ECHO: A WIFI – based Emergency Communication Platform

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ABSTRACT

Natural disasters are catastrophic events caused by nature which include floods, hurricanes, tornadoes, volcanic eruptions, earthquakes, tsunamis, and other destructive geologic processes. They cause death or destruction of telecommunication, properties, transportation and livelihood. Communication during and immediately after a disaster is an important component of response and recovery, in that it connects affected people, families, and communities with first responders, support systems, and other family members. Telecommunications and advanced technology are the lifelines of any major emergency response during and immediately after a catastrophic event. This research designed and developed an alternative information and communication system for disaster via a mobile application and a point-to-point (P2P) network and mesh network for communication system. Actual testing and evaluation of the system's functionality and range of operation were conducted. The developmental and experimental methods of research were used to solve problems on response to disasters that prompted development of innovation. To achieve this purpose a hybrid network topology using IEEE 802.11 protocol using mesh network and point-to-point network was designed. Suitable hardware, a power beam long range P2P network device and wide range Pico-station were chosen for the communication setup. Software modules were developed for the user interface in captive portal and mobile application. Testing and evaluation of the functionality and range of communication system were done. Evaluation of the system conclusively shows the device is portable, the mobile application is designed according to the desired graphical user interface (GUI) and can easy download through the captive portal. The designed hybrid network topology which is flexible reliable and has expanded adaption to non—critical failure and faults can be effortlessly analyzed and corrected. The developed system passed the functionality test.

Keywords: *emergency communication, Wi-Fi, ECHO*

1. INTRODUCTION

Natural disasters are catastrophic events caused by nature. These include floods, hurricanes, tornadoes, volcanic eruptions, earthquakes, tsunamis, and other destructive geologic processes. They can cause death or destruction of properties, transportation and livelihood. The seriousness of a catastrophe is measured in lives lost, monetary misfortune, and the ability of the population to rebuild.

When disaster strikes, the most common cause of communication failures is the physical damage to devices or components that make up the network infrastructure.

Over the past years, the Philippines has experienced more disasters from landslides to floods to volcanic eruption which Filipinos say that those disasters are becoming more severe, in part because of climate change. When disaster strikes, the effectiveness of disaster response operation is very critical to life saving; however, communication systems, including cellular networks, usually crash.

A year ago, government weather forecaster Loriedin De La Cruz briefs the media on Typhoon Melor at the weather bureau center in suburban Quezon City, which hits the eastern Philippines Monday, Dec. 14, 2015 causing evacuation of thousands residents in flood—and landslide—prone communities bracing the destructive winds, heavy rains and coastal floods of up to 4 meters (13 feet). Northern Samar and Eastern Samar were power with communication lines in Northern Samar down. Globe Telecom submitted a report to the NDRRMC, claiming difficulty in 2G and 3G signals in the province.

Rosette Martinez, communications officer of National Grid Corp. of the Philippines, said inspection of lines was still ongoing and could not determine when power would be restored in the two provinces [1].

The most common cause of communications failures during disasters is the physical damage to devices or components that make up the network infrastructure.

New information and communication technologies (ICTs) can offer real opportunities to improve the quality of community life. It is also important to deepen level of reflection on community dynamics and on the constraints encountered when introducing and using ICTs for development. A healthy information—aware society is concerned with bringing reliable and timely information to its members. In the context of disaster responsiveness making people aware of the benefits derivable from the use of ICTs will help make an in formed society on how to use them in disaster emergencies one[2].

In this sense, telecommunications and advanced technology are the lifeline of any major emergency response during and immediately after a catastrophic event. Through the use of ICT applications, quality information can be made accessible to key decision makers. Such technologies are paramount in enabling responders to make timely, informed decisions that save lives and ease human suffering.

The abovementioned problems encouraged the researchers to design and develop an emergency communication platform dubbed as "ECHO". The system has the ability to become a portable alternative communication tool. It has a mobile application capable of chat and voice call even without internet connection and Global System for Mobile Communications (GSM) communication and it is designed to transfer data using mesh network. The power source of the system is solar energy thus, it is not be affected by power interruption.

Objectives of the Study

This study aimed to design and develop alternative information and communication system for disasters. The study sought to attain the following: (1) determine the design requirements of the system considering accessibility and wireless protocol; (2) develop the software modules for the user interface; (3) design a hybrid network topology using IEEE 802.11 protocol; (4) select a suitable hardware for the communication setup; and (5) test and evaluate the communication system's functionality and range of operation.

2. MATERIALS AND METHODS

Pre-Design Stage

Developmental and experimental methods of research were used to find a solution to solve a practical problem that prompts develop of this innovation.

Table 1

ECHO Hardware Requirements

Hardware	Description
Long range Outdoor P2P network	Communication medium responsible for the long—distance transmission of data
Router Long Range Outdoor Pico station	Communication medium responsible for the widespread transmission of data
Router Board	Router operating system and a Web page that the user of a public—access network is obliged to view and interact with before access is granted.
Solar Panel System	Main power source of the device

Table 1 presents the ECHO hardware requirements responsible for wireless communication system.

Design Stage

The study focused on developing an alternative communication platform of communication in case of catastrophic event using of hybrid Wi—Fi outdoor system. This device will can be placed anywhere stricken by catastrophic event.

The device called ECHO is a solar powered communication device with five Wi-Fi outdoor systems and one point—to—point (P2P) network device. The Wi—Fi system covers up-to 200m per unit and P2P network range is up-to 20km.

The system was designed to a portable alternative communication tool. The developed mobile application is capable of chat and for voice call even without internet connection and GSM communication connecting to as much as 250 users. As designed, it can transfer data using mesh network. The device can be used when GSM communications are down during catastrophes.

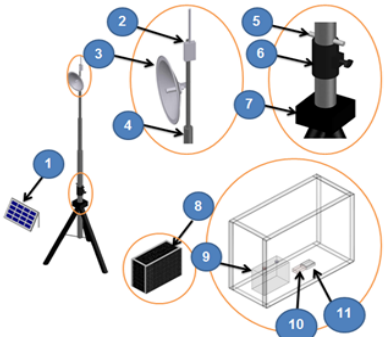
The android application developed is capable of chat and call even without internet connection. Two hundred and fifty users can connect to the system and use the mobile application.

Testing Stage

The project was tested to determine compatibility of the system to different mobile phones, range, speed, and functionality.

3. RESULTS AND DISCUSSIONS

System design was applied to determine the requirements of the system.



ECHO Parts	
1	Solar Panel
2	Pico Station
3	Power Beam
4	Portable Stand Pole
5	Safety Pin
6	Plastic Insert Sleeve
7	Leg Housing
8	Portable Tool Box
9	Battery
10	Power Inverter
11	Charge Controller

Figure 1. Hardware Components

The components included in the development of the system are shown in Figure 1. The designed portable communication tool is a 20ft portable stand pole that can easily be setup and can be moved anywhere. The power beam device creates connection between long distances and is unidirectional. It uses an antenna feed and a dish placed in high altitude to assure good connection of the power beams. The Pico Station device emits Wi—Fi signal in a much greater omnidirectional range compared to an ordinary router used at home.

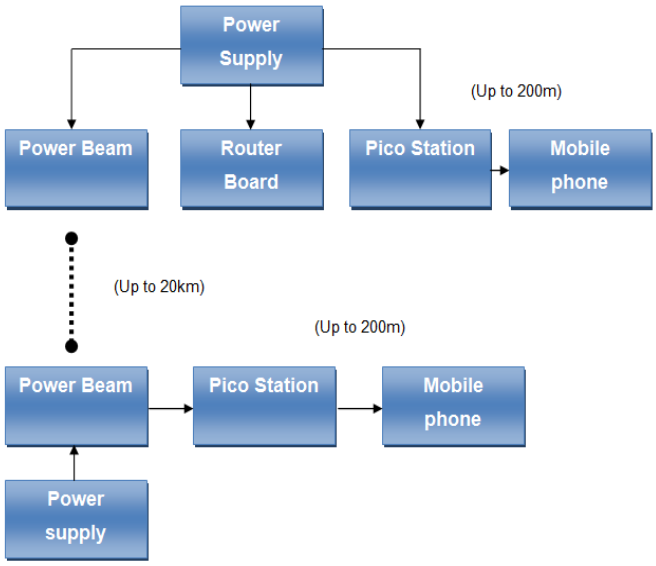


Figure 2. Block Diagram of ECHO

Figure 2 shows the complete block diagram of ECHO indicating the connection of all major components of the system including the solar panel, charge controller, battery, router board, wireless router Pico Station, and P2P (power beam).

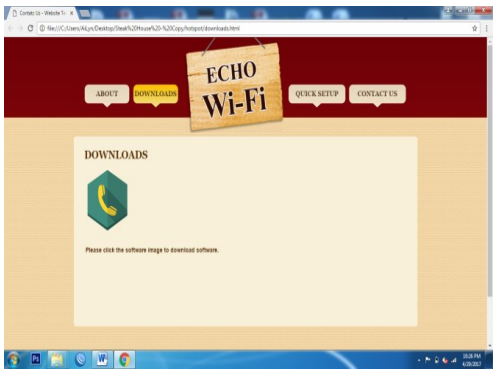


Figure 3. Captive Portal Downloads Page

Figure 3 shows the captive portal, accessibility of the design requirement of the system. The user friendly interface which allows the user easily enter the system and download the mobile application provided by the captive portal.

Figure 4 shows the graphical user interface (GUI) of the system illustrating features of application is composed of Call, Public Chat, Messages, Profile, About, Reset and Exit tab.

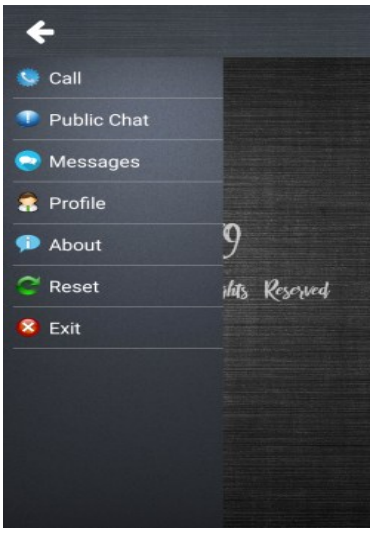


Figure 4. ECHO Design Android Application

Android was built on open Linux Kernel. This particular software for mobile application open source allows developers to introduce and incorporate any technological advancement.

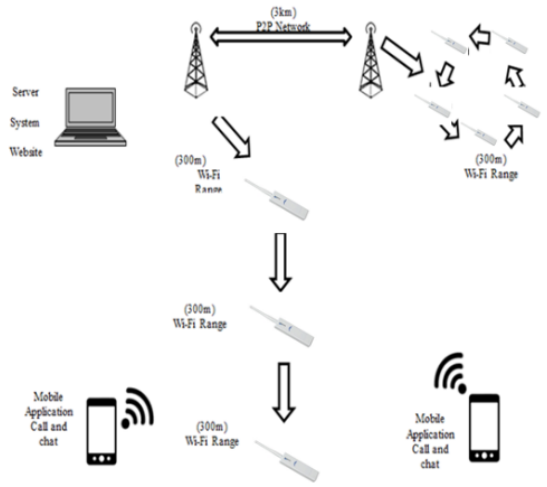


Figure 5. Hybrid Network Topology

The system's hybrid network topology is shown in Figure 5. The system makes use of hybrid wireless mesh protocol (HWMP), a mandatory layer 2 path selection protocol similar to 802.11. HWMP employs a combination of the proactive three-based distance vector protocol to support static mesh deployments and elements of the reactive ad hoc on-demand distance vector (AUDV) protocol to support mobile mesh deployment[4].

Figure 6. P2P Power Beam Parabolic Dish

Figure 6 shows a P2P power beam used in the system. Its maximum range is 20 km.

A P2P link can be established between two buildings into a WLAN. In addition to an antenna, a wireless bridge is required to link the wireless system into the building's network, regardless of whether it is wired or wireless[5].

Table 2. P2P Power Beam Specification

Dimensions	325 x 325 x 256 mm (12.8 x 12.8 x 10.1")
Weight (Mount Included)	1.203 kg (2.65 lb)
Operating Frequency	Worldwide: 5170 - 5875 MHz USA: 5725 - 5850 MHz
Range	up to 20km
Gain	22 dBi
Networking Interface	(1) 10/100 Ethernet Port
Enclosure	Outdoor UV Stabilized Plastic
Power Supply	24V, 0.5A PoE Supply
Wind Survivability	200 km/h (125 mph)
Wind Loading	200.2 N @ 200 km/h (45 lbf @ 125 mph)
Wireless standards	IEEE 802.11b/g/n

Table 2 presents the detailed P2P power beam specification. The power beam with 22 dBi directs RF energy in a tighter beam width. Focused in one direction, the power beam blocks or spatially filters out noise, so noise immunity is improved. This feature is especially important in an area crowded with other RF signals of the same or similar frequency. IEEE 802.11 wireless standard was used for the power beam.

Figure 7. Wireless Router (Pico Station)

Figure 7 shows a wide range wireless router (Pico Station). The Pico Station features speeds up to 100+ Mbps and range performance of up to 200 m. It can be deployed in indoor or outdoor environments, so the Pico Station M2HP is ideal for applications requiring medium range performance and a minimal installation footprint. The high performance, small form factor, and low cost of the Pico Station make it extremely versatile and economical to deploy.

The wireless router (Pico Station) detailed specifications are shown in Table 2. Pico Station has an operating frequency 2.4Ghz and 5 dBi antenna that delivers data at a rate of up to 100 Mbps and enables distances of up to 200m outdoor. It comes with a 10/100 ethernet port as well as 32MB of SDRAM along with 8MB of flash. For convenience, power over ethernet (PoE) 15v, 0.8A support allows mounting it where a power socket is not readily available. IEEE 802.11 wireless standards was used.

Figure 7. Router board

To facilitate offline website or a captive portal, a router board (Figure 7) was used. The user can easily access the system and download the mobile application even without internet connection.

Wireless protocol

IEEE 802.11 or Wi-Fi protocol was selected rather than other wireless protocols due to their availability in the market and compatibility with android phones to be used for alternative communication software.

Table 4 shows the tabulated data of wireless network protocols for the system functionality, mobile phone compatibility, speed and its frequency.

Table 4

Comparison of wireless network protocols

Wireless Protocol	Compatible	Speed	GSM Signal	Frequency
2G/3G	YES	3.1Mbps (peak)	YES	850, 900 or 2.1GHz bands
LTE	YES	3-5Mbps	YES	700MHz
WiGig	NO	7Gbps	NO	60GHz
Wi-Fi	**YES**	**11 Mbps to 54 Mbps and above**	**NO**	**2.4 GHz or 5 GHz**
Blue-tooth	YES	1-2Mbps	NO	2480 MHz
Zigbee	limited	0.25Mbps	NO	2.4GHz

Test the evaluation of the communication system.

ECHO was tested based on functionality and range of Wi-Fi communication.

Functionality

The functionality of the mobile application was evaluated by installing it in different android operating systems such as Jelly Bean, Kit Kat, Lollipop and Marshmallow.

Table 5

Functionality Testing of ECHO mobile application

Android Operating System	Version number	Result	
		Chat	Call
Jelly Bean	4.1–4.3.1	PASSED	PASSED
KitKat	4.4–4.4.4	PASSED	PASSED
Lollipop	5.0–5.1.1	PASSED	PASSED
Marshmallow	6.0–6.0.1	PASSED	PASSED

Table 5 shows the testing of the mobile application in different android operating systems. The ECHO mobile application was properly installed on different android operating systems. The application was properly installed on different android operating systems; the chat and call features properly worked.

Range of Wi-Fi communication

The range of Wi-Fi communication was evaluated by measuring the signal strength and speed in different ranges from the Wi-Fi router to the mobile phone. Results are show in Table 6.

Table 6

Range of Wi-Fi communication testing of the system

	Trial	Range	Signal Strength	Speed millisec-onds (ms)	Results
Pico Station	1	50m	-65 dBm	6.57ms	PASSED
	2	75m	-65 Bm	24.21ms	PASSED
	3	100m	-73dBm	33.3 ms	PASSED
	4	150m	-80 dBm	100ms	PASSED
	5	300m	N/A	Request Time Out	FAILED
Power Beam	1	50m	-65 dBm	1ms	PASSED
	2	75m	-65 dBm	1ms	PASSED
	3	200m	-65 dBm	1ms	PASSED
	4	16km	-94 dBm	8.94 ms	PASSED

For the Pico station, out of five trials passed Wi—Fi range test; one failed test was due to the over range of the user from the Pico Station.

The power beam testing passed all the five trials on set Wi—Fi communication ranges.

Table 7

Results of Testing of ECHO mobile

Number of Users connected				Result	
Trial	AP A	AP B	Total	Chat	Call
1	5	5	10	PASSED	PASSED
2	10	10	20	PASSED	PASSED
3	20	20	40	PASSED	PASSED

Table 7 shows the tabulated data for the number of users connected in the network and results in testing the connectivity of the mobile application. The above data contained the number of trials performed in the function of two access points (AP), access point A and access point B. The ECHO mobile application successfully passed all the trials for connectivity. However, there were times that the call function 1 – 3 seconds voice delay due to large number of users connected in the network. The chat function worked properly on a large number of users.

4. CONCLUSIONS

This study on use of ECHO as an innovation to respond to catastrophic has the following conclusions:

The portability of the device is the main consideration for implementation of ECHO. The mobile application works even without internet connection or GSM signal and is compatible in different android operating systems. The system's hybrid network topology is more flexible, reliable, and has expanded adaptation to non-critical failure. System faults can be effortlessly analyzed and corrected. The P2P and wireless router can cover long and wide distance communication. Generally, The overall functionality of the system was tested and the researchers concluded that the system hardware and software worked accordingly as designed.

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