Journal of Modern Science and Technology
Vol. 3. No. 1. March 2015 Issue. Pp. 251 – 262

PSTN Connected With Wireless Multi Hop Radio Relay - A Solution for Disaster Aftermath Communication

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Natural disasters are becoming more common across the world and they can be utterly devastating to people's lives and the environments. Our aim is to provide voice communication services to the emergency responders and civilians when pre-existing communication infrastructures have been destroyed. In this paper, we propose a new communication network architecture to connect victims of disaster area with emergency responders. This communication network should play a vital role right after any natural disaster during the recovery stage and the supply of relief.

Field of Research: Telecommunication Engineering

1. Introduction

Bangladesh is one of the world's most disaster-prone South-Asian developing countries, which is a victim to various natural disasters in almost every year. The Bay of Bengal has made Bangladesh the worst victim of catastrophic natural disasters such as earthquakes, hurricanes, floods, cyclones, and storm surges that routinely cause great loss of lives and livelihood of Bangladeshi people every year. One of many adverse effects of climate change has been the more frequent occurrences of natural disasters in the present time. The country was faced by thirty eight severe cyclones of varying intensities in the last thirty eight years. Communication plays a vital role after any natural disaster in the recovery stage, but during any natural disaster, the communication system usually gets destroyed. Consequently, most disaster-affected areas such as the remote islands and coastal areas may become unreachable. The emergency responders such as hospitals, police stations, cyclone centers etc. cannot communicate with other areas or emergency control rooms. As a result, loss of lives and assets increase after the disaster because of the emergency authorities cannot reach the affected areas in time.

One of the major one in recent times was that of 29 April 1991, the material damage was about 2.4 billion US dollars and human casualty of about 1,40,000 lives (EM-DAT, 2009). These kinds of natural disasters have become a great risk to the sustainable development effort of the country. After the disaster, some areas need medicines, some areas need food, and some areas need safe drinking water and other necessary things. Because of the damaged communication system, none can contact the emergency authorities.

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As a result, huge loss of lives and assets can occur. At that time, an emergency communication system is necessary to allow the first responders such as firemen, police, NGO's, government and medical assistance teams to coordinate quickly and efficiently to save the people of the affected areas.

In recently published literatures, there have been some work on Disaster and Risk Management, but there has been almost no work on the exclusive nature of Disaster and Risk Management for developing countries like Bangladesh where the communication infrastructure is usually not very developed. For example, the research work of Baldo et al (2011), Collins (2011), Fujiwara et al (2004), Manoj et al (2007) and Samarajiva (2001) focuses on the technical solution of emergency and disaster aftermath communication, but it emphasizes on wireless communication as the solution. The main challenge in that approach is that it is difficult to setup an emergency wireless communication system within a short time at a low cost in a developing country like Bangladesh. Our objective is to design a new emergency communication system for the emergency responders very quickly at a very low cost.

Our proposed solution of disaster aftermath communication uses wireless multi hop radio relay network infrastructure which can be deployed quickly in the aftermath of a disaster to provide communication services among emergency responders. We also highlight the challenges in making the technology effective. Our proposed solution can be used by emergency responders and, in some cases, civilians after a disaster. Our proposed solution provides voice communication services among the emergency responders through the proposed wireless multi hop radio relay network architecture.

In our paper, we analyze the data of last 30 years of various natural disasters of Bangladesh and analyze the benefits of using our proposed architecture to disaster aftermath communication. This paper is written on the basis of primary and secondary information like government reports, books, articles, electronic journals and so on. At first local issues like Bangladesh will be discussed. Then the proposed wireless multi hop radio relay network architecture and challenges are described. After that, we analyze the benefits of the proposed network architecture in terms of cost and time.

2. Impact of Natural Disaster

The world climate is undergoing a rapid and major change day by day with a negative effect on human habitation on earth. Bangladesh is one of the developing countries of south-east Asia. It is visited by different natural calamities almost every year. Our fate is that we have to survive by fighting against natural calamities. The result is that the people of developing countries are becoming victims year after year and suffering badly with the heavy toll on lives and properties. We have surveyed top ten natural disasters in Bangladesh from 1985 to 2014 sorted by affected people (EM-DAT, 2009).

We have shown a comparative state of natural disaster in following table:

Table 1: Top Ten Natural Disasters in Bangladesh from 1985 to 2014 Sorted By Affected People

<table>
<tr><th>Type of Disaster</th><th>Date</th><th>Total Losses</th><th>No of total affected</th><th>Remarks</th></tr>
<tr><td>Storm</td><td>29/04/1991</td><td>Death: 138866
$1780000</td><td>15438849</td><td rowspan="8">1. Homeless people
2. Shortage of food
3. Shortage of drinking water
4. Bacterial Infectious Diseases
5. Viral Infectious Diseases
6. Parasitic Infectious Diseases</td></tr>
<tr><td>Storm</td><td>24/05/1985</td><td>Death: 15000
$ unknown</td><td>unknown</td></tr>
<tr><td>Storm</td><td>15/11/2007</td><td>Death: 4234
$2300000</td><td>8978541</td></tr>
<tr><td>Flood</td><td>Jun-88</td><td>Death: 2379
$2137000</td><td>45000000</td></tr>
<tr><td>Flood</td><td>22/07/1987</td><td>Death: 2055
$330000</td><td>29700000</td></tr>
<tr><td>Flood</td><td>21/07/2007</td><td>Death:1110
$unknown</td><td>13771380</td></tr>
<tr><td>Flood</td><td>5/7/1998</td><td>Death: 1050
$4300000</td><td>15000050</td></tr>
<tr><td>Storm</td><td>29/11/1988</td><td>Death: 1000
$ unknown</td><td>10568860</td></tr>
</table>

The damage caused by the disasters is unthinkable and we cannot bring back the lives. However, in Table 1, we have also shown the number of people adversely affected by the occurrence of the natural disaster. The requirement of different affected areas is different. Some areas are in need of food, some areas are in need of medicine and some other areas are in need of drinking water. The emergency responders (government, Red Crescent, NGO's, etc.) need to communicate to the disaster hit areas for smooth conducting of operation. A simple solution suggested in (Samarajiva, 2001) is to use a satellite communication network as a backup. The same technology is also considered in other publications such as (Lee et al, 2010; Nagami et al, 2006). However, this type of communications is very costly and poses additional issues such as high delays. We need to reduce the sufferings in the disaster affected areas by providing telecommunication facility as fast as possible. We propose a solution to be used for both emergency responders and civilians in a disaster aftermath situation.

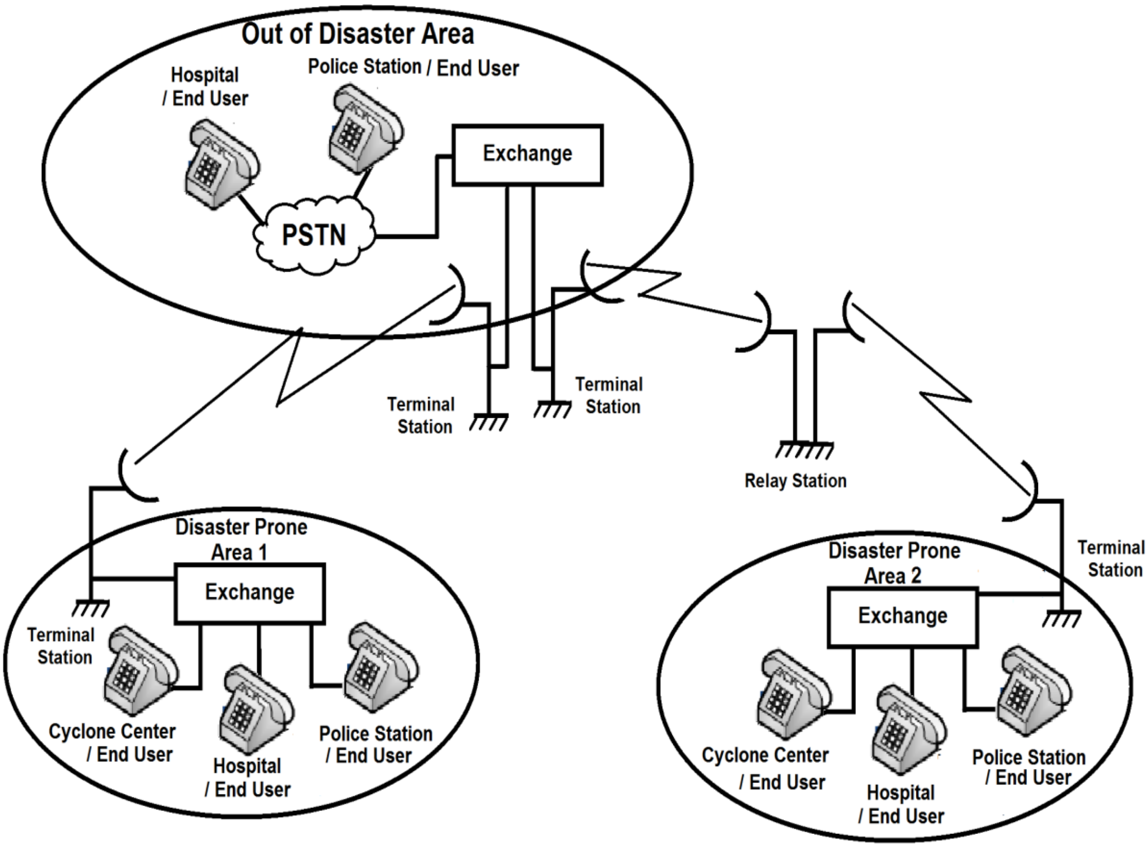
3. Proposed Network Architecture

Our proposed network architecture to be used in a disaster aftermath situation is shown in Figure 1. As shown in Figure 1, we make a distinction between (i) the disaster prone areas and (ii) the out-of-disaster areas. The disaster area is the zone where the pre-existing communication infrastructures have been destroyed and therefore the zone to be covered with the new infrastructure for emergency and civilian communications (Manoj et al, 2007). The out-of-disaster area is the zone not affected by the disaster. Our proposal is to provide communication to disaster prone area through radio relay in the disaster recovery stage.

The use of a wireless multi-hop radio relay network is a key aspect of our proposal for disaster aftermath communication. Our probable outcome is as follows:

a. To provide voice communication services to emergency responders.
b. To restore voice communication services to disaster prone areas.

Figure 1: Architecture of a Wireless Multi Hop Radio Relay



The installation and operation of the proposed architecture is described below.

3.1 End User

The “end” part of the term is probably derived from the fact that most information technologies involve a chain of interconnected product components at the end of which is the “user.” The term end user thus distinguishes the user for which the product is designed from other users who are making the product possible for the end user. It can be a hand-held telephone device used directly by an end-user to communicate.

3.2 Public Switched Telephone Network (PSTN)

It is a circuit-switched telephone network that are operated by national, regional, or local telephone operators, providing infrastructure and services for public telecommunication.

3.3 Exchange

It receives the signal from the user or other exchanges and forward to the required destination. The exchange generally performs three basic functions as described below.

a. It transmits signals over the connection or over separate channels to convey the identity of the called address (for example, the telephone number).

b. Alert (ring) the called station; they establish connections through a switching network for conversational used ring in entire call.

c. It processes the signal information to control and supervise the establishment and disconnection of the switching network connection.

3.4 Terminal Station

It communicates with other relays or terminal stations by transmitting and receiving radio waves in the Very High frequency, Ultra High frequency (e.g., microwaves) range.

3.5 Microwave link

It is a communications system that uses a beam of radio waves in the microwave frequency range to transmit signal between two locations, which can be from just a few meters to several miles or kilometers apart. We will use line-of-sight microwave propagation.

3.6 Relay Station

It receives a signal from any Terminal Station or other Relay Stations and again transmits the same signal to other Terminal or Relay Stations. In microwave radio relay, microwaves are transmitted between the two locations with directional antennas, forming a fixed radio connection between the two points. The requirement of a line of sight limits the distance between stations to 30 or 40 miles.

3.7 Technical Characteristics

There are several Radio Relay communication System are being used globally (SELEX, Ericsson, Aselsan). However we are providing following technical data of SELEX (Selex ES, 2013):

- Frequency band. 1350 to 2700MHz.
- TX/RX frequency separation. Minimum 40MHz.
- Type of modulation. CP-FSK.
- Frequency difference between Tx to Tx. 10 to 15 MHz.
- Frequency difference between Rx to Rx. 10 to 15 MHz.
- Input voltage. 220 VAC ± 10%.
- Power consumption. ± 130W.
- Battery Input voltage. 4 to 48 VDC

3.8 Operation

This operating procedure contains step by step analysis of setting up a connection between a telephone in a fixed network and a disaster affected area. We can assume 30 (thirty) numbers from any PSTN company (e.g., Bangladesh Telecommunication Company Limited in Bangladesh, Bharat Sanchar Nigam Limited in India) are dropped in the Exchange that is connected to one end of the Terminal Station. We can assign each number to a Hot Number (Selex ES, 2013).

3.8.1 PSTN Originated – Disaster Area Terminated Call Set-up

a. An End User of a PSTN operator dials to the disaster area. An example of dialed Number is +88-02-8888888 or +91-11-5555555 along with Extension Number. The dialed number is called the Number of Disaster Area which contains the following elements:

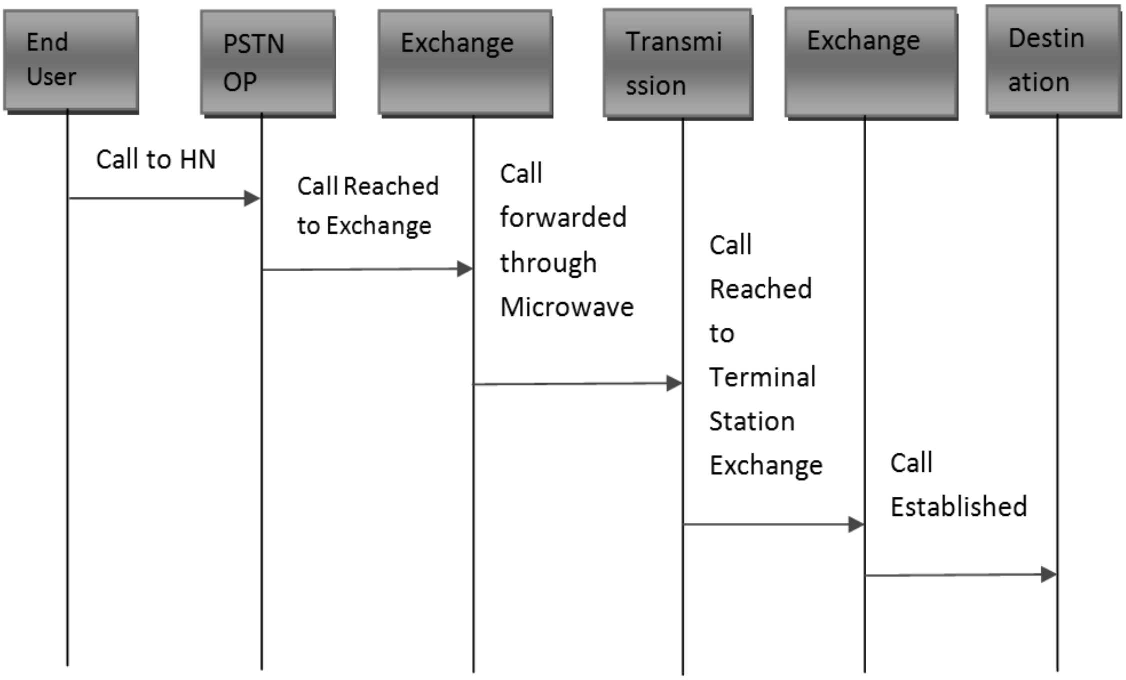
Number of Disaster Area = CC + NDC + HN + Ext

CC= Country Code (88 = Bangladesh, 91 = India, 358 = Finland).
NDC= National Destination Code (02 = Dhaka, 11= Delhi).
HN= Hot Number (8888888 or 5555555).
Ext= Extension Number (These numbers are allotted to some key point like Police Station, Hospital, Post Office, Cyclone Center in disaster area).

b. The call from End User of a PSTN operator is routed to the Exchange. The Exchange immediately forwards the call to the destination through microwave. The call may pass through several numbers of hops in air and terminates in the Terminal Station. The Call is then sent to the Exchange in the Disaster Area.

c. Finally the Exchange forwards the call to the desired destination. Figure 2 shows the routing of the call to the destination in the disaster prone area.

Figure 2: Call Setup of Disaster Area Terminated –PSTN Originated



3.8.2 Disaster Area Originated - PSTN Terminated Call Set-Up

a. An End User of a Disaster Area dials to the desired PSTN Operator. An example of dialed Number is 1000 along with +88-02-8888888 or +91-11-5555555. The dialed number contains the following elements:

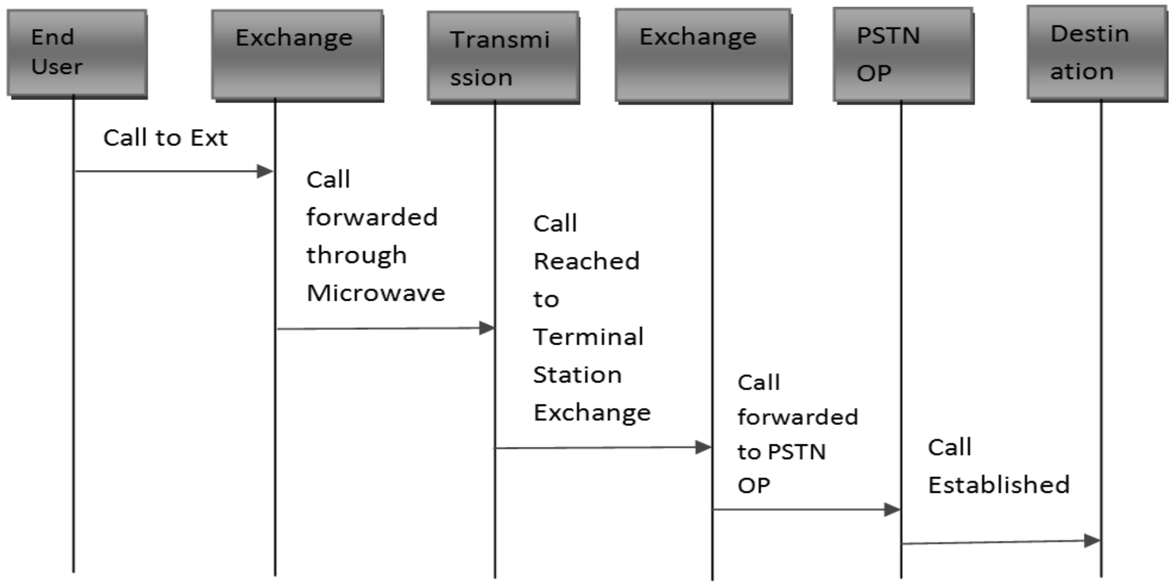
Dial Number = Ext + CC + NDC + PSTN

Ext= Extension Number (These numbers are allotted to Exchange).
CC= Country Code (88 = Bangladesh, 91 = India, 358 = Finland).
NDC= National Destination Code (02 = Dhaka, 11= Delhi).
PSTN Number= Any Number (8888888 or 5555555).

b. The calls from End User of a Disaster prone Area terminates at the Exchange. The Exchange immediately forwards the call to destination through microwave. Call may pass through several numbers of hops in air and terminates in the Terminal Station. The Call is then sent to the Exchange in the out-of-disaster area.

c. Finally, the Exchange forwards the call to the PSTN Operator for the desired destination. The routing of the call is done to the destination of any PSTN Number.

Figure 3: Call Setup of PSTN Terminated – Disaster Area Originated



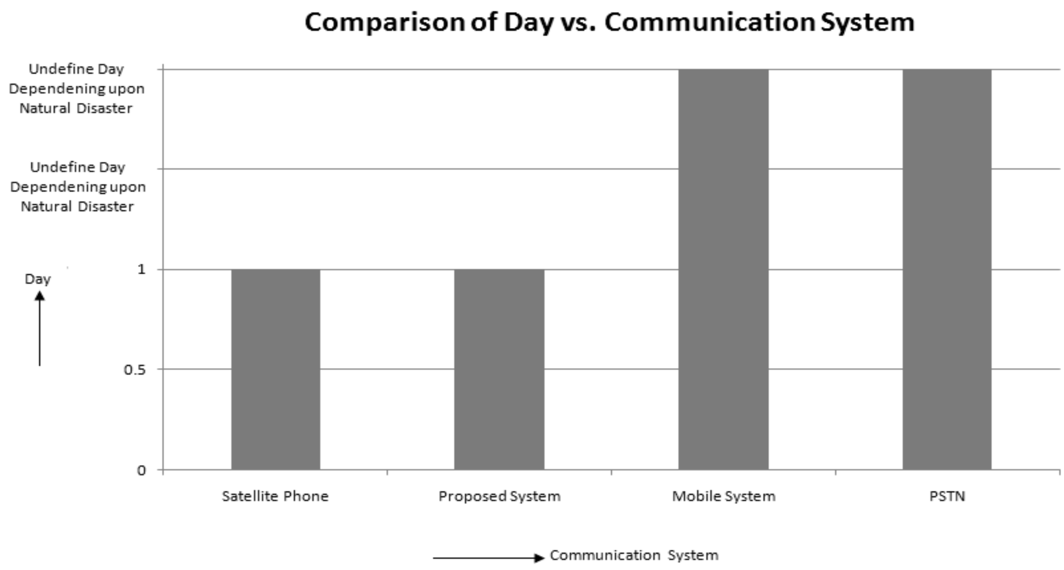
4. Analyze the Benefits of Proposed Architecture

The application of communication technology has a vital role in all phases of disaster management, mitigation and recovery of the damage. In this section, we discuss the cost analysis and reduction in time to recover the communication system in the aftermath of a disaster in the country.

From recent study, it is seen that the communication systems need rather long time to rebuild the existing communication systems. As a result, huge loss of lives and assets occur. After a natural disaster, there are usually many affected areas where there is need for food, drinking water, clothes, medicine, and emergency treatment to save lives. But because of the damaged communication system, it is not possible to communicate with the emergency responders. Figure 4 shows the comparison between our systems with the existing operators with respect to day to rebuild the systems.

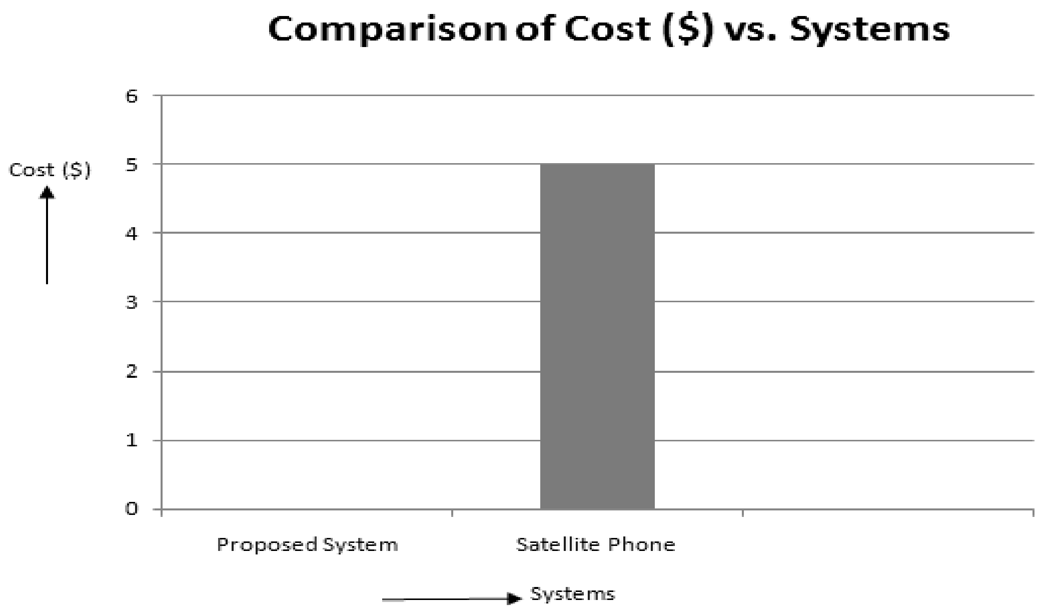
From recent studies, during any kind of natural disaster PSTN and others Mobile telecom systems are damaged and require longer time to rebuild the systems. At that time, the only way of communicating is the satellite phone, which can be used from the very first hour of the disaster. It also does not require any installation time. But it is too expensive to communicate to emergency responders using satellite phones. In our proposed radio relay network architecture, the important part is to reduce the time to establish the communication system between the disasters affected areas and the out-of-disaster area. In this system, the delay time is reduced to one day or just a few hours to install the system. For our analysis, we assumed the days to rebuild the system of PSTN networks and the mobile telecom networks are undefined for communication and it depends upon the natural disasters, whereas the satellite phone and our proposed system need only a few hours to one day.

Figure 4: Comparison between Our Systems with the Existing Operators With Time Delay



Cost analysis is an important matter for every communication system. Here we compare the cost of existing systems and our proposed system. Since in the period of natural disaster, all sorts of communication systems become damaged in the disaster prone areas. At that time, the only communication system is the satellite phone. Figure 5 shows the comparison between the cost of satellite phone and the proposed system.

Figure 5: Comparison between Our Systems with the Existing Operators With Cost



The satellite phone cannot be used by the mass people to communicate among one another, because it is too expensive. It can be seen that the cost of voice calls from a satellite phone varies from $0.15 to $5 per minute and for data transmissions the cost can be much higher. Making calls between different satellite phone networks is often similarly expensive, with calling rates of up to $15 per minute (Wikipedia). So, the Satellite phone is more expensive than other operators. In comparison to the satellite phone, our proposed system is cost free. Our proposed network architecture uses the required system resources and materials which are available to the army, navy and air force of the country. The government can use the resources to rebuild the emergency communication in the aftermath of a disaster. As a result, the installation cost of the system becomes zero as well as it minimizes the cost of installation and the communication to both emergency responders and civilians in the aftermath of a disaster. Thus, our proposed network architecture minimizes the cost of communications as a solution for disaster aftermath communication.

In our study, during a disaster it is important to supply the relief and medical treatment to the people of affected areas. The Ministry of Disaster Management and Relief authorities take the initiatives to overcome the damage and manage the relief for the affected areas. They collect donation and relief from different organization and foreign countries. The private organizations also work together with the government in the aftermath of a disaster. A proper distribution of relief goods is needed. The government manages the work with the help from the army, navy, air force, firemen, BGB, police and civil administration. The government should manage strictly the distribution process such that every affected people can get their help and relief goods. It is the duty of government to ensure that no one can be deprived of his/her rights. So, proper distribution is necessary to minimize the loss of lives and assets in the aftermath of a disaster.

5. Conclusion

There is no simple solution for solving emergency communication challenges after a natural disaster. In this paper, we have proposed a low cost solution that quickly reestablishes voice communication facilities among the authorized bodies in a disaster hit area. Our proposed network architecture is more efficient to implement and very quick to install, usually within one day, that will connect all the emergency responders (government, Red Crescent, NGO's, etc.) with the victims in the disaster hit areas. The solution would be able to mitigate the suffering and losses right after a disaster. The proposed solution would be very suitable to coastal areas of Bangladesh. This solution is more suitable to implement in developing countries like Bangladesh, which, through the use of this technology, will be able to achieve a uniform system that allows emergency responders to communicate. However, the main limitation of this system is that this system will not be usable by common people of the disaster hit area, because only authorized bodies such as the government, the first responders, and the NGS's can only use it.

6. Future Work

Our future work on the proposed solution will include enabling data communication along with voice communication. There has been some work done on data connectivity in the disaster hit area, but those solutions usually take a long time to implement. In our future work, we plan to provide data communication within one day in the aftermath of a natural disaster.

7. Acknowledgments

We are highly grateful to Almighty Allah who has helped us all the way through completion of this research work. We would like to express our heartfelt gratitude to their parents and their family for invaluable help and support all over this work. We would like to thank Dr. K. M. A. Salam and Dr. Hasan U. Zaman for providing us with an optimistic direction. Our research does not necessarily reflect views of other authors.

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