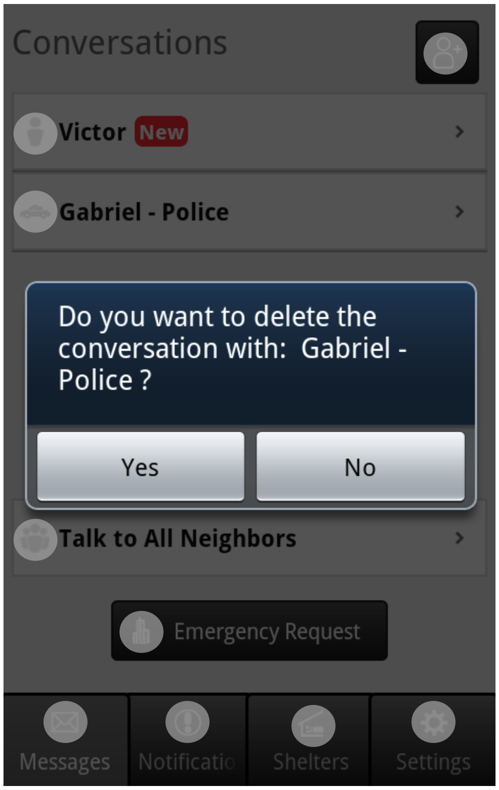
[2] The icons used on the user interfaces have been blurred to respect any ownership right that might apply

When the application is used for the first time, there are no conversations available and the user has to look for nearby users to start a conversation (Figure 3.a). To do so, the user will add new conversations by searching for nearby neighbors or for authority officers. This process will be explained in detail on section 5.2.

Once the user has started a conversation it will appear on a list located below the interface title (Figure 3.b). This list includes conversations not only with neighbors, but also with authority officers. To differentiate one type of user from the other, each row is identified by an icon. When the user presses one of these items, the application will present the chat interface shown in Figure 6.a, to continue the conversation only with the selected person. The "All Neighbor Conversation" button is located bellow the list of individual conversations. In contrast with the individual conversations, this option allows the user to chat with all surrounding neighbors (See section 5.3 for more details). The last element on this interface, "Emergency Request" button provides the option to send a message to the governmental emergency management agencies as a formal help request.

When a new message is received from the individual conversation section or from the conversation with all neighbors as well, a visual notification is presented. This notification consist of a red label that include a text that says "New" and is located right after the title of the conversation, and it is set to visible when a new message is received.

For the conversations with neighbors and authorities, the title is the nickname of the user. To delete an individual conversation or to clear the messages on a conversation with all neighbors, the user can press and hold the conversation on the list and select yes to confirm the action as shown in Figure 4 Confirmation dialog box to delete conversation



Do you want to delete the conversation with: Gabriel - Police ?

Figure 4 Confirmation dialog box to delete conversation

5.2 Add Conversation

This screen is presented to the user when he/she presses the add conversation button, which is located on the upper right corner of the messages screen shown in Figure 3. Using this screen (Figure 5), the user can see the people or authority officers that are nearby and available to start a new conversation.

Following the format of the rest of the sub-interfaces, this screen has the navigation bar that includes the back button to return to the conversations interface and the title to identify the interface, “Who is nearby?” in this case. Bellow the navigation bar, two tabs are provided to show the list of nearby neighbors and authority officers.

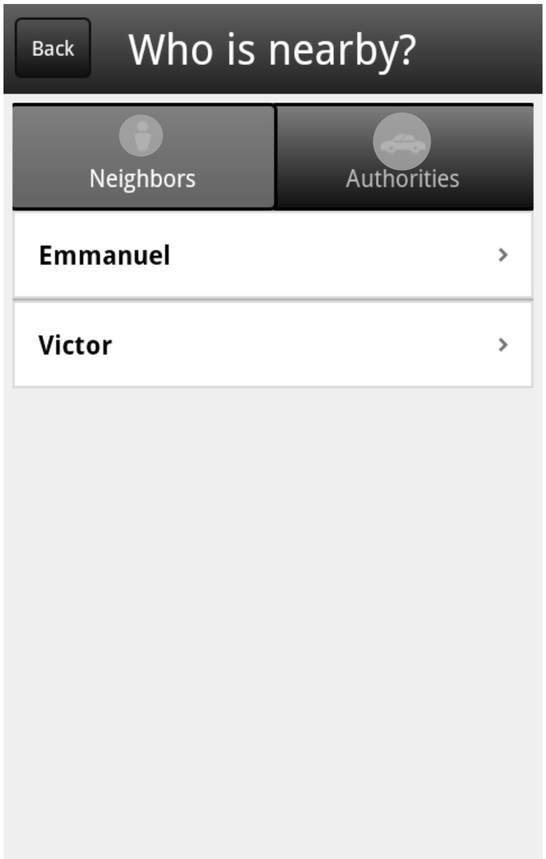
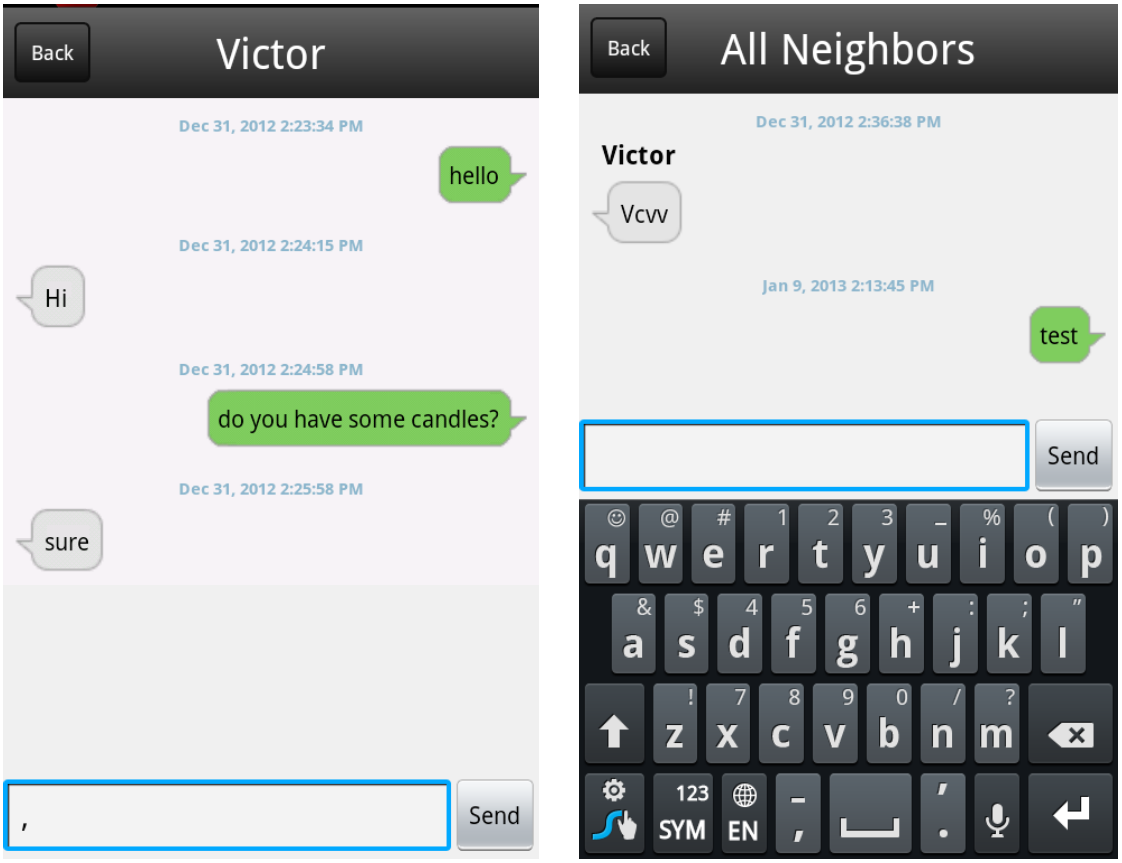


Figure 5 Add Conversation Screen

Pressing on the corresponding tab item the user can access the lists and selecting one of their items, the application initiates a new chat with the corresponding person or authority officer.

5.3 Chat Room

Using this interface the user can send and receive messages from other neighbors and authorities officers. Once the user has select a conversation on the interface described in section 5.1, depending of the type of conversation, the messages can be sent or received from only one person on an individual conversation as shown in Figure 6.a or they can be part of a conversation with all nearby neighbors as shown in Figure 6.b.



Dec 31, 2012 2:23:34 PM
hello

Dec 31, 2012 2:24:15 PM
Hi

Dec 31, 2012 2:24:58 PM
do you have some candles?

Dec 31, 2012 2:25:58 PM
sure

Dec 31, 2012 2:36:38 PM
Victor
Vcvv

Jan 9, 2013 2:13:45 PM
test

Figure 6 (a) Chat with one person, (b) Chat with all neighbors

The screen is composed of three sections. The upper bar includes a back button and the nickname of the person with whom the user is chatting. In the case of a conversation with all neighbors, it will show “All Neighbors” instead of a particular name. The back button will return to the previous interface, which will always be the messages screen (Figure 3). The list of messages is presented below the navigation bar and shows the messages that have been exchanged that correspond to the conversation selected. To present the text messages, this section uses a standard 9-patch bubble format (Android Developers 2012), which means that the messages are encapsulated on rectangular bubbles that differentiate received messages from those that were sent by the user. Received messages are gray colored and aligned left, and sent messages are green colored and aligned right. If the user sends a new message or a new one is received from another person, and the messages correspond to the conversation that is opened, the list of messages is automatically updated to include the new message. If this is the case, the “New” label notification on the Conversations list (Figure 3), will not be shown because the conversation was open by the time the message was received. Other element that is present on this section is the date and time label. This label shows the time stamp when the message was sent or received that includes the date in “Month day, year” format and the time in “hh:mm:ss” format. When a new message is added to the list, this label is located over the message and centralized horizontally on the list.

The last significant element on this interface is the message input section. Located at the bottom, this section contains an input text box and the send button. Using the text box, the user will enter the message that will be sent. When the user presses on the text box, the keyboard will be presented without obstructing the visibility of the text box (Figure 6.b). This keyboard is set by the user as a system setting, and in most devices the “swipe keyboard” is available for a faster data entry. After the message has been entered, the send button is pressed which will close the keyboard, clear the text on the input text box, send the message, and update the conversation.

5.4 Help Request

This application provides a screen from where the user can create a new help request to local authorities (Figure 7) by pressing the “Emergency Request” button on the screen shown in Figure 3. As specified on the Appendix I, currently, the principal way to contact the emergency management agencies is by phone service. Through this interface, the application emulates the service provided when the user makes a phone call to these agencies.

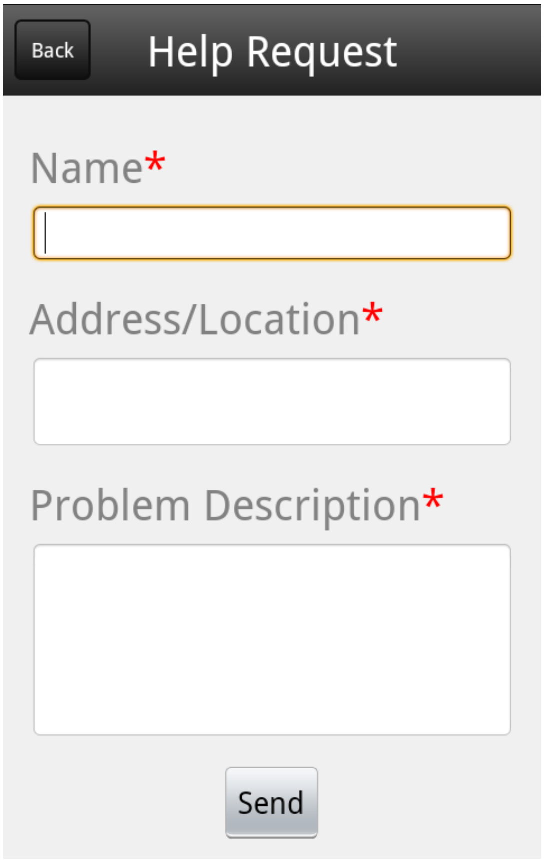
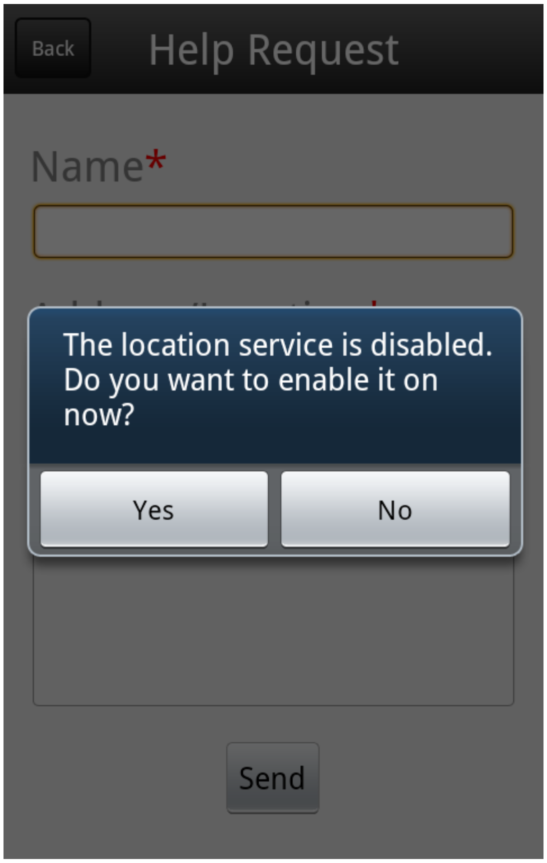


Figure 7 Help Request

To create a new help request using this application, the user will provide only the minimum required information. The digital form on this interface consists of three fields the user needs to fill out before send the request: full name of the user, description of the location or the address and a brief description of the situation. The description of the location needs to be included because the GPS (Global Positioning System) location will not always be available, but if the device is able to acquire its position from the GPS before sending the request, the coordinates of the location will be included on the request. If the GPS service is not enabled on the device, the application will show the dialog box shown in Figure 8. Once the user finishes entering the information, the next step of the request is to press the send button to submit the help request. If the user want to desist of sending the request before submit it, the back button can be pressed at any time or the user can press cancel on the confirmation screen. As soon as the authorities receive the message, the user will receive a notification indicating that the request has been processed.

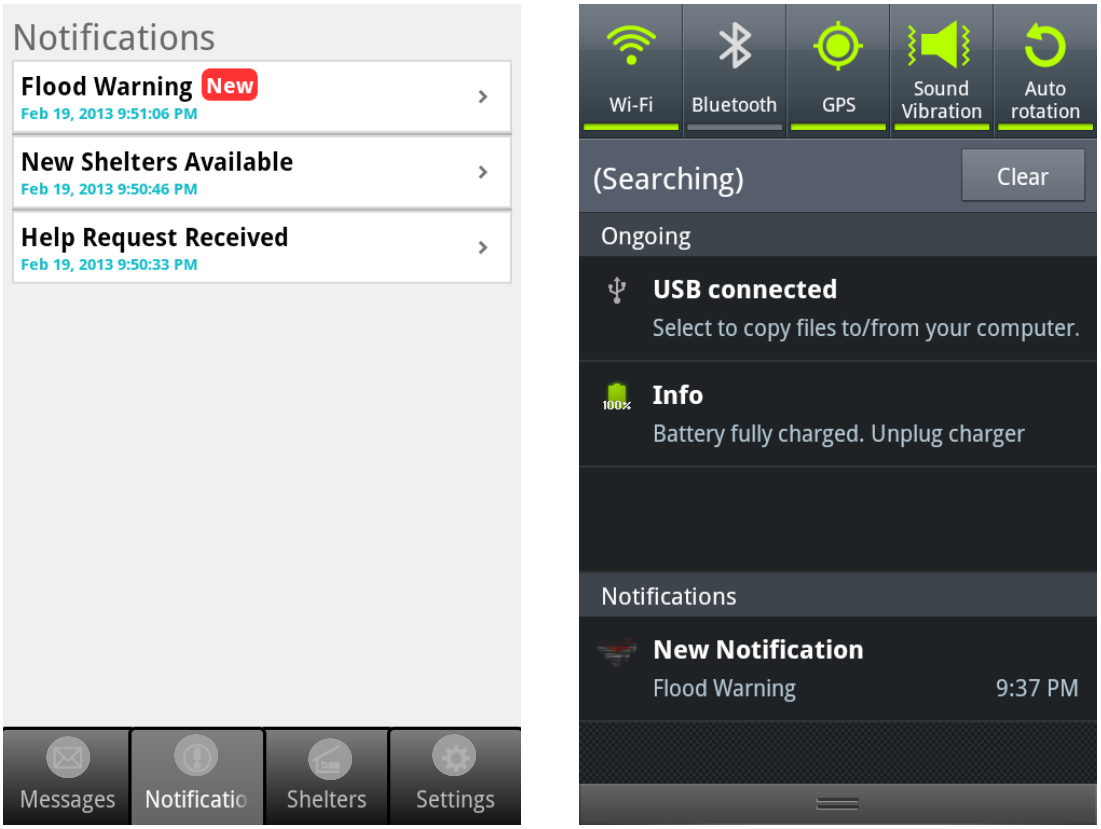


The location service is disabled. Do you want to enable it on now?

Figure 8 Confirmation screen to enable the location service

5.5 Notifications

When a major emergency occurs, governmental agencies, especially the emergency management agencies, send massive notifications to all citizens in the affected areas to provide any necessary information. The application provides this interface where the user will be able to see the notifications sent by the governmental agencies. These notifications are sent to all reachable devices and could include any information these agencies would like to provide to all citizens for example: areas that need to be evacuated, weather statuses, and so forth.



Notifications

Flood Warning New
Feb 19, 2013 9:51:06 PM

New Shelters Available
Feb 19, 2013 9:50:46 PM

Help Request Received
Feb 19, 2013 9:50:33 PM

(Searching) Clear

Ongoing

USB connected
Select to copy files to/from your computer.

Info
Battery fully charged. Unplug charger

Notifications

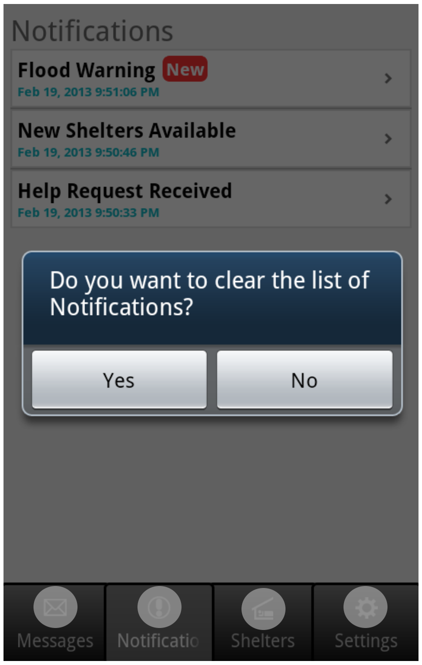
New Notification
Flood Warning 9:37 PM

Figure 9 (a) Notification screen, (b) System Notifications

This screen (Figure 9.a) provides a list of the notifications that have been received. Each item on this list provides the title of the notification and the time it was received. By selecting one of the list entries, the application will present Notification Details screen shown in Figure 11. In this screen, the title of the notification as well as the date it was received is shown on the top of the interface bellow the navigation bar. The rest of the interface is reserved for the message, which can be scrolled down to see the rest of the information if the content does not fit on the screen.

When a new notification is received the application will show a toast notification to let the user know that a new notification has been received. In addition to the toast, the same "New" label used for new messages, will be placed on new notifications that have not been opened and a new system notification will be created as shown in Figure 9.b (Android Developers

2013). To clear the list of notifications, the user can press and hold anywhere on a list entry and select yes on the pop up dialogue box that appears (Figure 10).



Notifications

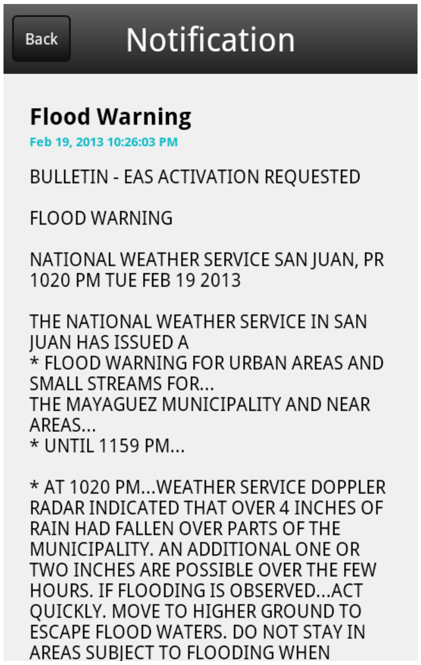
Flood Warning New
Feb 19, 2013 9:51:06 PM

New Shelters Available
Feb 19, 2013 9:50:46 PM

Help Request Received
Feb 19, 2013 9:50:33 PM

Do you want to clear the list of Notifications?

Figure 10 Confirmation dialog box to clear the Notification list



Notification

Flood Warning
Feb 19, 2013 10:26:03 PM

BULLETIN - EAS ACTIVATION REQUESTED

FLOOD WARNING

NATIONAL WEATHER SERVICE SAN JUAN, PR
1020 PM TUE FEB 19 2013

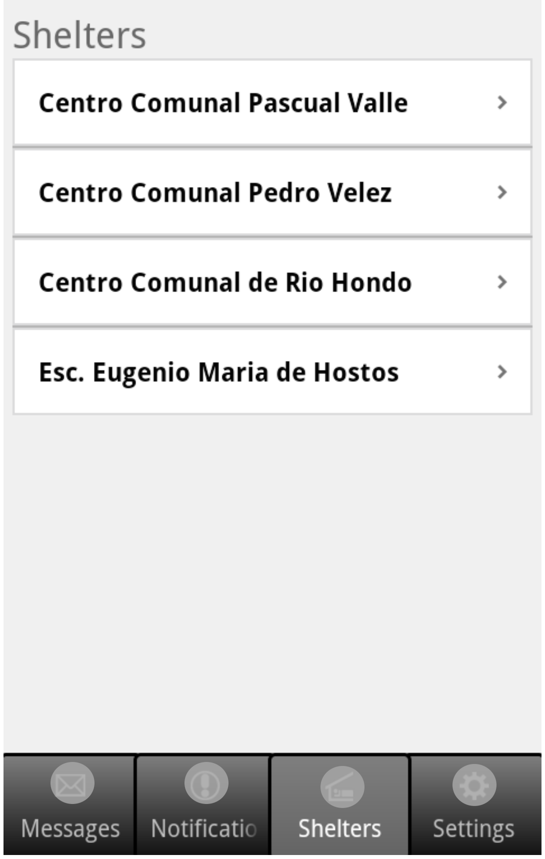
THE NATIONAL WEATHER SERVICE IN SAN JUAN HAS ISSUED A
* FLOOD WARNING FOR URBAN AREAS AND SMALL STREAMS FOR...
THE MAYAGUEZ MUNICIPALITY AND NEAR AREAS...
* UNTIL 1159 PM...

* AT 1020 PM...WEATHER SERVICE DOPPLER RADAR INDICATED THAT OVER 4 INCHES OF RAIN HAD FALLEN OVER PARTS OF THE MUNICIPALITY. AN ADDITIONAL ONE OR TWO INCHES ARE POSSIBLE OVER THE FEW HOURS. IF FLOODING IS OBSERVED...ACT QUICKLY. MOVE TO HIGHER GROUND TO ESCAPE FLOOD WATERS. DO NOT STAY IN AREAS SUBJECT TO FLOODING WHEN

Figure 11 Notification details

5.6 Shelters

During situations when citizens need to be evacuated and there are no communication services, this application provides a mechanism to search for nearby shelters that have been opened on the affected area. The application will search for nearby shelter and will present the results on a list as shown in Figure 12. Every item of the list is identified by the name of the shelter and the user can access more details by pressing one of them. This list is updated every time this interface is opened, so if a new shelter is available, it will appear on the list.



Shelters

Centro Comunal Pascual Valle

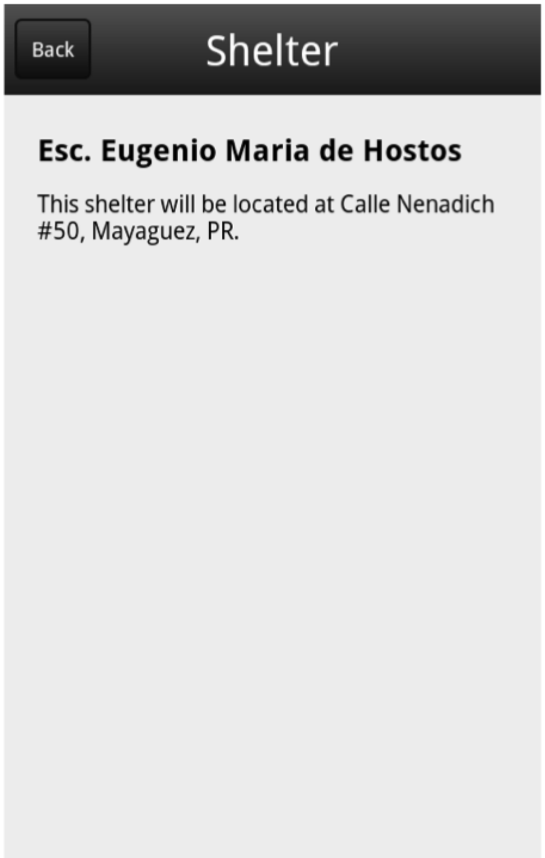
Centro Comunal Pedro Velez

Centro Comunal de Rio Hondo

Esc. Eugenio Maria de Hostos

Figure 12 Shelters screen

If the user selects one of the shelters, the application will present its details on the Shelter Details screen (Figure 13). In addition to the name of the shelter, the details may include the location of the shelter, items that will be helpful during the stay in the shelter and any other information that the citizen need to know before going to the shelter. The navigation bar is included on the top of this screen, which provides the back button and the title of the interface.



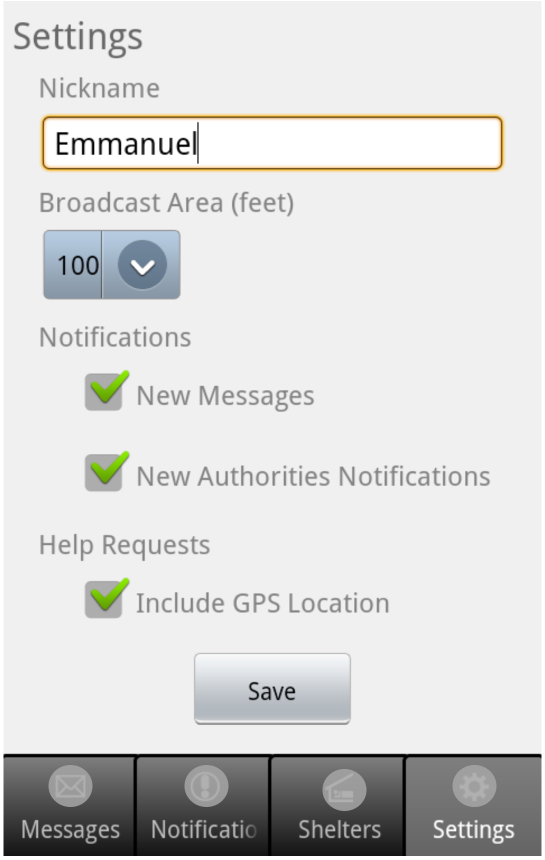
Esc. Eugenio Maria de Hostos

This shelter will be located at Calle Nenadich #50, Mayaguez, PR.

Figure 13 Shelters details

5.7 Settings

This screen (Figure 14) provides the controls to manage the settings available for the screens previously addressed. The first setting is the nickname of the user. Each device is identified using an ID generated by the application (refer to section 6.3) for implementation purposes but it is not shown to the user because it is difficult to read and remember. To provide a more intuitive way to identify a device from the perspective of the user, a nickname is used instead. The default nickname is “User” but it can be changed as preferred by the user. In addition to the nickname, the user can change the broadcast area and the notification preferences. By establishing the broadcast area, the device creates a geographical perimeter around the device and the user will only be able to communicate with devices within the distance specified. The notifications can be enabled or disabled and the user can also indicate if he/she want to include the GPS location on a Help Request.



Settings

Nickname

Emmanuel

Broadcast Area (feet)

100

Notifications

☑ New Messages

☑ New Authorities Notifications

Help Requests

☑ Include GPS Location

Figure 14 Settings screen

CHAPTER 6

6 IMPLEMENTATION ASPECTS

6.1 Application and User Interaction

This section presents the tasks that can be performed by the user on the application, as well as the actions the application performs in respond to these tasks. Please referrer to Figure 15 and Figure 16.

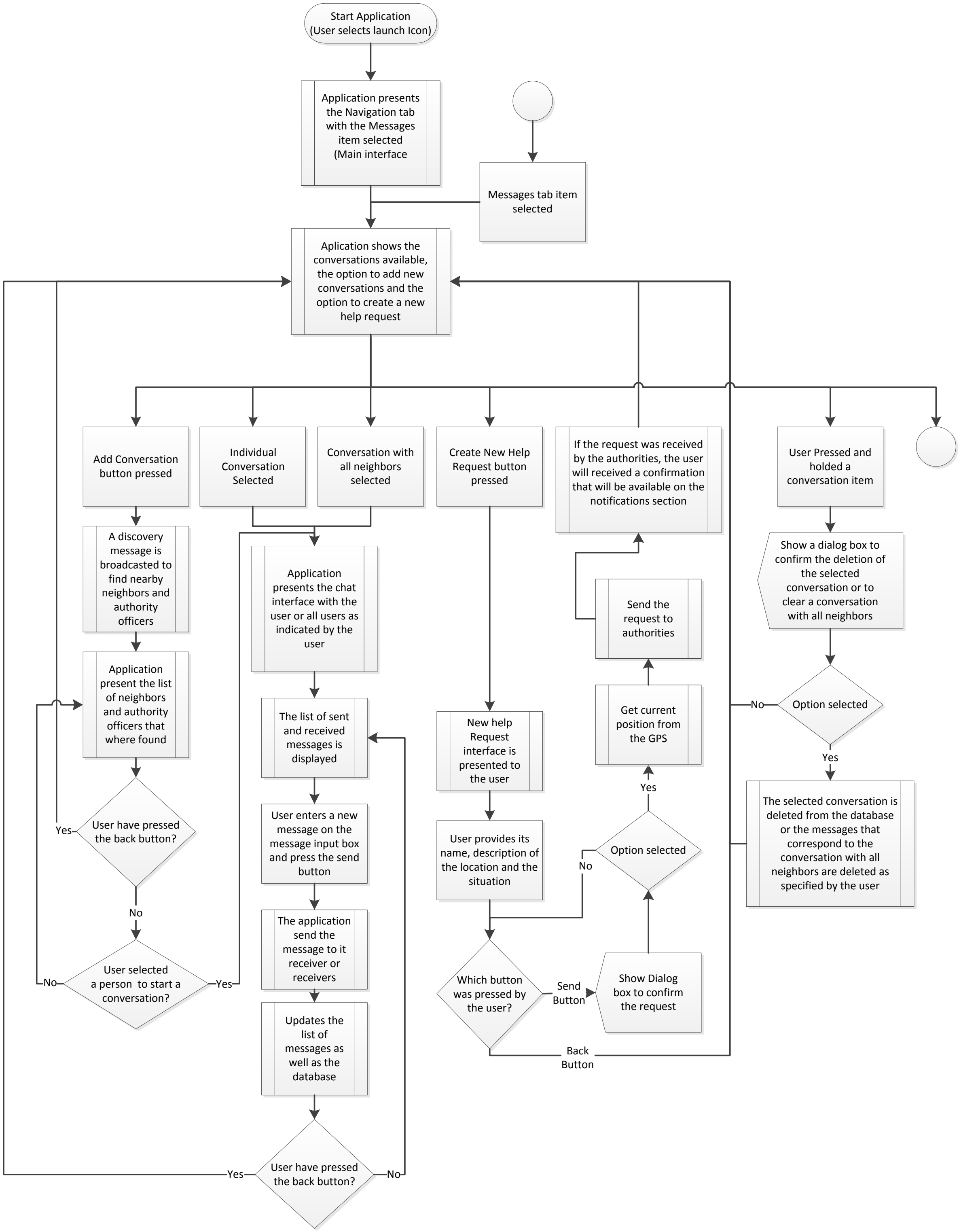

Start Application (User selects launch Icon)
Application presents the Navigation tab with the Messages item selected (Main interface
Messages tab item selected
Aplication shows the conversations available, the option to add new conversations and the option to create a new help request
Add Conversation button pressed
Individual Conversation Selected
Conversation with all neighbors selected
Create New Help Request button pressed
If the request was received by the authorities, the user will received a confirmation that will be available on the notifications section
User Pressed and holded a conversation item
A discovery message is broadcasted to find nearby neighbors and authority officers
Application presents the chat interface with the user or all users as indicated by the user
Show a dialog box to confirm the deletion of the selected conversation or to clear a conversation with all neighbors
Send the request to authorities
Application present the list of neighbors and authority officers that where found
The list of sent and received messages is displayed
New help Request interface is presented to the user
Get current position from the GPS
No
Option selected
Yes
Yes
User have pressed the back button?
Yes
User enters a new message on the message input box and press the send button
User provides its name, description of the location and the situation
No
Option selected
The selected conversation is deleted from the database or the messages that correspond to the conversation with all neighbors are deleted as specified by the user
No
The application send the message to it receiver or receivers
No
User selected a person to start a conversation?
Yes
Which button was pressed by the user?
Send Button
Show Dialog box to confirm the request
Updates the list of messages as well as the database
Back Button
Yes
User have pressed the back button?
No

Figure 15 User interaction and application responses (A)

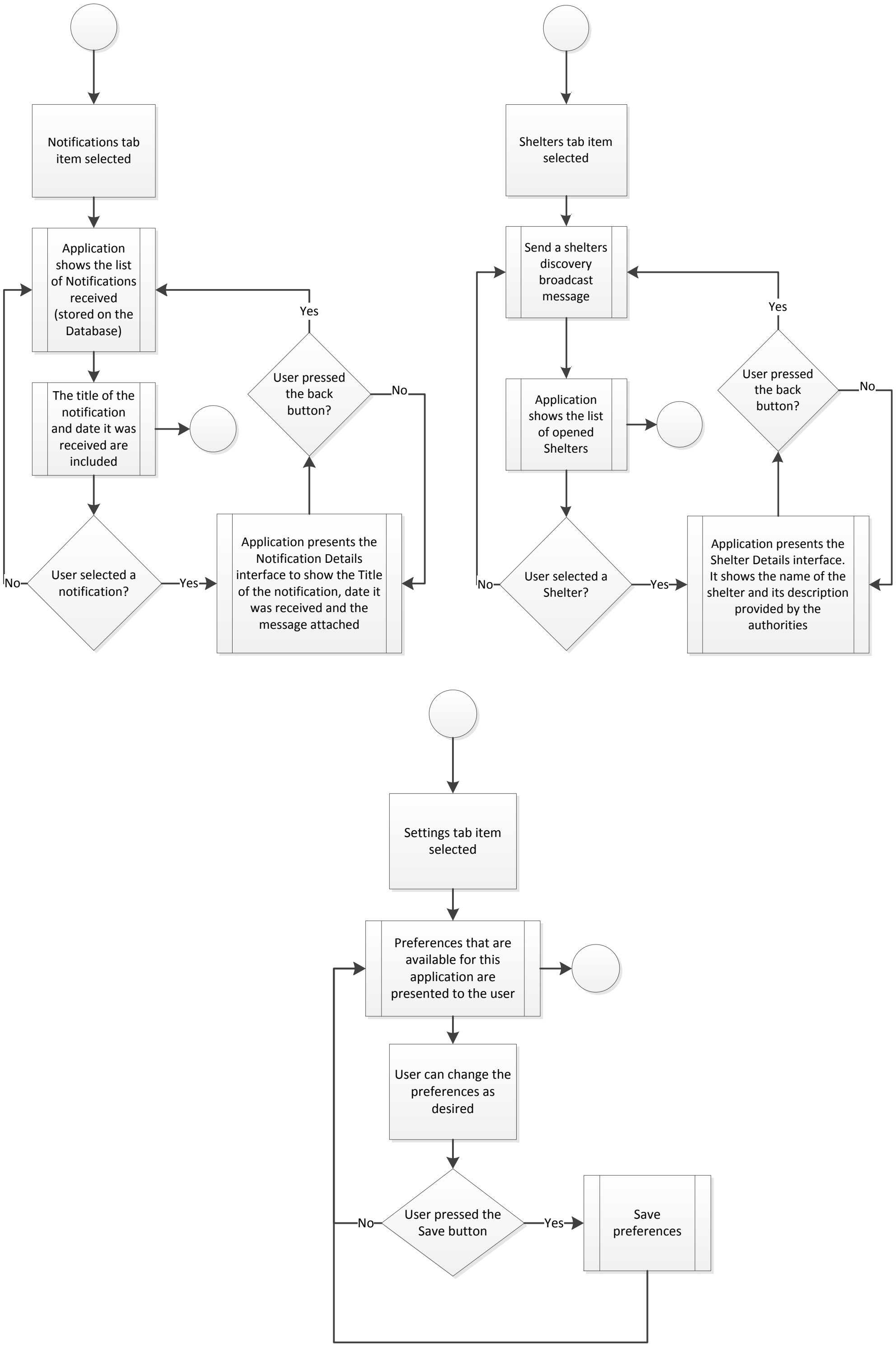

Notifications tab item selected
Application shows the list of Notifications received (stored on the Database)
The title of the notification and date it was received are included
User selected a notification?
No
Yes
Application presents the Notification Details interface to show the Title of the notification, date it was received and the message attached
User pressed the back button?
Yes
No
Shelters tab item selected
Send a shelters discovery broadcast message
Application shows the list of opened Shelters
User selected a Shelter?
No
Yes
Application presents the Shelter Details interface. It shows the name of the shelter and its description provided by the authorities
User pressed the back button?
Yes
No
Settings tab item selected
Preferences that are available for this application are presented to the user
User can change the preferences as desired
User pressed the Save button
No
Yes
Save preferences

Figure 16 User interaction and application responses (B)

6.2 User Interfaces Implementation

An important aspect needed before starting the development of this project was the understanding of the Android Operating System and its fundamental elements, such as what an Activity is and how it is managed. Programmed using Java language, an Activity provides the implementation of the interfaces previously address. These activities can call other activities to allow the user performs other actions on the application. An Activity can maintain references to other objects and internal instance, as well as place data in persistence storage and connect to external resources (Android Developers 2011). An XML file is used to provide the specifications for the layout of each of the interfaces and the functionality is implemented by the corresponding Activity. Every time a user press a button, selects a field, close a window or lock the phone, it generates an event that can be handled by a listener of an Activity. To do so, necessary listeners are declared to notify the Activity when the event has occurred and specified the corresponding actions. In addition to these Activities, normal object or classes can be declared to perform specific tasks that are not directly related with the interface. Some of these classes can be dedicated to provide local database management, access to external resource and so forth.

6.3 Communication Schema and Messages Management

Most Android communication systems use intermediary servers that manage and deliver all messages to the corresponding addressee. Instead of relying on an active connection to a remote server, this application connects directly (peer-to-peer) with other devices or governmental authorities through VESO-Mesh. Once the device is connected to VESO-Mesh using a WI-FI interface, the application can receive or send messages with reachable devices. Each node of the VESO-Mesh covers an indoor range up to 150 feet and an exterior range up to 460 feet in optimal conditions as specified on the standard IEEE 802.11g (IEEE 2003). Every message contains information that identifies the sender, indicates the type of message and provides parameters that associates the message with the corresponding graphic interface component to update the user interface when a new message is received. The devices are identified using an ID (device_id) that is created calculating the MD5 of the MAC address of the device’s Wi-Fi interface. An MD5 Message-Digest takes a string representation of the MAC Address and outputs a 128-bit hash value that is more difficult to restore its original value (Rhee 2003). This id is used to distinguish the device even if the user is connected to a different network where the connection parameters are different or even if the nickname of the user has been changed. The application obtains the connection parameters of the devices that will interact with it, through a discovery process that results in an association of the device ID of these devices with their current network addresses, which for VESO-Mesh is the IP address. Once this information is obtained, the application can send messages to this address through the port number 2562. The actions performed by the application when a new message is received are shown in Figure 17.

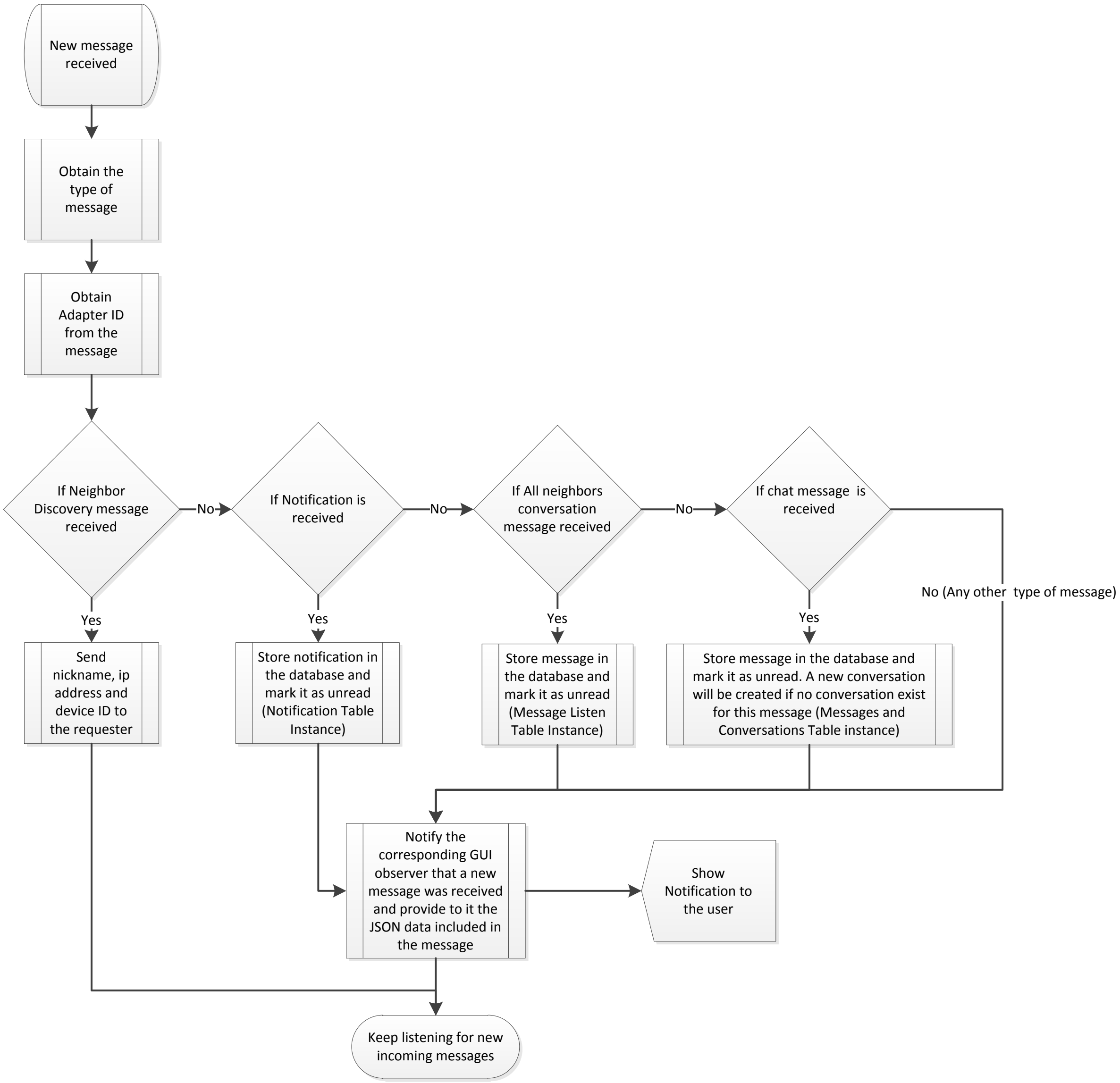

New message received
Obtain the type of message
Obtain Adapter ID from the message
If Neighbor Discovery message received
No
If Notification is received
No
If All neighbors conversation message received
No
If chat message is received
No (Any other type of message)
Yes
Send nickname, ip address and device ID to the requester
Yes
Store notification in the database and mark it as unread (Notification Table Instance)
Yes
Store message in the database and mark it as unread (Message Listen Table Instance)
Yes
Store message in the database and mark it as unread. A new conversation will be created if no conversation exist for this message (Messages and Conversations Table instance)
Notify the corresponding GUI observer that a new message was received and provide to it the JSON data included in the message
Show Notification to the user
Keep listening for new incoming messages

Figure 17 Incoming messages management

To notify the user interface when a new message on a chat session is received or the emergency management authorities have sent a new notification, the application uses the Observer Pattern (refer to section 6.5.1 for more details). Every graphic interface that needs to be notified when the application receives a new message, is identified with an adapter ID and registered on the entity of the application that manages the new messages. When a message is received and it has an adapter ID that corresponds to the chat interface for example, this interface will be notified to update the list of messages. In addition, every chat message and notification is stored on a database even if the corresponding GUI component is not active or not registered.

Decreasing the amount of overhead data that is sent through the network is an aspect that is important during a major emergency. Characterized for the high traffic on communication systems, applications must be conscious on the use of the network resources. For this purpose the application uses two technologies that contribute to this aspect. The protocol used to send the messages is the UDP protocol, which reduce the package size and processing overhead, in comparison with other protocols like TCP. Since UDP is a connectionless oriented service, it requires less processing and provides a lighter package header (Stallings 2010). The other technology used is a markup language knows as JSON (JavaScript Object Notation), which provides a structured organization of the data with a simpler and lightweight format compare to other markup languages like XML (JSON 2012). This aspect decreases the size of the overhead that is necessary to send a message and also it facilitates the parsing process, which makes the application more efficient. Java[3] provides the capability to encode data into a JSON string, which can be decoded not only by an Android application, but also by other platforms and programing languages.

6.4 Data Storage

When a new notification or conversation message is received, it is stored on a database located on the phone. The application has the logic to create the database when it is first time ran, insert new instances on it, update them, delete or read as well as update or delete the database. The schema of the database is specified as follow:
Conversations(_id, user_name, neighbor_ip, device_id, read)
Messages(_id, message, time_date, me, device_id)
Message_Listen(_id, user_name, message, time_date, neighbor_ip, device_id, me, read)
Notifications(_id, title, message, time_date, read)

[3] Java is the programing language used for the implementation of this application

When a notification is stored on the database, it includes the title, the date and time when it was received, the message included, and it is marked as unread. The same happens with the messages of a conversation with all neighbors (Message_Listen). Slightly different, when a message of an individual conversation is received, the corresponding conversation instance is marked as unread instead of the instance of the message. This flag will be used to activate the notifications when they are shown on the screens respectively. Eventually, when the notification or the conversation is opened, it is mark as read by updating this flag.

This schema was implemented using SQLite. SQLite is a Relational Database Management System (RDBMS) used to store and manage user-defined data. It can process complex queries that can produce reports and data summaries to provide necessary information combining data stored in multiple tables. Some particular aspects of SQLite are that it does not require a separated server to provide its functionalities and all data is stored in a file inside the device. Once it is built, it occupies just a few megabytes of memory and with the proper adjustments this aspect could be improved making it more suitable for mobile application where these resources are limited. Setup of the system is not necessary and all transactions comply with ACID (Atomicity, Consistency, Isolation, and Durability) paradigms (Kreibich 2010). In general, SQLite includes enough functionality to provide the same services as others DBMS like MySQL, IBM DB2 and Oracle.

6.5 Design Patterns

A design pattern is in general “a solution to a problem in context” (Freeman and Freeman 2004). This application came up with several design challenges that required the implementation of innovative solutions to make the application more efficient, facilitate the implementation and the updating process in the future. Some of the most relevant problems were how to notify the user interface that a new message has been received so it can be updated and show any required notification. Another problem was how to make the communication and data storage components available to the graphic interface without having to pass the reference between the interfaces, and finally how to make the same list component have different behavior and use it for different purpose throughout the application. The following sections discuss the design patterns that were used to solve these problems.

6.5.1 Observer Pattern

The observer pattern defines a one-to-many dependency between objects where many dependents objects need to be notified and updated when one object changes state. This pattern solves the problem of having many objects verifying a change on state on a subject update, instead they are declared as observers and the responsibility for monitoring for an event is delegated to a subject. The subject knows the observers that will be notified because they register themselves on the subject, so that when the event occurs the subject can notify the observers and they can get the information from the subject regarding the events (Trott and Shalloway 2008). As shown in Figure 18, to implements this pattern, first, every observer must behave in the same way by implementing the same interface to facilitate the notification process and the implementation of the subject as well. This common interface will prevent the subject of having to handle each different type of observers, aspect that will difficult its implantation. The second step is passing the responsibility of the registration to the observers instead of letting the subject determines which observer it has to notify.

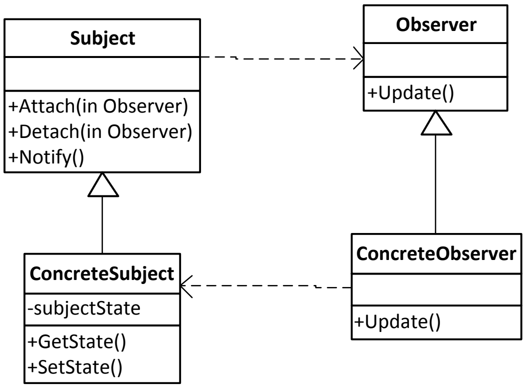


Figure 18 General representation of the observer pattern

To provide way for the observers to register on the subject, two methods must be included on the subject: attach(Observer) to add the observer on the collection of observers and detach(Observer) to remove the observer from the collection. The last step is the mechanism to notify the observers. Each observer will implement a method called “update” which contains the code to handle the event. This method will be used by the subject, to notify the respective observers and it may include information that will be used by the observer to perform the action.

6.5.2 Singleton Pattern

When different objects need to refer to an instance of other object and for some reason, only one instance this object is allowed to be created, this is the intent of the singleton pattern. This pattern guarantees that only one instance of an object will be created and all objects that reference it, share the same instance. In addition, this pattern provides a global point of access to it. As presented in Figure 19, the singleton will have a method that will return the instance of the singleton and will block the access to its constructor so no other object can create an instance of it (Trott and Shalloway 2008). This method, often called “getInstance”, will check if the object has already been instantiated. If this is the case, the method will return the reference to the object. If not, the method will instantiate the object and returns its reference. Regarding the access of this instance, this pattern makes this instance accessibly to any object that requires it by declaring public and static the “getInstance” method, and by declaring the instance as private and static. This methodology allows other objects to access the singleton directly through a static call instead of passing the reference between objects. Furthermore, all instance fields of this unique singleton are preserved as unique as well.

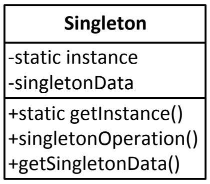


Figure 19 General representation of the Singleton pattern

6.5.3 Strategy Pattern

The intention of the strategy pattern is to “Define a family of algorithms, encapsulate each one, and make them interchangeable. The strategy lets the algorithm vary independently from the clients that use it” (Trott and Shalloway 2008). In other words, this pattern separates parts of the implementation that perform the same task but in different ways and including different actions. Instead of having all algorithms together in one class, they are separated on a family of algorithms. Depending on the context or when they are needed, the main class or client will select one of these strategies. Basically the selection of the algorithm is separated from its implementation, providing the selection upon context. As specified in Figure 20, this pattern is implemented by having an abstract class that provides an abstract method specifying how to call the algorithm. This abstract class constitutes the strategy and the class that uses it by aggregation is call the context or client. Every subclass of the strategy will implement the algorithm as needed. In this way, by instantiating a different strategy implementation, the client will have a different behavior for the same strategy. If a new algorithm needs to be added, a new strategy subclass will be added and minimum changes on the client will be required.

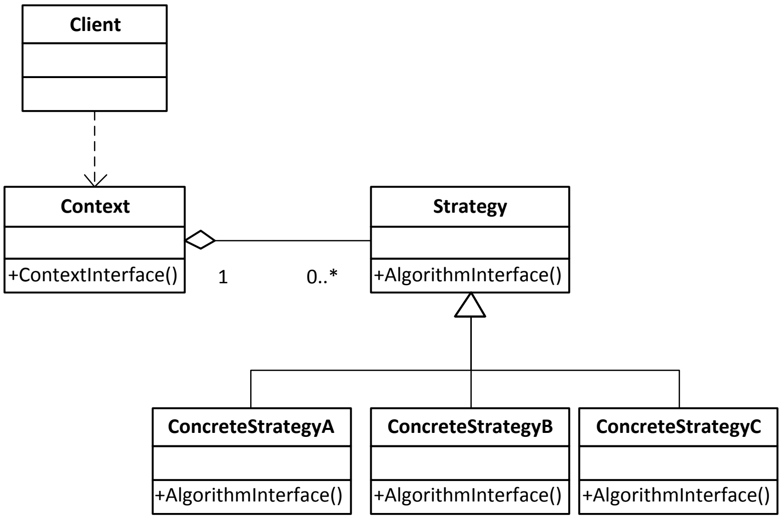


Figure 20 General representation of the Strategy pattern

CHAPTER 7

7 HEURISTIC EVALUATION

This chapter presents a summary of the heuristic evaluation made to the user interface of the application. Heuristic evaluations are used to identify usability problems in the user interface at earlier stages. A heuristic evaluation was conducted by two user interface evaluators based on Jakob Nielsen's heuristics for the design of user interfaces (Nielsen 1995, Nielsen 2003). During the evaluation process a user interface evaluator interacts with the application looking for users' and system actions and responses that have the potential for interaction problems. The evaluator detects and describes potential problem while the designer analyses the problem and produces fixes for them. He/She assigns a severity rating to each problem depending on the eventual consequences of the problem in the interaction with the user and state of the system. The following rubric was used to measure the severity of the usability problems:

1 – Aesthetic Problem

2 – Minor Usability Problems: Low priority

3 – Major Usability Problems: Important to be fixed

4 – Catastrophic Usability Problems: Imperative to be fixed

7.1 Nielsen's Heuristics

The Nielsen's heuristics used for the user interface evaluation are described below (Nielsen 2003) (Nielsen 1995):

- *Simple and Natural Dialogue* (*Aesthetic and minimalist design)*
    - Dialogues should not contain irrelevant or rarely used information. All the information displayed should be clear and concise, since all the irrelevant information diminishes the visibility of the relevant information.

- *Speak the User's Language (Match between system and the real world)*
    - The terms used in the application should be expressed in words familiar to the user rather than in system-oriented terms.

- *Minimize the User's Memory Load (Recognition rather than recall)*
    - The user should not have to remember information that the application cans store/reuse. The instructions should be simple and easy to retrieve.

- *Be Consistent (Consistency and standards)*
    - The users should have the same results if they repeat the same action. The similar icons, labels and groups should be related.

- *Provide Feedback (Visibility of system status)*
    - The application should keep users informed about what is happening in the background and provide feedback for actions that take time to finish.

- *Provide Clearly Marked Exits (User control and freedom)*
    - If the users chose an option by mistake, the application should help them to leave the unwanted state.

- *Provide Shortcuts (Flexibility and efficiency of use)*
    - The application should have features help novice users, but also it should have shortcuts to speed up the interaction of experienced users.

- *Provide Good Error Messages (Help users recognize, diagnose, and recover from errors)*
    - The error messages must never criticize the users or their abilities. They should constructively suggest a solution.

- *Error Prevention*
    - The application should reduce/eliminate error-prone conditions. Also, before any commit, the application should ask users for a confirmation.

- *Help and Documentation*
    - If the documentation is necessary, that data should be easy to get, precise and focused on the users' tasks.

7.2 Evaluation Results

This section presents a summary of the results of the heuristic evaluation including a description of the problems that were found and the severity assigned to each one. The results are presented in a per screen basis and then ordered based on the severity of the problem.

7.2.1 Messages

Problem 1

The user is allowed to write a message to another user or to all nearby users. However, the application does not allow users to write a message to a selected group of people. During an emergency, users might need help from several persons, and/or authorities at the same time.

Severity: 3

Problem 2

When the user selects the option to talk with a rescuer or with the authorities (e.g. the police), the rescuer is added to the list all conversations. If the users are talking with several persons at the same time, the conversation with the authorities could be hard to find.

Severity: 3

Problem 3

The list of recent conversations does not have a visible option to remove a conversation from the list.

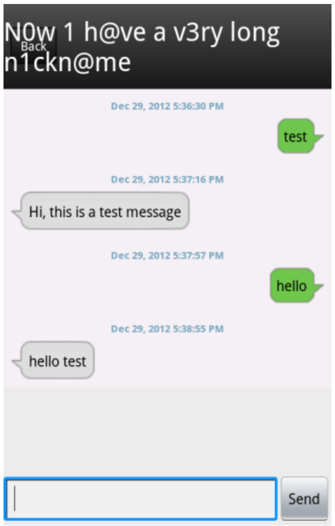
Severity: 2

7.2.2 Chat Screen

Problem 1

The users can have a very long username because the number of characters is not limited by the developer. If the user decides to have a very long nickname, then some of the functionalities on this screen (e.g. the back button) will be behind the nickname (Figure 21).

Severity: 3



N0w 1 h@ve a v3ry long n1ckn@me

Dec 29, 2012 5:36:30 PM

test

Dec 29, 2012 5:37:16 PM

Hi, this is a test message

Dec 29, 2012 5:37:57 PM

hello

Dec 29, 2012 5:38:55 PM

hello test

Figure 21 Chat screen title length problem

7.2.3 Help Request

Problem 1

The users can send empty help requests.

Severity: 4

Problem 3

If the users click the back button by mistake, everything is erased.

Severity: 4

Problem 2

If the users have their GPS turned on, then the application will take the user's position and send it as part of the help request. There is no written notice in the interface that let them know that the application is using their position.

Severity: 3

Problem 4

It is not clear where/when the users will receive the response of an emergency request.

Severity: 3

Problem 5

When the user clicks the "Emergency request" button, the window that appears is called "help request".

Severity: 1

Problem 6

The "Name" field allows user to add numbers and symbols.

Severity: 1

7.2.1 Notifications

Problem 1

It is difficult to determine which notifications are new. When the users select the notifications tab, the notifications are sorted by time/date, but the read notifications are identical to the unread notifications.

Severity: 4

Problem 2

The users do not have the option of deleting the old notifications or the ones that are irrelevant to them.

Severity: 2

Problem 3

When the users receive a new notification a message is displayed on the screen. This message disappears after a certain amount of time. If the user is not looking at the screen, then they will not be able to read the message.

Severity: 2

7.2.2 Settings

Problem 1

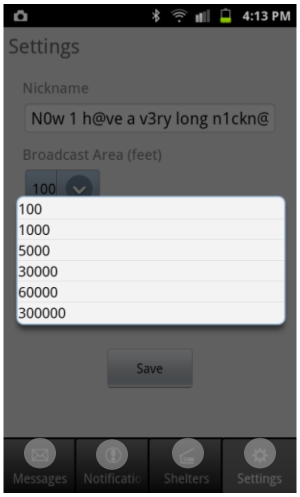
The username is only displayed on the settings window. If the users write and send a message, then they will not know which username they were using. Since the username is not a mandatory field that users must set before using the application, then they could be using the default username without knowing about that.

Severity: 2

Problem 2

The space between the numbers in the broadcast area (Figure 22) is smaller than the fingers' size.

Severity: 2



Settings

Nickname

N0w 1 h@ve a v3ry long n1ckn@

Broadcast Area (feet)

100

Figure 22 Broadcast area preference

7.3 Actions Taken

This section describes the actions that were taken as a result of the observations presented on this evaluation. Some of the findings will be considered as new features that will be added on subsequent versions of the application.

7.3.1 Chat Screen

- A maximum amount of characters was set on the input field that corresponds to the nickname on the Settings screen. In addition, depending of the size of the display, although the nickname could be too longer to be displayed on the navigation bar. Is that is the case, the application will replace the character that exceed the maximum length of the designated area by "…" at the end of the nickname to indicates that is longer than the field where it is shown. Taking the nickname presented in Figure 21 as an example, the application will show "N0w 1 h@ve ve…" instead, which has a length that make it fit on the designated space.

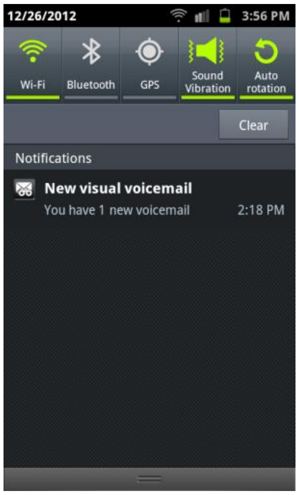
7.3.2 Help Request

- All fields on this interface are mandatory, so for this reason the application will validate each field before sending the request to make sure that all of them have been filled. If one of the fields is empty the application will present an error message when the user presses the send button.
- A check box is provided on the settings screen to let the user select if he/she want to include the GPS location (coordinates) in the help requests.
- If a user is canceling a help request by pressing the back button, then the application will show a dialog box asking if the user want to cancel the message (Yes/No). In this way, the user will have the option to confirm if they want to withdraw the request, or return to the form if he/she touched the back button by mistake.

- When the user send the message, the application will show a message indicating that the user will receive notifications regarding the status of the request and that they will be available on the notifications screen of the application.
- A constraint was added to the "Name" field text box to only allow letters.

7.3.3 Notifications

- The application will show the "New" label right to the title of the notifications that are unread. This label will have the same format and style as the one used to identify conversations that have unread messages.
- The cellphone will vibrate and emit a sound when a new notification is received. In addition, the application will create a standard Android notification that will appear on the notification window of the devices (Figure 23) that indicates that a new message has been received.



New visual voicemail

You have 1 new voicemail 2:18 PM

Figure 23: Android Standard Notifications Window

7.3.1 Settings

- The space between the items in the dropdown that corresponds to the broadcast area was increased to facilitate the selection of the items.

CHAPTER 8

8 TEST BED

The development of this application especially the implementation of the communication components were carried out using only one wireless router for simplicity purposes and to avoid problems related with the network during the debugging and testing process. To provide a more realistic scenario, although on a smaller scale, a test bed was configured to test the application using VESO-MESH and in the same time, serves as a proof of concept.

8.1 Test Bed Configuration

As shown in Figure 24, the test bed for this project consisted of three wireless routers, two Android devices and one laptop computer. These routers are not the same used on the actual implementation of VESO-Mesh, but for the purpose of this test, they provide the same communication functionalities.

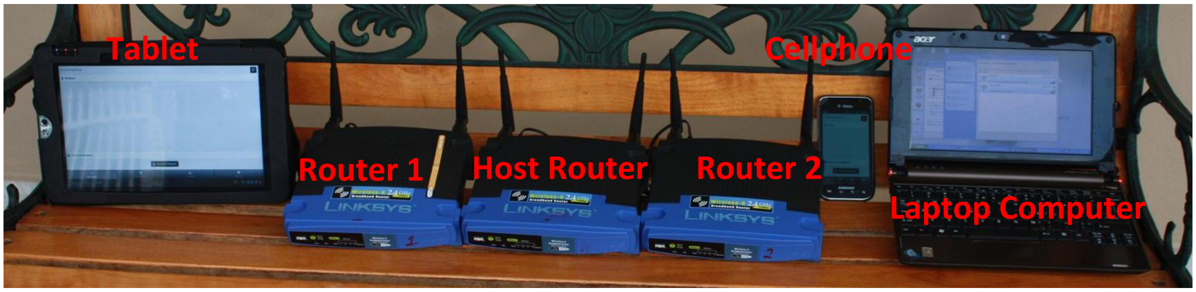


Figure 24 Test bed components

These routers together form a wireless mesh network where one of the routers is the host (located in the center) and the other two are clients. The links between the routers and the android devices as well as the laptop computer are created wirelessly using Wi-Fi (802.11g) following a mesh network topology. There are two principal ways to configure these links in a mesh network. One is using Ad-Hoc mode which means that these links will be created dynamically when a new intermediate device (router) is connected to the network. Not only intermediate nodes, but also end devices are able to work as repeaters of the data that is sent through the network, which ends in a more distributed arrangement of the network. Even though this methodology is the most commonly used to establish a mesh network, it cannot be used as it is, because Android devices does not support this mode and they are not able to connect to networks that are configured in this mode (Google 2012). Google is planning to add support in Android to this mode in the future, but legacy versions of Android will not be able to connect to the mesh in this mode. A current solution to this problem is adding wireless access points that serve as a bridge between the Ad-Hoc mesh network and a regular Wi-Fi Network that is supported by Android devices. This solution was tested for this project and it works, but for simplicity, the second option to create a mesh network was used instead. This configuration consists of a Wi-Fi network using AP mode (Access Point) with static links between the nodes, avoiding the use of Ad-Hoc. WDS (Wireless Distribution System) provided the ability to create static wireless links between nodes and for this test bed, Router 1 and 2 were connected to the host router using this methodology. These links are configured on each router using the mac address of the wireless interface of each one. The devices used regular discovery and configuration process where the host router is the DHCP (Dynamic Host Configuration Protocol) server which provides the connection parameters to the end devices to connect them to the network. This network accepts new end devices (laptops, cellphones, and so forth) but in contrast with the first mesh network configuration, it will not accept new intermediate devices (routers, and so forth) unless the links are configured manually. With the first option, both internal and end point devices can be added dynamically, which make it more suitable for a real environment, but for the purpose of this test, the static configuration will be used.

8.2 Test Execution

The test was conducted in an indoor scenario with obstructions between the nodes and in an outdoor scenario with a clean line of sight between the nodes without any obstacles. The Research and Development Center (CID by its Spanish name) building of the University of Puerto Rico at Mayaguez, was selected for the indoor test, because its walls are thick enough to provide the desired obstruction (concrete walls) for this test. As shown in Figure 25, the host router was located in room F-218, and router 1 and 2 were located in room F-212 and room F-221 respectively with approximately 40 feet between them and the host. The cellphone was located on room F-224, and the laptop computer on room F-221 and both were connected to the router on room F-221 and the tablet was located in room F-209 and connected to the router on F-212.

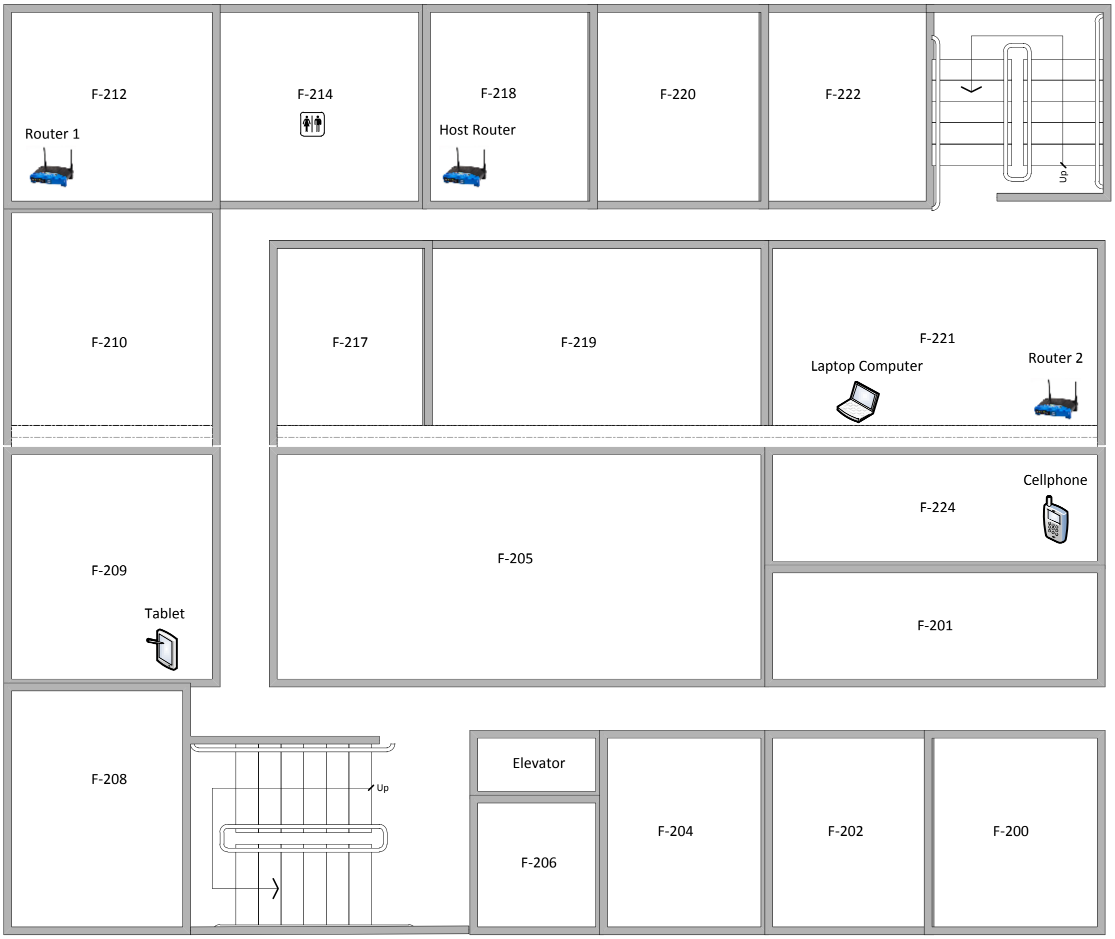


Figure 25 CID building floor plan of the second level

The application that was executing on the tablet was able to communicate with the application executing on the cellphone on a chat session and with the laptop as well which provided the emulation of the authorities' services.

The coordinates of the location selected for the outdoor scenario are 18.293366, -65.922304 (Google format), which proportioned an area with a line of sight between the intermediate nodes and in addition, with different elevations. The routers and end devices were positioned as shown in Figure 26 and Figure 27. Router 1 was installed in the house with the lower altitude and the host router 110 feet separated from router 1 with +13 feet of difference in elevation. Router 2 was located in the house with the higher elevation 154 feet separated from the host router and +32 feet of difference in elevation[4]. The tablet was connected to Router 1, and the laptop and the cellphone were connected to Router 2. All services and functionalities of the application addressed on Chapter 4 and section 5.1 were tested, and all of them performed properly during the test. More information regarding the configuration of the test bed and the status of the routers during the tests is available in the Appendix IV.

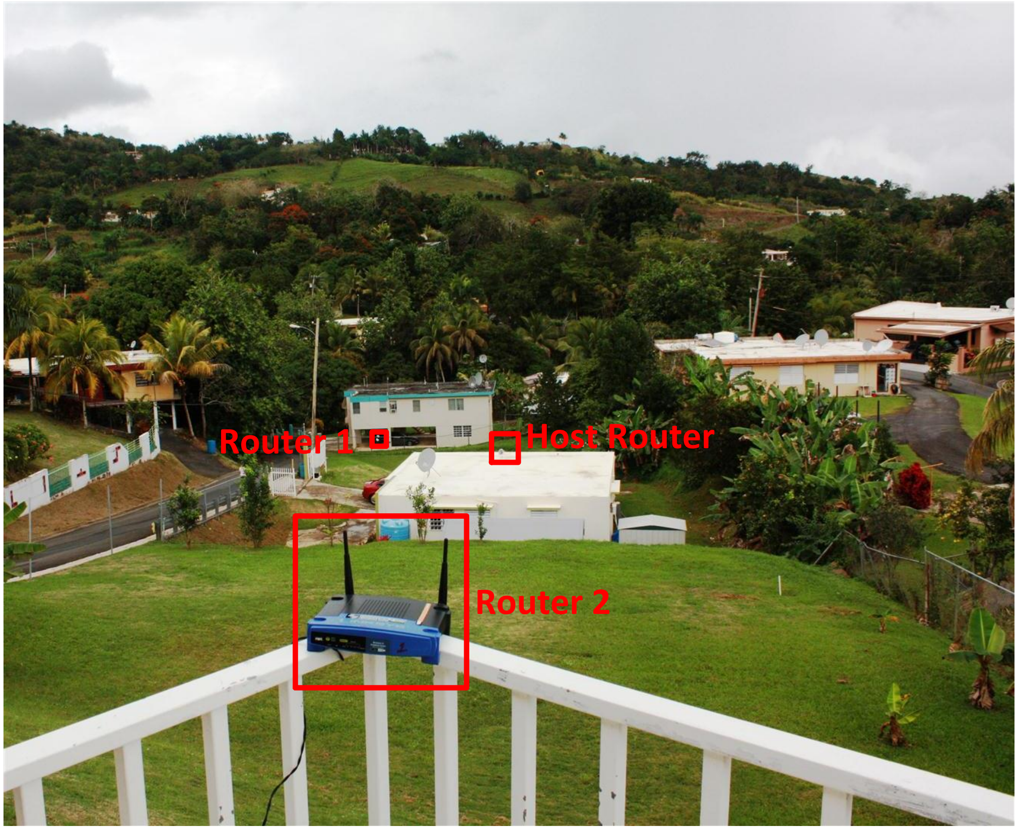


Figure 26 Router arrangement

[4] These measurements were obtained by the land surveyor Eng. Ismael Del Valle

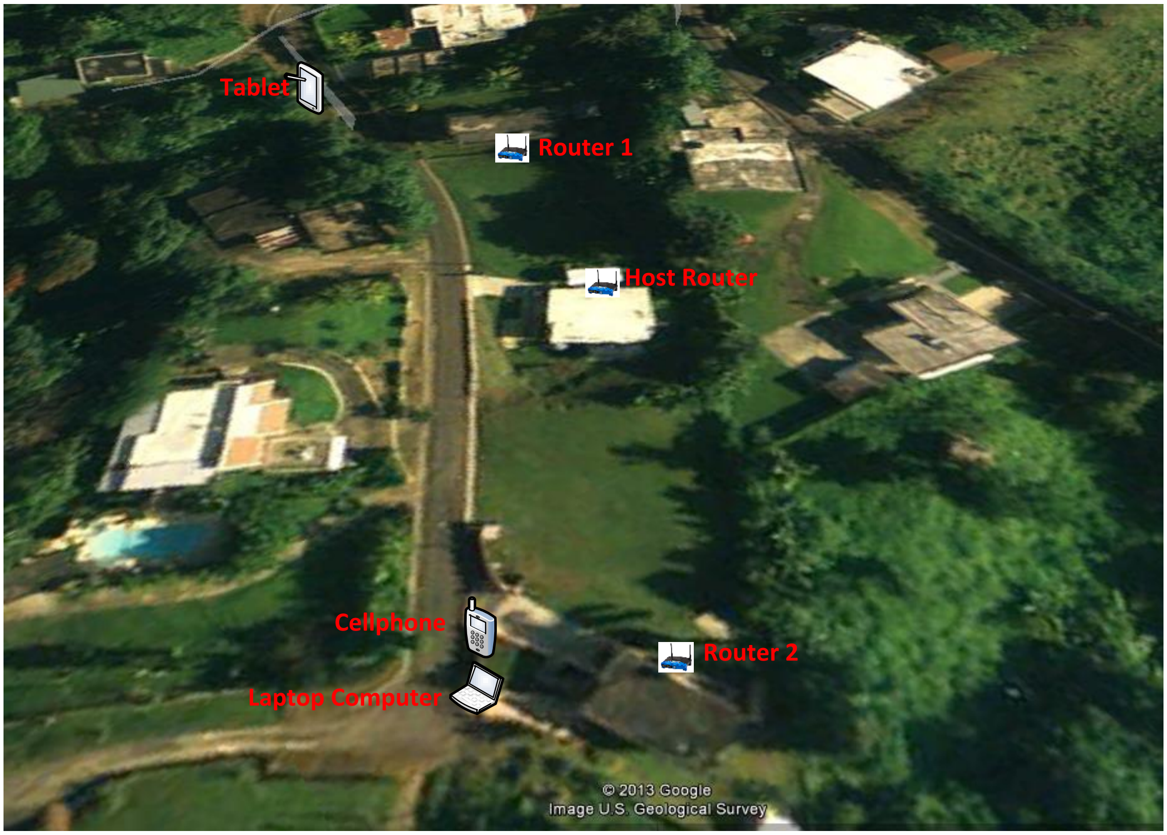


Figure 27 Outdoor test bed scenario

CHAPTER 9

9 CONCLUSION AND FUTURE WORK

Different major disaster events have demonstrated the vulnerability of current communication systems. Failure of wireless services, internet and phone services have left communities not able to contact family members, neighbors or even the authorities to get help.

The developed system adds an alternative to the conventional communication methodologies after a major disaster and promotes the support between citizens. Furthermore it provides a communication means for the authorities to receive help request from citizens, send notifications to them and provide information regarding the available shelters. As part of this project an Android application was developed which provides the necessary functionalities to contact nearby neighbors or authority officers, receive notifications and information about available shelters. An emulator of the services provided by the authorities on this system was implemented for testing purposes, but eventually it can be integrated with the Emergency Management Agencies CAD systems (Chapter 3) to facilitate the data entry process on new cases. Both the Android application and authority services are able to establish communication peer-to-peer over a wireless mesh network, which in a real situation would serve as a backup emergency network using VESO-Mesh.

The design and implementation of the user interfaces were performed following the usability heuristics in the best way possible to improve the user experience interacting with the application. In addition, a final heuristic evaluation was performed by external evaluators to detect and correct usability problems on the interface. This project was finished within the established timeline and once the implementation of the application was concluded the system was tested in small scale real scenario using a wireless mesh network in an outdoor and indoor environment. All the functionalities provided by application worked properly in both environments.

In the future, encryption will be added to the messages to increase the security by using a certificate services that will be provided by Veso-Mesh. The developed project could be integrated with CAD systems of the emergencies management agencies in Puerto Rico. In addition, usability testing of the user interfaces with real users will be considered for future work.

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APPENDIX

Appendix I - Task Analysis

Task Analysis Report

Emergency Management and Disaster Administration Department of Carolina, Puerto Rico and Puerto Rico State Emergency Management Agency

The mission of the Security Department of the Carolina Municipality in Puerto Rico is to watch for the protection and wellness of the community before, during and after adverse situations. This department is composed by four major divisions: the Local Police Department, Fire Department, the Office for Integrated Security Services and Virtual Technology, and the Emergency Management and Disaster Administration Department or AEMEAD (Manejo de Emergencias y Administración de Desastres). This last department is responsible to provide the mechanism to manage situations whose consequences could affect the life and goods of citizens. The steps followed are: mitigation, preparation, response and, finally, the recovery of victims and property. Following are some of the procedures, logistics and actions performed by the aforementioned department during an emergency.

Due to its geographic location, Puerto Rico is very susceptible to hurricanes, especially during the months from June to November. This atmospheric phenomenon is the most significant disaster event managed by the Emergency Management and Disaster Administration Department of Carolina. During major emergencies, this department activates a committee known as Emergency Operation Center or COE (Centro de Operaciones de Emergencias). The main municipality and state agencies representatives, including the Major and his/her cabinet, compose the COE. In case of a hurricane, the committee is activated 72 hours prior the strike. This committee leads all preventive procedures including evacuations, the activation of shelters, and so forth on areas that have been previously identified with potential risk of suffer significant damages. After the hurricane, this committee coordinates all works to restore the damages that have been registered. Furthermore, this committee receives and resolves support requests from citizens. The following are examples of some support requests they manage: flooding, river overflows, landslides, potable water distribution, search and rescues, vehicular rescues by extrication, debris removal, toxic material spills management, maritime rescue and so forth. Basically, this agency coordinates different emergency resources including fire fighters, police departments, health services, and other supporting agencies in order to solve situations that happen not only during hurricane, but also after earthquakes, tsunamis, fires, terrorism attacks, or any emergency situation on a daily basis. Some of the agencies that are part of the COE are the Department of Housing to coordinate shelters and food distribution for the refugees, the Recreation and Sport Department provides the transportation of evacuated people and the personnel of the Department of Public Works helps with the removal of debris and reopening of main streets so vehicular traffic can be restored and brigades can access the affected areas. To provide a distributed support and management of the situations, the MEAD is divided in three zones: Isla Verde, Barrazas and City center which is the head quarter and host of the COE when it is activated. Each location is capable of manage all the emergencies that happen within the corresponding area. The requests can be received directly from the location office or can be referred from other location including the head quarter. In addition, every location could provide support to other zones and municipalities if needed.

To communicate with the community during a general situation, the primary methodology used is the EIS or Emergency Information System, which uses the radio and TV stations to broadcast any notification regarding a general emergency situation. As part of the preventive actions, this agency coordinate tsunami warning drills to further educate people about the guidelines that will be followed if this event occurs and to test the EIS. For the last drill performed in Carolina, in addition to the EIS, an initiative was started to include text-messaging notification sent by all cellphone companies in PR but only “Claro PR” participated during the drill where all customers received a text message indicating the tsunami alert. The reason for the lack of participation of other companies on this drill and to provide a permanent text messaging governmental notification system is because companies have to cover the cost of sending text messages in mass and in addition, the participation is not mandatory. For this reason this method is not completely available to the authorities.

Other communication mechanism is the use of official Municipality web pages, flyers, press releases for written press, radio and television, seminars and car megaphones or big audio systems to announce on streets, for example, that people need to be evacuated on a specific area. In locations identified with high probability of an impact of Tsunami, authorities have installed a series of massive audible alarms that are activated when a tsunami have been detected before it strikes the coast. On the other hand due to institutional policies, social networks like Facebook and Twitter are not allowed to be used as emergency notifications broadcasting methodology or to receive help requests from citizens. In case of a major blackout in communication services, the MEAD counts with satellite phone service that also can be used to receive notification from the West Coast and Alaska Tsunami Warning Center. When a citizen needs to make a request to the authorities, there are different ways they can do so. The principal methodology to contact the municipality services regarding an emergency or for any help request is by calling the Office for Integrated Security Services and Virtual Technology at 787-769-4000 or by calling 911 which eventually forward the request to them if they are required to attend it. This office is in charge of receiving the requests from citizens and refers them to the corresponding municipality organism. If the request does not correspond to an emergency, people can also visit the office in person on one of it locations or by sending an email or fax.

MEAD has expressed the vulnerability of the telephone service in a circumstance of a major disaster as strong earthquakes. Disaster like this one have never happened during modern Puerto Rico, but base on similar situations in other countries, telephony services have been affected during this situations. So far, only sporadic interruption has been registered, but they are aware that citizens had encountered problems contacting the office due to problems with the telephone service in affected area.

For the communication between members of the department of security, they use email, fax, wired phone, cellphone and two-way radios that operate on 25 different channels distributed by purposes. In case of a significant adverse event, the frequency 800 MHz is designated to communicate between departments to manage the emergencies. The state government is currently working on a project with the FCC to designate this frequency for this purpose not only in Carolina, but also in the rest of the municipalities to provide interoperability between all local emergency agencies using this medium.

When a request for help is received, the person does not have to provide any information out of what is essential to provide the help. In general, the details that are requested are the name of the person that make the request, address where the help is needed, contact phone, and a short description of the incident. However, depending on the circumstances, the person that makes the request might not be able to provide all this information. For this reason, indicating a short description of the location can be enough to make the authorities able to manage the situation. An example of a message received from a phone call could be "There was a car accident in front of the airport", and this information is all the authorities needs to start managing the situation. In a situation like this one, the will send a unit to inspect the area and send any other information required.

Puerto Rico Emergency Management Agency or AEMEAD (Agencia Estatal para el Manejo de Emergencias y Administración de Desastres) aims to handle situations that arise during a state wide adverse event. Created under the Act 211 (PR, August 2, 1999), this governmental agency is the point of contact between citizens and the different government agencies, since it coordinates all efforts needed to solve the emergency citizen's situations. Once the agency receives the emergency, it determines which governmental agencies are needed and tracks the status of the claim until it is solved. During a significant emergency, the different agencies representatives, assist citizens who had lost their houses and/or are in danger. In addition, they coordinate which shelters are going to be available and how the food distribution will work.

It is important to notice that this agency does not provide direct services to citizens; they only coordinate the necessary personnel within the chain of command to solve the citizens' request(s). Those requests are obtained through 911 or the citizens can call directly to the agency. Then the information is introduced to a system known as Computer Aid Dispatch

(CAD), which is used to track the status of the situation. Since all the state governmental agencies, are connected to this system, they can update the status based on the actions that have been taken. To manage the requests, the agency designates a group of people (dispatcher) to each location and they work in different shifts to ensure that citizens have the service 24 hours. In this manner, they can assist citizen with their emergency requests but also with other requests (non-emergency).

Once the request is received through the 911 or directly to the agency on the 787-750-7766, the emergency is transferred to the agency through the CAD, and then they coordinate which resources are necessary to solve the situation. Most of the time, the communication between the agency and the different resources is through CAD, but phone service, radio frequency, text messages or email are used as well. In case of a major disaster, where those services might not be available, they could use a special system called KP4. This system permits the communication between the emergency management agencies in Puerto Rico and emergency management agencies (e.g. NOAA and FEMA) in the United States. In addition every director inside the agency, as well as all governmental agency chief officers, has satellite phone service.

Similar to Carolina, AEMEAD counts with an Emergency Operation Center (COE), in this case, composed by the governor and representatives of all state agencies. All decisions made by this committee are transferred to regional offices (11 locations) that coordinate local resources including municipal emergency management offices and local COE committees. To communicate with communities, central press office uses television, radio and written press during emergencies and furthermore, web portal (www.manejodeemergencia.pr.gov) and flyers for prevention purposes.

A new initiative that has been started a few years ago along the island is called Community Emergency Response Team (CERT), a federal program that educates people about how to deal with disasters that might affect their location (CERT 2012). This program provide knowledge in basic disaster response skills including fire safety, search and rescue, team organization and medical operations so people that participate of this program can help and assist other neighbors or coworkers on an emergency event when authorities response is not immediately available.

Appendix II - Previous Emergency Situations

Hurricane Katrina

As an example, during the hurricane Katrina in 2005, floods and winds caused a collapse in communication infrastructure along the Gulf coast from Florida to Louisiana especially New Orleans (NOAA 2005). These failures affected residential phones, cellphones and other communication systems. Fiber optics, copper, coaxial and wireless towers constitute the backbone of these systems and were damaged considerably. As a result, more than 1.75 million customers (Mohammed and Krim 2005) remained without these services for more than two months due to the difficulties encountered accessing the affected areas. Executives from BellSouth Corp, main service provider in this area, as well as officers from AT&T Corp and Sprint Nextel Corp, addressed the severity of the damages and the difficulty to repair them. Text messaging and web communication were slightly available in some places, but due to power failures on cellphone towers, were eventually affected. After this event, Reed E. Hunt, chairman of the Federal Communication Commission, expressed the need of a National emergency wireless network (Mohammed and Krim 2005).

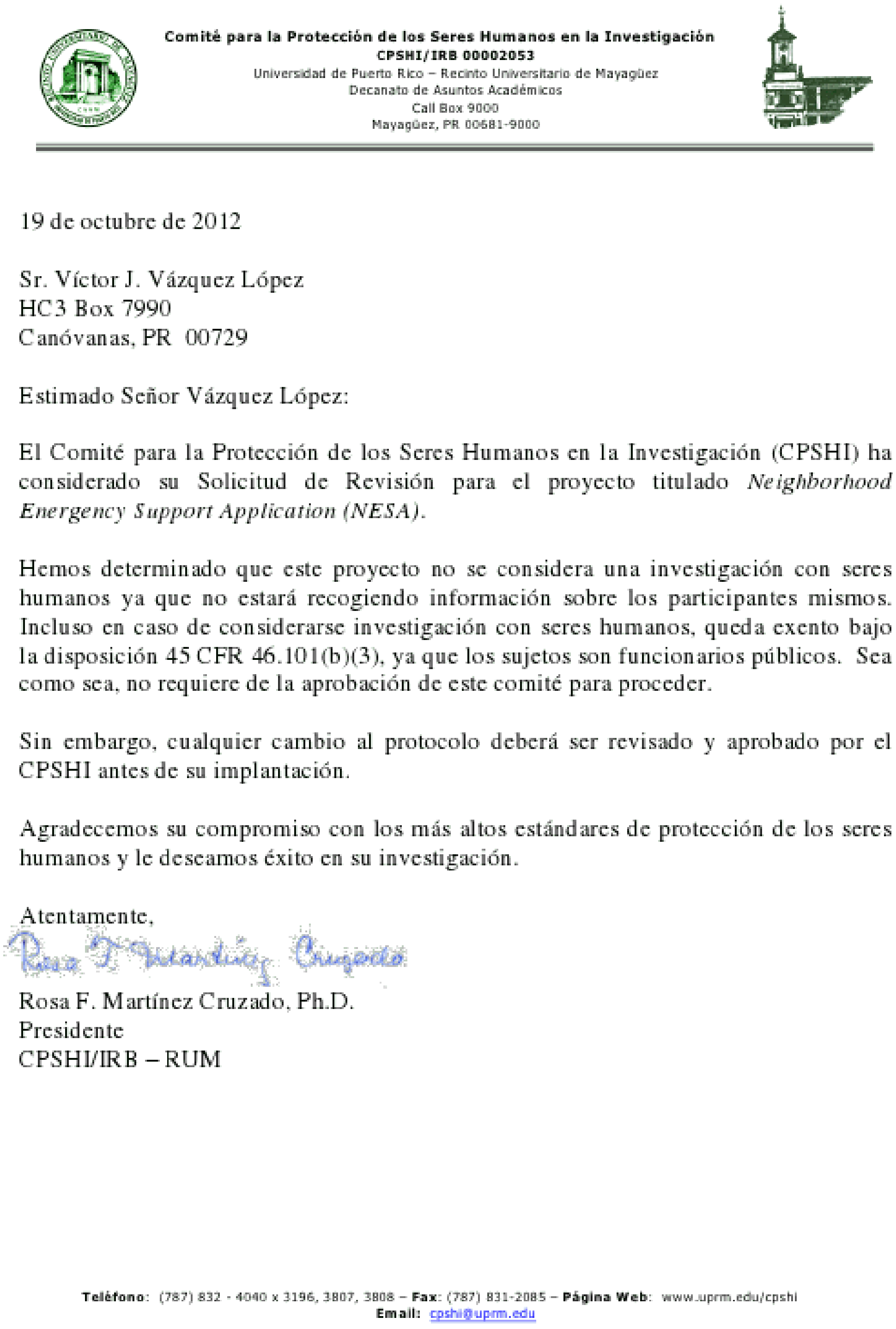
Hurricane Alex

Five years later, during the month of July 2010, Mexico suffered the impact of hurricane Alex. The damages were estimated in 203 millions of pesos (approximately $15 millions of dollars). More than 2,000 houses sufferer damages and more than 400 were affected severely (Fernández-Valverde 2010). After this hurricane, the circumstances in terms of communication systems were very similar to those of Katrina (i.e. failures were reported on traditional telephony systems, as well as on cellular and Internet services). Major communication companies in Mexico, Telcel, Movistar, Telmex, Axtel, Alestra and Iusacell, suspended their phone, text and Internet services respectively (Terra Mexico 2010). “Telefonía Movistar” particularly, reported a rupture in 4 fiber optic links that affected not only a considerable part of Mexico, also other countries in Central America including Nicaragua. Only one link was affected during the pass of the hurricane, but as consequence of river overflows and floods, three additional links suffer damages. These floods, in addition to the rain, prevented the repairs delaying the process of restoring the services (La Voz del Sandinismo 2010).

Earthquake in Chile (2010)

Another considerable event was the earthquake of Chile in February 2010. Citizens mentioned that even though their mobile devices had backup batteries, Internet and telephone services were not available. In addition, due to the power failures, they was not able to use the television and the only way to receive information, particularly regarding the possibility of a Tsunami after the earthquake, was only through one radio station. For this reason the lack of a backup communication system was criticized (Schifferli 2010).

Appendix III - CPSHI Authorization



Comité para la Protección de los Seres Humanos en la Investigación
CPSHI/IRB 00002053
Universidad de Puerto Rico – Recinto Universitario de Mayagüez
Decanato de Asuntos Académicos
Call Box 9000
Mayagüez, PR 00681-9000

19 de octubre de 2012

Sr. Víctor J. Vázquez López
HC3 Box 7990
Canóvanas, PR 00729

Estimado Señor Vázquez López:

El Comité para la Protección de los Seres Humanos en la Investigación (CPSHI) ha considerado su Solicitud de Revisión para el proyecto titulado *Neighborhood Energency Support Application (NESA)*.

Hemos determinado que este proyecto no se considera una investigación con seres humanos ya que no estará recogiendo información sobre los participantes mismos. Incluso en caso de considerarse investigación con seres humanos, queda exento bajo la disposición 45 CFR 46.101(b)(3), ya que los sujetos son funcionarios públicos. Sea como sea, no requiere de la aprobación de este comité para proceder.

Sin embargo, cualquier cambio al protocolo deberá ser revisado y aprobado por el CPSHI antes de su implantación.

Agradecemos su compromiso con los más altos estándares de protección de los seres humanos y le deseamos éxito en su investigación.

Atentamente,

Rosa F. Martínez Cruzado

Rosa F. Martínez Cruzado, Ph.D.
Presidente
CPSHI/IRB – RUM

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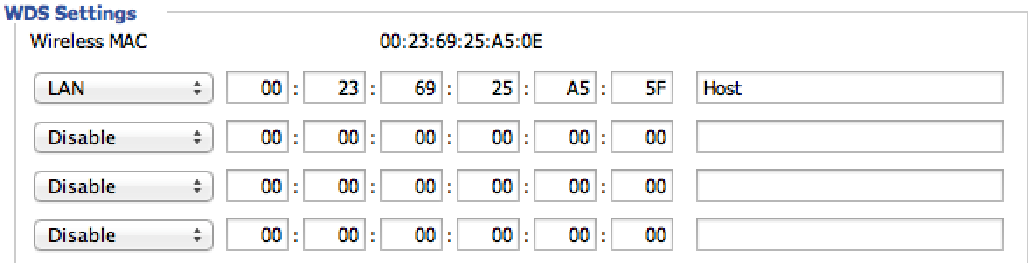
Email: cpshi@uprm.edu

Appendix IV - Test bed Configuration and Routers status

WDS Configuration

Router 1

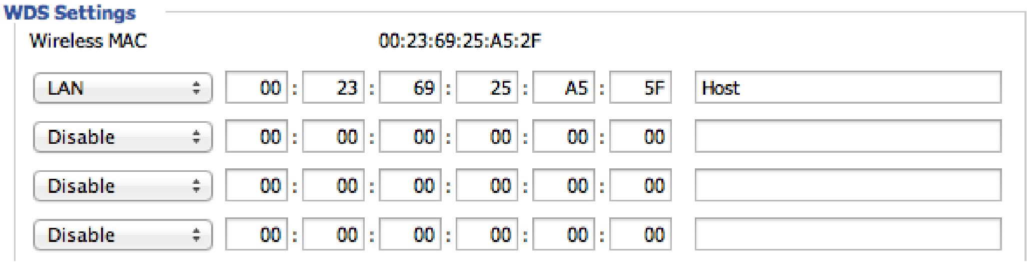


WDS Settings

Wireless MAC 00:23:69:25:A5:0E

LAN	00	23	69	25	A5	5F	Host
Disable	00	00	00	00	00	00	
Disable	00	00	00	00	00	00	
Disable	00	00	00	00	00	00	

Router 2

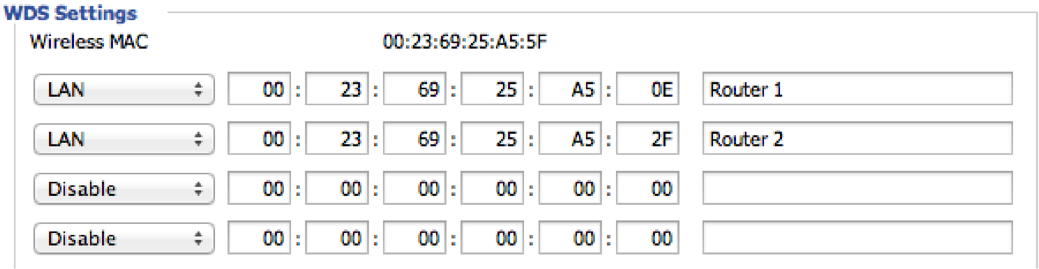


WDS Settings

Wireless MAC 00:23:69:25:A5:2F

LAN	00	23	69	25	A5	5F	Host
Disable	00	00	00	00	00	00	
Disable	00	00	00	00	00	00	
Disable	00	00	00	00	00	00	

Host Router

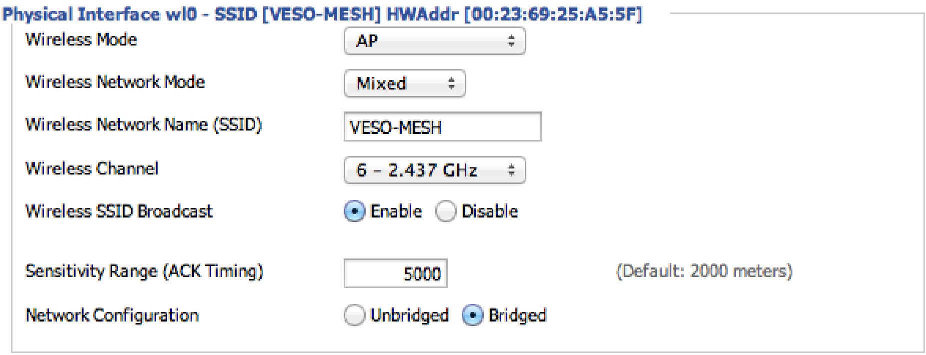


WDS Settings

Wireless MAC 00:23:69:25:A5:5F

LAN	00	23	69	25	A5	0E	Router 1
LAN	00	23	69	25	A5	2F	Router 2
Disable	00	00	00	00	00	00	
Disable	00	00	00	00	00	00	

Wireless Interface Parameters

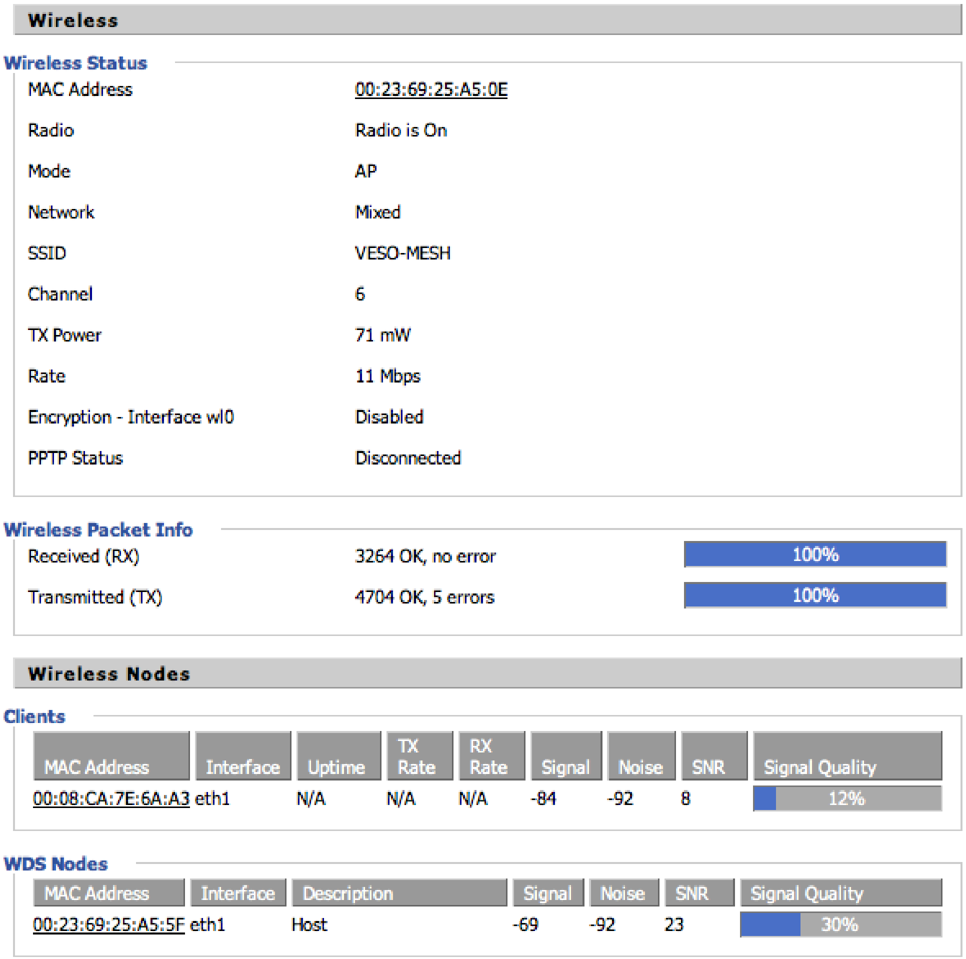


Physical Interface wl0 - SSID [VESO-MESH] HWAddr [00:23:69:25:A5:5F]

Wireless Mode	AP
Wireless Network Mode	Mixed
Wireless Network Name (SSID)	VESO-MESH
Wireless Channel	6 - 2.437 GHz
Wireless SSID Broadcast	● Enable ○ Disable
Sensitivity Range (ACK Timing)	5000 (Default: 2000 meters)
Network Configuration	○ Unbridged ● Bridged

Indoor test routers status

Router 1



Wireless

Wireless Status

MAC Address	00:23:69:25:A5:0E
Radio	Radio is On
Mode	AP
Network	Mixed
SSID	VESO-MESH
Channel	6
TX Power	71 mW
Rate	11 Mbps
Encryption - Interface wl0	Disabled
PPTP Status	Disconnected

Wireless Packet Info

Received (RX)	3264 OK, no error	100%
Transmitted (TX)	4704 OK, 5 errors	100%

Wireless Nodes

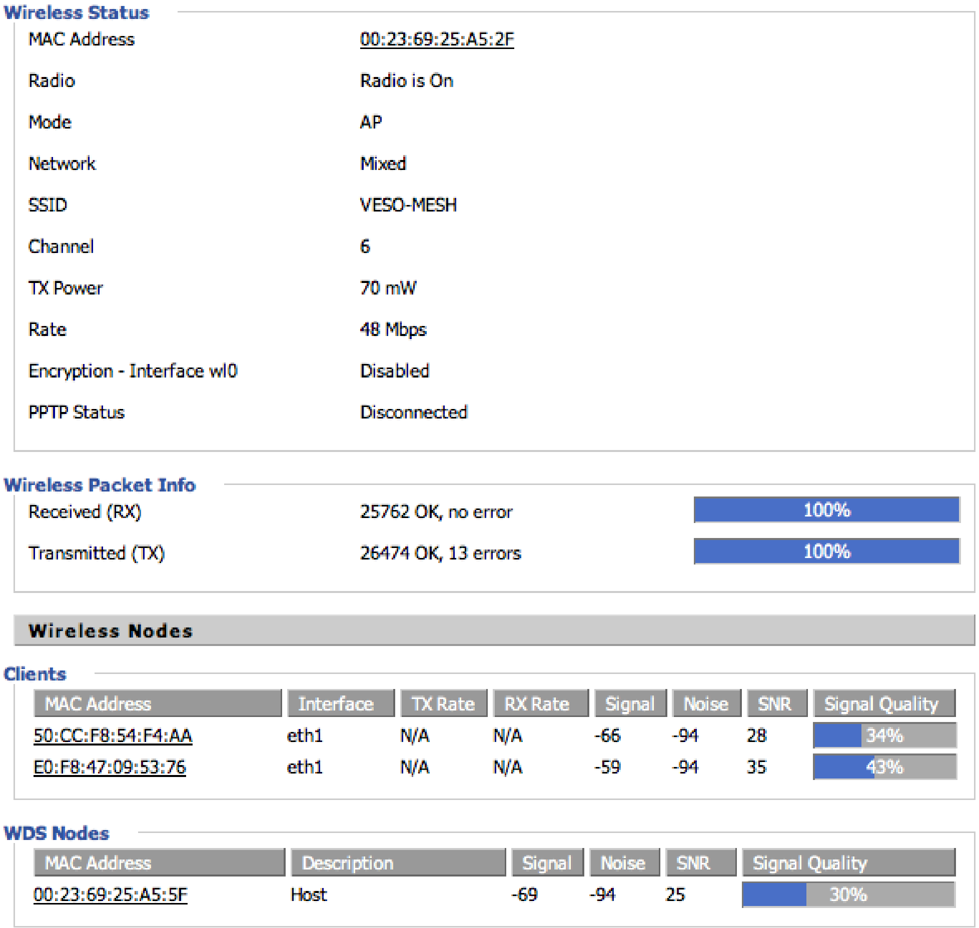
Clients

MAC Address	Interface	Uptime	TX Rate	RX Rate	Signal	Noise	SNR	Signal Quality
00:08:CA:7E:6A:A3	eth1	N/A	N/A	N/A	-84	-92	8	12%

WDS Nodes

MAC Address	Interface	Description	Signal	Noise	SNR	Signal Quality
00:23:69:25:A5:5F	eth1	Host	-69	-92	23	30%

Router 2



Wireless Status

MAC Address	00:23:69:25:A5:2F
Radio	Radio is On
Mode	AP
Network	Mixed
SSID	VESO-MESH
Channel	6
TX Power	70 mW
Rate	48 Mbps
Encryption - Interface wl0	Disabled
PPTP Status	Disconnected

Wireless Packet Info

Received (RX)	25762 OK, no error	100%
Transmitted (TX)	26474 OK, 13 errors	100%

Wireless Nodes

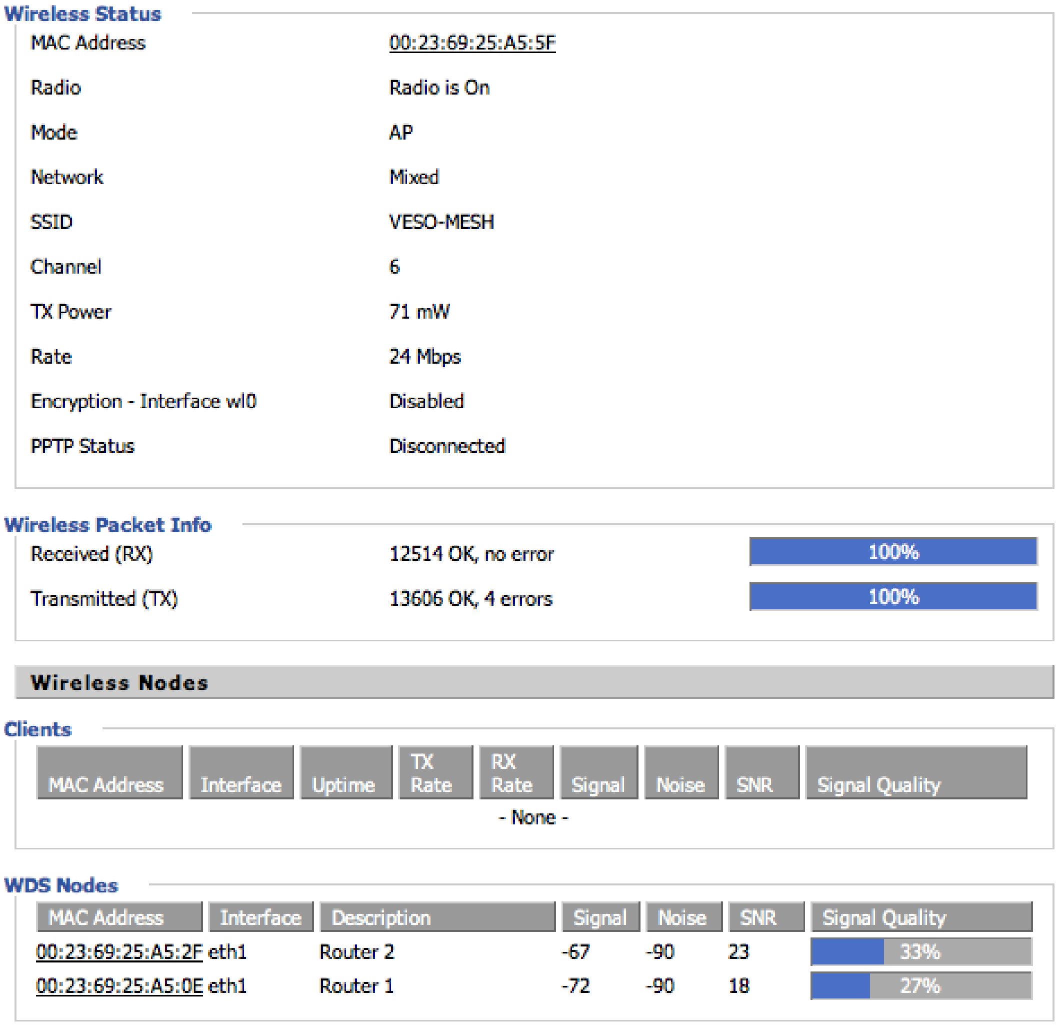
Clients

MAC Address	Interface	TX Rate	RX Rate	Signal	Noise	SNR	Signal Quality
50:CC:F8:54:F4:AA	eth1	N/A	N/A	-66	-94	28	34%
E0:F8:47:09:53:76	eth1	N/A	N/A	-59	-94	35	43%

WDS Nodes

MAC Address	Description	Signal	Noise	SNR	Signal Quality
00:23:69:25:A5:5F	Host	-69	-94	25	30%

Host Router



Wireless Status

MAC Address	00:23:69:25:A5:5F
Radio	Radio is On
Mode	AP
Network	Mixed
SSID	VESO-MESH
Channel	6
TX Power	71 mW
Rate	24 Mbps
Encryption - Interface wl0	Disabled
PPTP Status	Disconnected

Wireless Packet Info

Received (RX)	12514 OK, no error	100%
Transmitted (TX)	13606 OK, 4 errors	100%

Wireless Nodes

Clients

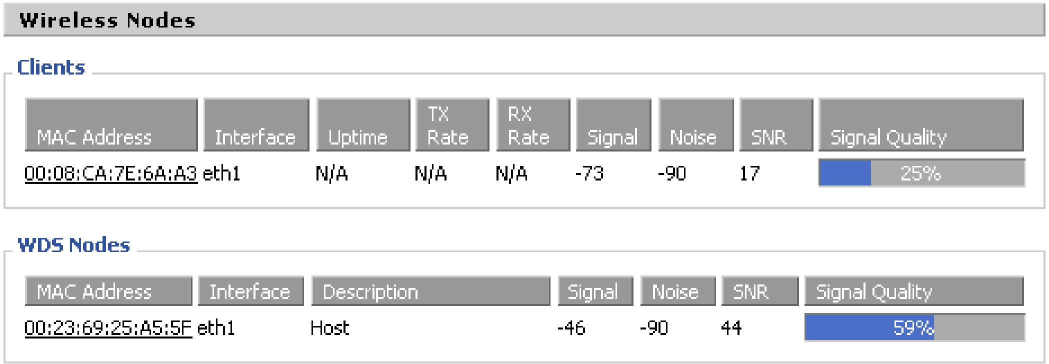
MAC Address	Interface	Uptime	TX Rate	RX Rate	Signal	Noise	SNR	Signal Quality
				- None -				

WDS Nodes

MAC Address	Interface	Description	Signal	Noise	SNR	Signal Quality
00:23:69:25:A5:2F	eth1	Router 2	-67	-90	23	33%
00:23:69:25:A5:0E	eth1	Router 1	-72	-90	18	27%

Outdoor test routers status

Router 1



Wireless Nodes

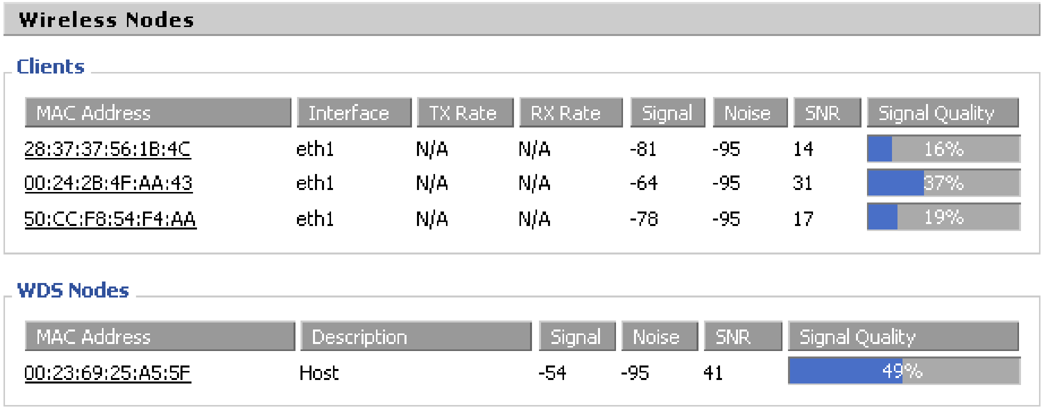
Clients

MAC Address	Interface	Uptime	TX Rate	RX Rate	Signal	Noise	SNR	Signal Quality
00:08:CA:7E:6A:A3	eth1	N/A	N/A	N/A	-73	-90	17	25%

WDS Nodes

MAC Address	Interface	Description	Signal	Noise	SNR	Signal Quality
00:23:69:25:A5:5F	eth1	Host	-46	-90	44	59%

Router 2



Wireless Nodes

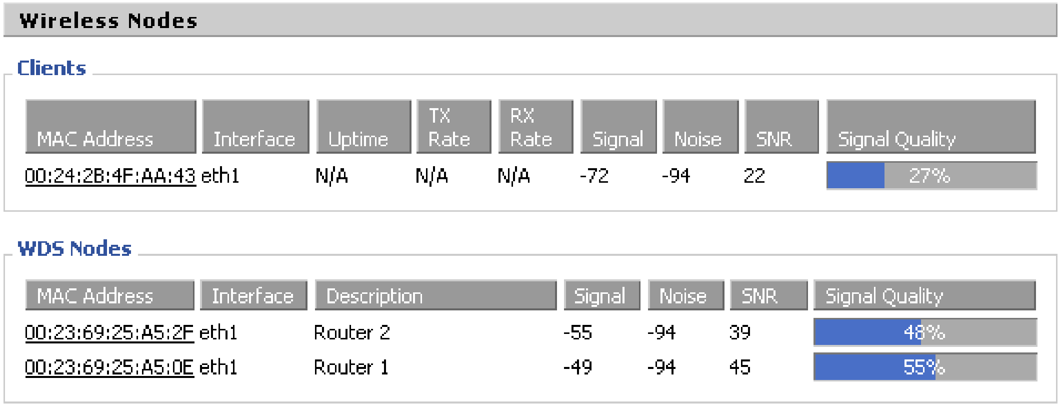
Clients

MAC Address	Interface	TX Rate	RX Rate	Signal	Noise	SNR	Signal Quality
28:37:37:56:1B:4C	eth1	N/A	N/A	-81	-95	14	16%
00:24:2B:4F:AA:43	eth1	N/A	N/A	-64	-95	31	37%
50:CC:F8:54:F4:AA	eth1	N/A	N/A	-78	-95	17	19%

WDS Nodes

MAC Address	Description	Signal	Noise	SNR	Signal Quality
00:23:69:25:A5:5F	Host	-54	-95	41	49%

Host Router



Wireless Nodes

Clients

MAC Address	Interface	Uptime	TX Rate	RX Rate	Signal	Noise	SNR	Signal Quality
00:24:2B:4F:AA:43	eth1	N/A	N/A	N/A	-72	-94	22	27%

WDS Nodes

MAC Address	Interface	Description	Signal	Noise	SNR	Signal Quality
00:23:69:25:A5:2F	eth1	Router 2	-55	-94	39	48%
00:23:69:25:A5:0E	eth1	Router 1	-49	-94	45	55%