Enhanced Emergency Communication using Mobile Sensing and MANET

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ABSTRACT

Emergency response services are often delayed due to the destruction or non-availability of the communication network. This research work proposes Mobile Adhoc NETwork (MANET) architecture integrated with mobile sensing concepts, for reviving the communication network in disaster hit areas. Mobile sensing in emergency scenarios can very well address issues like victim localization etc. and offer help in providing specific information about the affected area to the responders and control stations. This paper proposes a design that utilizes the existing the mobile devices such as smartphones, laptops, etc. in the field to provide the required communication facility. A new buffer system powered flooding methodology is also proposed to cater to the challenging environment. The mobile adhoc network architecture proposed is implemented and tested using several android based mobile phones. An android application named Android app for Emergency Communication (AEC) was developed and it enabled users to send messages to emergency services as well as their dear ones even when they are in regions with no cellular coverage.

Categories and Subject Descriptors

C.2.1 [**Network Architecture and Design**]: Wireless Communication

General Terms

Design, Experimentation

Keywords

Mobile sensing, Emergency Communication, MANET, Android

1. INTRODUCTION

Every year world is hit by large scale disasters like earthquake, flood, landslide, tsunami etc. In addition to these natural calamities, there are man-made disasters like bomb-shelling, nuclear explosion, etc. Telecommunication failure is one of the major impacts of such disasters. The loss of communication systems makes the rescue operation tedious. This reduces the pace of rescue operations which may lead to death of people. The people in the disaster remains isolated from the outside world due to this very reason. Hence, the goal of the project is to develop a system that can provide an effective communication system even when cellular network is down. Research papers [1] and [2] discuss about the causes of failure of communication systems during disaster and they claims the unavailability of communication owe to either physical damage or network traffic overload.

Figure 1: Disaster

The existing systems for emergency communication need extra equipment such as satellite phones, relay points etc. It also requires the user should be aware of the operation of the new device. The users may not be even aware of the failure of existing communication system. The proposed system doesn't need any new devices or new technology. The users can use their own smartphone or similar mobile devices for communication. A Mobile Adhoc NETwork (MANET) based network architecture can offer the solution. A MANET is a type of ad hoc network that can change locations and configure itself on the fly. Since MANETS are mobile, they use the available infrastructure to to connect to various networks. This can be a standard Wi-Fi connection, or another medium, such as a cellular or satellite transmission. The efficiency and reliability of such a system can be enhanced by making use of mobile sensing concepts by adding features like victim localization.

The paper is structured as follows. Section 2 presents the existing systems that have addressed the issues regarding emergency communication. Section 3 introduces the mobile sensing paradigm and Section 4 discussed about the communication network characteristics in a post-disaster scenario. Section 5 explores the research challenges. Section 6 gives the architecture of the system. Sections 7 presents a novel flooding approach tweaked to cope requirements in emergency situations. Section 8 discusses about the Android app developed and other experimental details. Finally, conclusions are drawn in section 9.

2. RELATED WORKS

Communication in disconnected ad hoc networks using message relay [3] introduced a new methodology of passing message between groups of mobile hosts, by actively modifying the trajectories to transmit messages. It also discusses two classes of algorithms depending on two different assumptions: (a) the movements of all the nodes in the system are known and (b) the movements of the hosts in the system are not known. Another research by Jan Beutel et al [4] presents Bluetooth Smart Nodes which can store information, compute and communicate using standard wireless interfaces on a limited resource platform. These wireless enabled small devices are capable of interacting in a heterogeneous environment. But, unfortunately, these researches did not considered the limited power processing of mobile nodes. Researchers have explored the possibility of using Bluetooth in the development of a Mobile Ad-Hoc Network (MANET) suitable for transmitting data between Symbian OS based Smartphone's. It also present the design of a collaborative application engine by making allowances for the restrictions associated with Bluetooth [5]. It also addresses the issues that be encountered during try to make a bluetooth network of smartphones.

Auto-BAHN (Automated Broadcast Ad Hoc Network) [6] is an Android app developed by Thomas Wilhem for emergency communication. By creating broadcast, ad hoc networks using smartphones, it is possible to allow messages requesting help to pass between phones until they are intercepted by emergency services. And, this was for which Auto-BAHN was designed for.

Yao-Nan Lien et al [7] proposed a low cost easy to deploy walkie-talkie communication system based on a MANET P2Pnet of volunteer's laptops. They used Wi-Fi over multi hop for data transfer. The system is designed to support emergency communications in the early hours of a catastrophic natural disaster when external assistance is blocked by the paralyzed transportation system. .It is very useful in the situation when face-to-face communication or wireless links is blocked by the obstacles since our multi-hop system can bypass obstacles easily.

Mesh routers can provide access to external network in a network of mesh clients [8]. While the infrastructure provides connectivity to other networks such as the Internet, Wi-Fi, Wi-MAX, cellular, and sensor networks; the routing capabilities of clients provide improved connectivity and coverage inside the WMN. Multi hopping technology is used to achieve larger connectivity. And also they tried for battery powered routers. Yoshitaka Shibata et al [9] introduced a larger scale distributed disaster information network system based on Mobile Adhoc network (MANET). MANET is used for the access network for residents and volunteers around the disaster area and evacuation places. The evacuated residents and volunteers can flexibly communicate with others though MANET using IP based terminals, wireless IP telephones and Mobile PCs. Some of the wireless mesh network concepts were borrowed into our system.

Participatory Sensing is a technique that aims to turn personal mobile devices into advanced mobile sensing networks. The prime goal of participatory sensing has been to enhance and evolve existing methodologies by improving quantity, quality and credibility of community gathered data [11]. Incorporating this to the conventional emergency communication system can make them more robust and efficient.

All the afore-mentioned methodologies and applications for emergency communication were not developed targeting people who are in a traumatic state or who do not know much about the technology. Those applications also don't look into the location tracking of the user. The prime aim of our system is to develop a user-friendly emergency app for such users and to tackle the emergency scenario specific research challenges.

3. MOBILE SENSING IN EMERGENCY SCENARIOS

Mobile sensing is a new application paradigm that harnesses mobile devices as sensor nodes for data collection. It is like a synonym of Participatory Sensing. This transforms the people into a high sensing platform. Though a new methodology, it is already used in a variety of domains including environmental monitoring, surveillance and mobile social services. By transforming the public citizens to virtual sensors, high efficient and trustworthy systems could be developed.

Mobile devices like smartphones, laptops, palmtops, tablets, etc are occupied with some desirable features like heterogeneous network support, GPS (Global Positioning System), camera and sensors as shown in figure 2. In the perspective of emergency communication, these characteristics can be employed in tracking down a victim as well as in learning about the disaster-hit area. Connectivity and coverage issues can be solved to a large extent by making use of different wireless communication technologies like GSM, 3G, Bluetooth, WiFi and WiMaX in a collaborated and combined fashion.

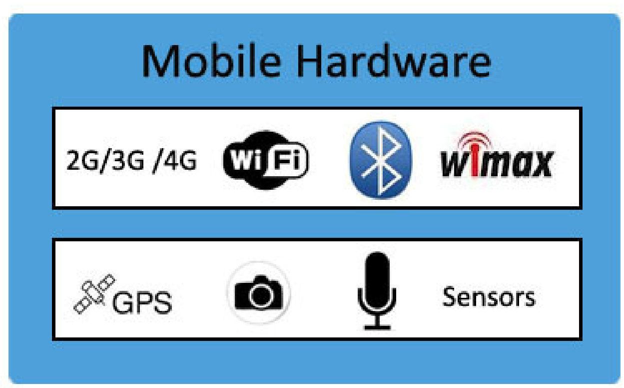

Figure 2: Hardware provisions in a Mobile Device

4. COMMUNICATION NETWORK IN POST-DISASTER SCENARIO

Disaster-hit victims, refugees of battle and other calamity-affected citizens need to find some means to contact medical, police or some other emergency services. They must be able to let their dear ones know that they are safe and communicate with friends and relatives to seek help. But such needs of victims are hindered by failure of telecommunication services in those areas. Broadband Mobile Communications Research Lab (BMCRL) has done research about the possible strategies for setting up emergency communication networks [10]. They also studied about the possible infrastructures possible for communication in both pre-disaster and post-disaster situations. It also dealt with an ad hoc based emergency communication scenario.

The communication network can be revived by creating a mobile ad hoc network of mobile devices and coupling it with the few base stations and associated infrastructure that remains after the disaster had happened. Quick deployment, auto-configuration, power control and scalability are some of the requirements needed for an efficient emergency communication network in a post-disaster situation.

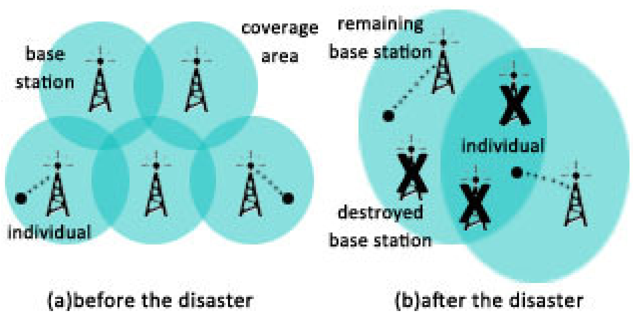

Figure 3: Illustration of telecommunication crash [10]

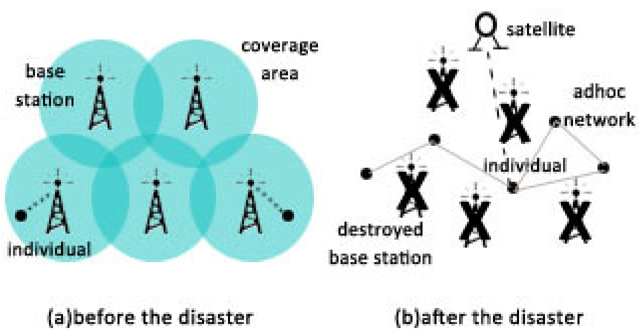

Figure 4: Emergency Network based on an adhoc network [10]

5. RESEARCH CHALLENGES

To design and develop a mobile sensing powered emergency communication system, multiple research challenges need to be addressed effectively. The most interesting challenges in such a system are listed below.

- Participation and performance - The efficiency of a mobile sensing system largely depends on the number of users that are willing to participate. The more the number of participants, higher will be the efficiency of the system. But in a disaster hit area, we cannot expect large number of participants as some will be injured.
- Location awareness - In an area where cellular network is unavailable, global positioning system is not possible as most smartphones rely on A-GPS (Assisted GPS) service for find their current location. In such a scenario, localization algorithms can be employed over the MANET. This would help to track the user easily.
- Information fusion - The whole system consists of different patches (groups) of participants. So employing information fusion, both data fusion and decision fusion, can reduce the data size and add the reliability of the system. Terrain information supplies an important context for ground operations. So such in formations should be given priority to make the sensed data worth.
- Connectivity and Coverage - A minimum coverage and connectivity should be present for the system to work. Buffer powered flooding of messages can guarantee the successful delivery of them.
- Limited Processing Power- The limited processing capabilities of a mobile phone need to be considered. Hence, the processing algorithms need to be adaptive and optimized accordingly.
- Privacy - Encryption of the sending data would be a good choice to conserve privacy. Another desirable facility would be user can select the degree of privacy he/she desire.

User-friendliness, data visualization and dependency on heterogeneous networks are some of other research challenges which are worth of mention. The following figure shows the logical view of the research challenges.

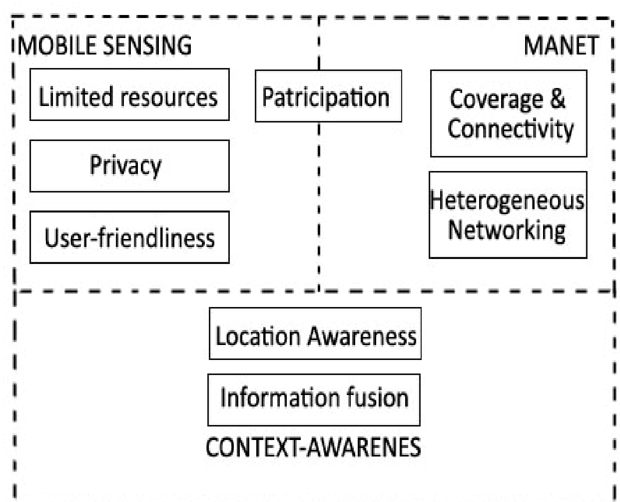

Figure 5: Logical View of Research Challenges

6. MANET BASED EMERGENCY COMMUNICATION SYSTEM

In times of emergencies, cellular and phone systems are often destroyed or severely damaged, which prevents civilians from communicating with fire, police, or medical services. By creating broadcast, ad hoc networks using smart phones, it is possible to allow messages requesting help to pass between phones until they are intercepted by a phone which has either cellular connection or Internet access available, so that it could forward the messages to emergency services. The basic architecture for the same is shown in the below figure, is capable of conveying emergency messages in the format of text, by creating a self-configurable (MANET).

All of the existing methodologies and applications for emergency communication were not developed targeting people who are in a traumatic state or who do not know much about the technology. But still, in such a post-disaster scenario, the victims will be willing to help each other as far as possible. Hence, our system tries to make use of this inbuilt motivation by creating a virtual mobile sensing environment, where the users themselves will form patches of working group.

The system consists of smartphones which forms patches of BT (BlueTooth) node networks. Patches more or less resemble piconets in a scatternet, but vary in the say sense that they needn't overlap each other. But since the nodes are mobile, they might overlap at some point of time, when the exchange of data can occur between the adjacent patches. These nodes will keep on forwarding the data until it is intercepted by a smartphone with cellular connection or internet connection so that the message could be finally send to the actual destination. This destination could be either some emergency service stations or some other mobiles which may be even being pretty far away from the source.

The entire system is viewed as patches. We refer the patch at the end, i.e. one in the cellular range, as 'Patch n' and all other patches as 'Patch i'. We also define a term called 'Patch 0' which includes the origin node, i.e. the sender is said to be in 'Patch 0'. The message flow between these patches is depicted in the figure 7.

The sender, belonging to patch 0, initiates the communication procedure by sending service discovery request to all the nodes in its communication range, to identify all the nodes with the application installed. All the nodes which recognize this request respond with a service discovery response. At this point, the connection is established between the sender and all the identified nodes. Using participatory sensing would means more chunks of data and this large data should not prevent the successful delivery of message. So as a precaution at first, the sender only sends the help message with the GPS data appended. The intermediate nodes receive this message and they pass it to all the nodes in their vicinity. This procedure continues, until some node belonging to patch n obtains this message and this node will forward this message to the control station. On receiving this, control station could either send emergency responders immediately or could even ask for more sensed data like temperature values, captured images, etc. to study about the disaster-hit area and to determine the effect of the disaster.

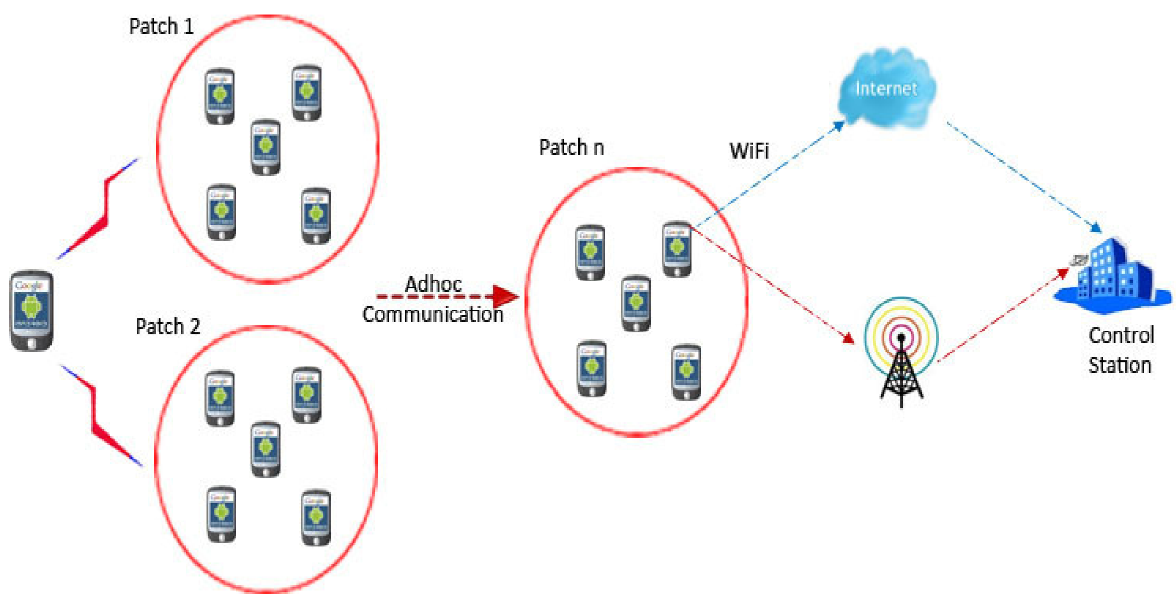

Figure 6: MANET-based Mobile Sensing Platform for Emergency Communication

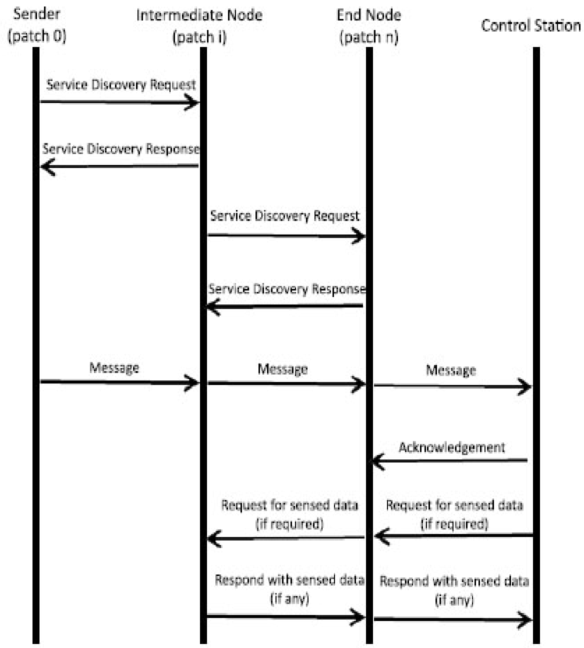

Figure 7: Message Flow

7. BUFFER POWERED PROBALISTIC FLOODING ALGORITHM

In an emergency situation, the top priority is the successful delivery of messages to the desired destination. But often due to the likely less number of participants and the highly mobile nature of the participating devices, the task of efficient routing is a big challenge.

Various routing algorithms have been developed to cater the specific needs of an ad-hoc environment. Routing algorithms are of two types - proactive ones like OLSR (Optimized Link State Routing Algorithm) and reactive ones like AODV (Ad-hoc On-Demand Distance Vector). Proactive routing algorithms are table-driven ones and hence they require more processing power and resources compared to the latter set of algorithms. Reactive routing algorithms do not depend on routing tables and hence are more apt for mobile environments. They also consider the dynamic nature of wireless link in a network of mobile devices.

Flooding algorithms are preferred over the usual complex routing algorithms as one has to maximize the probability of successful delivery of message(s). But in an emergency scenario, a mobile node cannot always find a neighbor in its communication area to forward the message. Hence, we introduce a buffer in each node so that the received message is temporarily stored in its buffer until the message is passed to a satisfactory number of nodes that comes in its vicinity.

Now the above procedure is tweaked by introducing probability to reduce the number of redundant messages and the algorithm is called BPF (Buffer powered Probabilistic Flooding) approach.

The probability ‘p’ should be a function of density and it should be wisely chosen. Here, its value is made dynamic by making use of a procedure computeP(), which will run on each nodes at regular intervals to cope with the needs of MANET. The probability ‘p’ is computed as

$$p = 1 \div N$$

, where N is the neighbor count.

The buffer powered flooding algorithm and the algorithms which assist it as well as the notation used in algorithm are given below.

Table 1: Notations Used

M	Message
n_i	Node with index i
Buff n_i	Buffer of node with index i
localBcast()	Local Broadcast procedure
BPF()	Buffer powered Probabilistic Flooding procedure
computeP()	Compute probability ‘p’ procedure
N_i	Neighbor count of node i

Algorithm 1: BPF(m,p)

1: on receiving message m at node n_i

2: if message m received for first time then

3: add m to buffer Buff n_i

4: Call localBcast(m)

5: else

6: Call localBcast(m) after a delay d with a probability p

Algorithm 2: localBcast(m)

1: on receiving message m at node n_i

2: Broadcast message m to n_j ¥ $j \neq i$

Algorithm 3: computeP(n)

1: Compute neighbor count N_i with the help of HELLO messages and responses

2: Calculate p = (1/N)

8. EXPERIMENTATIONS AND RESULTS

The experimentations and results are presented as two sub-sections

1. Simulation of buffer powered flooding algorithm
2. Development of Android App

8.1 Simulation of Buffer powered Flooding Algorithm

A comparison study of various routing protocols on MANET using QualNet was performed. It was carried on a region of dimension of 1km x 1 km with a total of 15 nodes, occupied with IEEE 802.11 b antennas, moving randomly according to RWP (Random Way Point) mobility model as the movement of victims of a disaster is not based on some tactical way or based on some pre-computed optimal path. The destination was assumed to be fixed. The minimum and maximum speeds of nodes were 0m/s and 10m/s respectively. The pause time was fixed. For the simulation, one protocol belonging to proactive class – OLSR and one protocol belonging to reactive class- AODV was chosen. These two algorithms is also compared with a simple flooding protocol .The simulation results implied that flooding approach is the apt for emergency scenario as we cannot afford to lose the valuable messages from victims. AODV wins over OLSR in MANET environment as AODV is an on-demand routing protocol and considers the dynamic nature of wireless links in mobile scenarios.

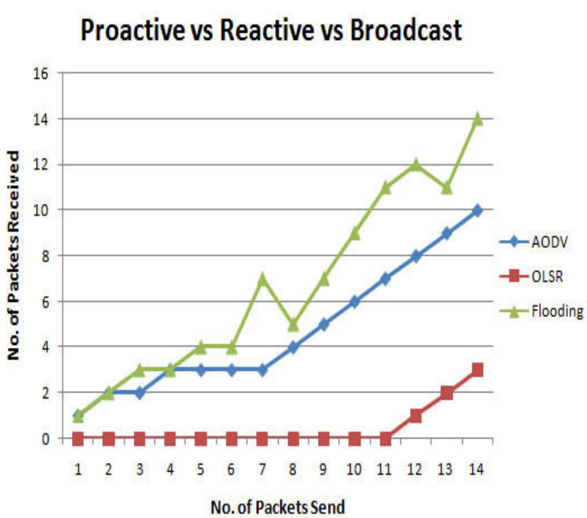

Figure 8: Simulation study of proactive, reactive routing and broadcast protocols

The below simulation carried, again on a region of dimension 1 km x 1km, validated our claim that buffered powered flooding was better in disaster-hit area with small number of participants. Beyond a particular number of nodes for a particular area, the flooding algorithms had a probability of 1 for delivering the messages to the desired destination in 60 seconds. MAC contention and some of the constraints specific to post-disaster scenarios were not considered during the development of MATALB program.

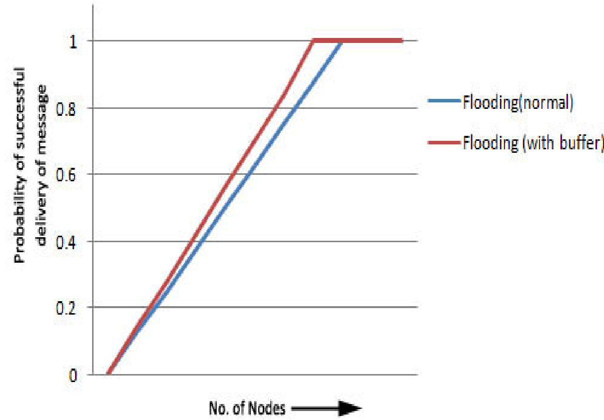

Figure 9: Probability rate of successful delivery in 60 seconds for different flooding approaches

Another MATLAB program was developed to study the afore-mentioned BPF algorithm against the normal flooding protocol. The simulation results indicated that one could reduce 36% redundancy by using BPF approach.

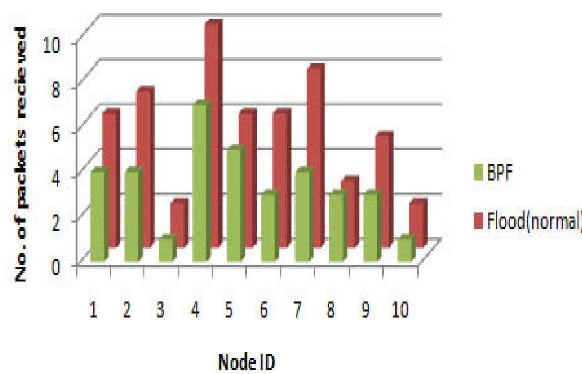

Figure 10: Redundancy rate of packets using normal flooding and BPF

8.2 Android App for Emergency Communication (AEC)

An android app named Android app for Emergency Communication (AEC app) capable of sending message using an ad hoc network of smartphones, using Bluetooth, was developed. Once disaster strikes, the users have to manually switch on the app. The app has an option to send message where the user could himself enter the message. In addition to the emergency numbers like 112 and 911, user could also wish to send the message to their dear ones. This input message will be appended with GPS data and other sensed values like temperature, light, etc. This makes the destination, often a control station, easy to track down the victim and understand the urgency of the situation.

The app developed was successfully tested in a testbed of five HTC Google Nexus Smartphones, which uses Android OS, v2.1 (Eclair). Of them, only one was provided with cellular connection. The A-GPS (Assisted Global Positioning System) was used to get the location of the node which has cellular connection. A localization with this node as reference point can yield a precise position of the actual victim.

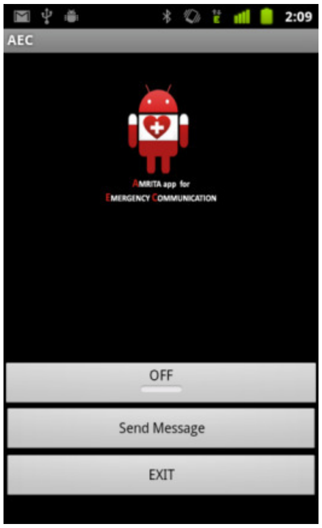

Figure 11: Android App for Emergency Communication

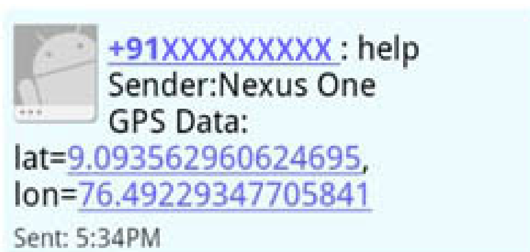

Figure 12: Message received at the destination

9. CONCLUSION AND FUTURE WORK

Due to various reasons like congestion in the network and damage of communication infrastructures, in a post-disaster scenario the telecommunication will be damaged, which implies that one cannot rely on the cellular communication anymore. Several systems and research papers have addressed the issues associated with this and offer solutions by creating temporary connection for emergency communication. Unfortunately, most of them required extra devices and technologies for empowering the existing communication. Also, in such systems, users should be well adverse with such new technologies and devices. This project aims to develop a Mobile Ad hoc Network (MANET) based emergency communication system that employed existing mobile devices by turning the victims of disaster into participants. The android app developed would help the users to send messages to emergency services as well as their dear ones.

In future we hope to incorporate voice-to-text conversion in smart phone for the generation of text messages, which can make the system more user-friendly. The use of laptops of victims can create virtual access points which can actually aid in creating ad-hoc networks including these laptops and the available smartphones, employing Wifi technology which can provide better connectivity. The system needs to be further optimized for attaining low power consumption feature.

10. ACKNOWLEDGMENTS

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