Ad Hoc Network as a Solution in Disaster Management

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Abstract

Whenever some natural disaster occurs, the immediate and most dreadful impact is a communication failure. It can easily be understood that communication systems can make a significant difference between survivals for life and death for those affected areas. Due to the potential for existing telecommunication infrastructure to be damaged, disasters are one of the most difficult implementations of multihop ad hoc networks. Following a natural disaster, the deployed cellular network system could be partially or entirely lost. Multihop ad hoc network is an intriguing option for dealing with a lack of communication in crisis situations. In many situations, ad hoc networks have been used for recovery or communication links. The main reason behind the concept is that they are infrastructure less and can adopt any topology. Though in the research arena disaster situations are one of the challenging areas. The situation can be disastrous in many ways, in this paper underwater situation like flood etc. have been considered as a case study. It has been observed that a significant gain in the signal strength ranges from 50–70% have been achieved which is quite respectable in disaster situations. The performance has been evaluated in terms of energy and signals gained. The research has been carried out and promising results were evident from the simulation. The new scheme performs better in certain cases and minor delay can be acceptable in the disastrous situations. We present criteria for ad hoc networks used in disaster for emergency response, with a focus on delay, packet delivery ratio, size, speed, and providing network status awareness through the network's nodes.

I, Introduction

Ad hoc networks have emerged as one of the reliable communication technology, which can deal with the situations during any disaster. Key aspect used is communication between people suffering and rescue team members to save lives. In this case, situations of conditions like flood or tsunami etc. have been considered. It has been observed that a mobile ad hoc network (MANET) can be used in these situations like climate, weather observation, earthquakes in the ocean (Tsunamis), underwater level navigation and tracking. These types of ad hoc networks which work under the waters also, termed as underwater mobile ad hoc networks (UWMANET) [1,2]. The working can be understood as; the mobile node collects data from sensors which are deployed underwater temporarily and then it acts as a communication medium between the sensor node and a base station which can be based on surface. Though the process is simple, still it has some issues like security, energy etc. Security can easily be avoided in those disastrous situations, energy aspects are taken into account while establishing such a network [3].

These days underwater networks are established and these are used for many applications. These can be environment monitoring, disaster applications, undersea explorations, assisted navigation, underwater sea space and ocean water level monitoring, etc. the underwater network is covered by several different components such as batteries, sensors, modems, and robots. The major points that come into sight at first instance in case of a disaster are (a) Communication which gets demolished immediately, (b) Data handling in a proper manner, (c) trying visual data capture as much as possible (d) multiple connectivity.

Underwater wireless sensor networks are made up of nodes that can be deployed both above and below the water. Both nodes in the same network, as well as the base station, must communicate and exchange information. Data is transmitted using acoustic, electromagnetic, or optical wave media in sensor network communication systems. Due to its attenuation properties in water, acoustic communication is the most common and commonly used form among these types of media.

In the case of UWMANET, the network established can be assumed as; Sensor nodes, Gateway nodes, Mobile nodes and Mobile base station node. Firstly, **topology** can be a major issue in an underwater sensor network. MANET is known for adaptability in any topology. Secondly, the **distribution of nodes** in an underwater while setting up MANET can be a point. These nodes will be used for underwater communications. Thirdly, in MANET **energy** is one of the major constraints. This becomes even more important underwater. The proposed plan must take care of the issue that it consumes a very limited amount of energy for reliable data transmission. Lastly, **robustness** as the network must be able to communicate for a longer time and that too in a stable manner. There should be least malicious nodes. [4, 5, 6]:

This paper has been designed to make use of an ad hoc network as a concept used in one of the solutions. It has been observed that it can be used as a technological tool to boost dying or depleting signals. This concept can be used in recovery operations during a disaster. In this work a new concept has been introduced, this will create a new ad hoc environment, deploy it in critical situations with components available. This will be able to get as many signals as available within the constraints. Rest of paper has been distributed as: section II indicates the problem to set up points. section III is the proposed plan, section IV discusses the results, section V draws the conclusion and section VI discusses the future works.

II. Problem Setup And Concept Setup-

In the case of natural disasters, the most common thing that occurs very quickly is network failure and loss of links. The reasons for the failure of communication in disaster situations can be some of the few outlined below as:

1. *Network infrastructure gets damaged with the devices for establishing a new network.*
2. *Cables and mast gets broken and can be destroyed ofently.*
3. *Natural phenomemon like rain, fog or heavy smog can innturrupt wireless network signals.*
4. *Burst of data can create congestion and can be difficult to handle.*

The concept was visualized as a research area and some suggestions were introduced for carrying out the problem. Initial setup was for underwater setup and later on, it was generalized for all situations. It is very clear that if setup can work underwater, then it will be able to work in all situations in a better manner. The setup created as shown in Fig. 1.

In underwater situations, sensor nodes [7, 8, 9, 10] are deployed, these sensor nodes have a lifetime suitable for communication and are also able to charge using solar light or other mediums. Sensor nodes are stable deployed randomly. Sensor nodes are used to trace any signals, these signals can send to next level using mobile nodes. The mobile nodes can act as routers as well. These nodes take the data to gateway nodes and these nodes take data to the base station. Transmission speed is approx. 50 kilobits per second (kbps), packet size mostly is 1024 bytes. This data is handled using satellite communication by telecommunication agencies. Comparison based performance (CBR) is adopted as it is used for any type of data for which end-systems require a predictable response time and amount of bandwidth.

Simulation has been done for assessing real-life situations. In case of disaster response, many models have been highlighted. Some most widely used are synthetic, map-based, and trace-based mobility models [11].

The most used can be identified as synthetic mobility model. Their creation is mostly done using Generator, something like BonnMotion [12]. In this type of model, the case area, i.e. disaster area can be categorized into three parts. One will be designated as an incident site, the other two are casualty and transport. Communication methods built on physical communication infrastructure used to have several limitations. Wireless communication networks have limited range and signal strengths and energy also plays a crucial role in the overall working of the network as well as infrastructure. [13]

Another model used is Map-based. As the name suggests it is based on some sort of Global Positioning System (GPS) system or real maps. The map-based scheme uses the real-time centers such as fire station, neighborhood, houses and medical camps for using as infrastructure which is established after the disaster [14]. As is obvious in the application of map-based systems, this is more accurate also, there is another scheme called Trace-based. It is slightly different in the manner that it takes care of the real movements of people. In this case, movements can be obtained using sensors or sort of smartphones.

There are also a variety of problems associated with the network's scale. A network solution must be versatile in terms of the number of nodes required to cover an operating area in order to be realistic. Ad hoc networks, on the other hand, would be able to reach only portions of the operating region at any given time in an operation where restricted manpower resources are looking for a missing person over a wide geographical area. In this scenario, each search party will have its own ad hoc network, which means these ad hoc networks may need to be replaced with gateways to cellular and/or special emergency networks. Ad hoc networks must interact with larger networks in order for this to be possible. In this situation, it's important that applications that use information from ad hoc networks can still use that information from other networks.

Wireless ad hoc networks do not have the same big disadvantages as the three dominant alternatives. The key drawbacks to using cellular networks are their limited availability and the difficulty of linking sensors. Sensors must be able to connect to a cellular network in order to operate in this setting. This feature is found in some GPS trackers and other remote monitoring devices, but not commonly in small and simple sensors.

lil. Proposed Solution

Nodes interact with each other without the need for a central system or some form of infrastructure, according to the traditional view of ad hoc networks. As a result, nodes serve as both routers and hosts, generating content and efficiently disseminating it across the network. In traditional MANETs (Mobile Ad hoc Networks), where routing protocols must deal with node mobility and continuous topological changes in order to create and maintain a communication route between a pair of source-destination nodes, mobility is actually an issue. MANET's initial concept was to replicate wired Internet connectivity, such as TCP/IP, in mobile environments. In mobile contexts, however, replicating TCP/IP communications over a multihop route is a difficult job. Since its inception, the MANET paradigm has developed, resulting in new ad hoc paradigms based on the fundamental concept of communicating electronic devices through a multihop communication route in a decentralized manner.

The ad hoc solution still has been considered as a major solution in rescue operations. It seems that in future whenever some undue disaster happens, the deployment of ad hoc networks [15, 16] can be a solution. Various essentials things are categorized as:

A. Antenna

These are deployed to boost dying signals or fading signals. This was essential to provide some sort of communication (if possible). Though many options exist, for the said propose TL-ANT Model was used as shown in Fig. 2. These Antennas are good and suffice the purpose as they can handle the severe conditions like fast winds blowing off the order of around 100 km/hr., dramatic temperature swings. These also have a life of at least 10–20 days without getting destroyed.

B. Carrier

These are needed to carry these antennas to the desired place. The distances can vary. Sometimes 10–20 km distance and sometimes 3 to 10 meters above the earth. It is important that these remain active and for the purpose either solar panel or other media to remain active can be used. The process is difficult and may need Government help. As it requires either air transfer or road transport. As usual, the better way out is to transfer via air media. Cranes can be used as shown in Fig. 3.

C. Location finding

The Antennas can communicate about 10–20 km without fail and will be able to gather data and transmit that data. To trace the locations GPS can be used. One of the popular media was Garmin drive 61 lifetime maps + traffic (LMT) and was able to deliver good links. Connections are made using telecommunication agencies working in the area which is vital for internet access and phone services.

D. Recovery Process

The track's location of each antenna is carried out using GPS to bring each safely to the ground from disastrous locations. In addition to this more Wireless Access points can be used for the higher gain in signal quality. This may increase budget issues. In place of these Range extenders can be used. This can be the best solution and also more economical.

Iv. Results

A case study has been taken as an example, the area used is 1 kilometer (km) and approx. 72 houses have been used. The simulations have been used to create scenarios. Network Simulator (NS-2) has been used. Houses have been used as Nodes, 100 nodes have been taken as a replacement for 72 houses. Out of 100 nodes, 72 nodes have been connected for communication. The area used is 1.5 km × 1.5 km. Traffic used as CBR, two packet sizes were used as 512 and 1024 bytes.

For the simulation of the underwater sensor network, a scenario was created with 100 underwater sensor nodes, 8 mobile nodes and 1 mobile base node. The simulation area is 1.5 km × 1.5 km, and the transmission range for each node is 400m. For node mobility, random waypoint model has been used and the node speed is 10 meters (m).

To show the loss or gain of energy the unit “decibel” is used.

$$dB = 10 \log_{10} P_2 / P_1 \text{ where } P_1 - \text{input signal and } P_2 - \text{output signal}$$

When the experiment was carried out in the given area as shown in Table I, There has been a significant gain in signal strengths.

Table 1 Depicting gain in signal

<i>Antenna</i>	<i>Signal Strength</i>	<i>Signal Power</i>	<i>Gain</i>
4–6 feet down	100 meters	2–6 dBi	14 dBi
9–13 feet down	70 meters	3–7 dBi	22 dBi

In the simulation the situation was changed to normal, i.e. no initial energy was given and no sensors were used, it was just like a natural disaster situation. Not underwater, it was a general situation. It was seen that signal gain was remarkable and if possible the system will be able to transmit dying or depleting signals even after 3–4 hours of signal loss. In this case, initial signal strength was allocated to check the gain in signal strength as shown in Table II as signal strength gain.

Table 2 Depicting gain in signal

<i>Frequency</i>	<i>Antenna</i>	<i>Signal</i>	<i>Initial Signal</i>	<i>Gain</i>
4–5 GHz	6–9 feet	400 meters	3–7	37 dBi
4–5 GHz	15–18 feet	60 meters	5–6	34 dBi

The energy required by the nodes to operate is high [19] regardless of any protocol used. It has been observed that the energy required is more when there is a requirement of signals and the signal strength weakens with loss of energy. It has been analysed that antenna gain is expressed in decibels. In this case 'i' means isotropic. This factor means that the change in power is referenced with respect to an isotropic radiator. dBi is the gain of an antenna system relative to an isotropic radiator at radio frequencies. Gain shown in two tables is in dBi. This gain reflects antennas ability to direct signals in a particular direction. The gain is substantial. More work is going on to find packet delivery and delay. In the present work, in the worst situations, the gain was approx. 50 percent, while in some cases when one or more powerful antennas were added, it reached a maximum of 70 percent.

Experiment was carried out further with many combination of nodes. Various combinations were made as 06 using 20 nodes scenario, 12 (for 40 nodes), 18 (for 60 nodes), 24 (for 80 nodes), 30 (for 100 nodes), 36 (for 120 nodes), 42 (for 140 nodes), 45 (for 150 nodes). Initial energy was assigned as 50 joules. Transmission power used is 0.7 watt and speed was kept at 1 m/s to 3 m/s. simulations were carried out using NS2. Graph shows the results. It is clear that when more and more combinations were used in disaster scenarios better energy management occurred and more delivery was expected. The energy consumption was similar to the normal AODV protocol but it keeps on decreasing with the modified UWNET protocol which was named as new. As the number of nodes keep on increasing the energy consumption started to goes down which is positive indications.

Packet delivery graph shows evident results. Initial there was not much gain but as number of connections increased there were more signals and more connections were established. The signal shows more connectivity in case of the new protocol although there is slight improvement in the results but considering the disaster situation this connectivity is highly appreciated with the percentage of packet delivery remains stable and more packets will be transmitted.

The above graph is packet delivery ratio in comparison with pause time. The pause time refers to the mobile nodes which were stable till the certain time and after the pause time they will start the movement. The results were taken with the constant speed of 6.0 ms and the number of nodes were 50. It shows significant improvemt in the results with the packet delivery ratio. The packet delivery improved with each phase of the pause time. The improved ratio of PDR keeps on performing better as the pause time increased.

It has been seen that the delay has been increased a bit but it shows the same pattern followed by the original AODV protocol. The delay is slightly higher in the new protocol but it is acceptable in the disaster situation. As it was expected that there might be delay more in case of the speed of movement is

increased consistently but the important fact is that the performance is similar to the AODV protocol as well.

As stated earlier that the Pause time is the time when the nodes start to move so here in the above figure it is showing the results of delay vs Pause time. The linear lines displays that the linear curve for the new protocol is keep on improving as compared to the AODV which started to go down as the with the increasing pause time.

V. Conclusion

An analysis has been done starting with the underwater problem of data depletion to general disastrous situations. A general solution has been proposed. This will take care of situations that come under the category of disaster and sudden loss of signal or communication. It has been observed in the study that proper antenna insertions are a vital matter. At times it actually can change the scenario a lot. It was observed that a gain in signal strength of more than 70% can be achieved. This process can be adopted at a mass scale in case of disasters and lives can be saved. The result shows that the improvement is there for the simulation carried out with the scenario set for the test. The underwater communication can also be tried as well. The results were carried for the stability of the network and the energy used by the nodes. The energy used is not much even in the disastrous situation although the security aspects were not tested, although that may not be very important in the disaster situation. The most important is the connectivity to be established and it will perform well in the disaster. The Packet Delivery Ratio is more with respect each pause time which shows that the connectivity was good even when the nodes start to move.

Vi. Future Work

More research is clearly required; in particular, more work is required to achieve the desired interoperability among the various ad hoc paradigms, which is a prerequisite for obtaining an essential and comprehensive ad hoc framework for disaster response. In this regard, the use of smartphones appears to be critical in achieving this goal, as it is a portable device that is used on a daily basis by civilians.

In maximum situations, evaluations presented in literature have been confined to only one disaster scene. While there can be various situations like an earthquake, a volcano, a tsunami, and a hurricane. So more realistic scenarios should be there for evaluations.

Simulations and system's performance have not evaluated in the re-life scenarios. Evaluation can be done with particle requirements on these systems where a disaster situation occurs and can be accessed with better clarity and advantage.

Deploying the automated WSN is the area to be researched more as manual placement of the nodes in a disaster situation can be difficult. This applies to both before or after the disaster.

This research work undergo with the static nodes, it is unclear the actual performance of the proposed work with mobile nodes. The study needs to be further done with the mobile nodes.

Existing works are there providing feasibility and other different ad hoc networks in a unique system though further research is required to find the optimal solution.

The simulation environment can be expanded more to get more realistic results. The security aspects can be looked for the future work where we can try to implement the ad hoc network with security protocols as well. The security and stability will be more effective but need to check the energy consumption on after the implementation of the security protocols. The energy plays a vital role in the mobile nodes as they work on the batteries. In future we will try to address the all there factors energy, stability and security.

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Author contributions

Vishal Dattana Literature review, writing of the manuscript and conceived of the presented idea **Ashwani Khush** review of the final manuscript, supervision, **Raza Hasan** review and submission and developed the theory and performed the computations **Salman Mahmood** review and verified the analytical methods **Vikas Rao Naidu** review.

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Figures

Figure 1

Basic Architecture

Figure 2

Rosewell rxn 180ube3 [7] TL-ANT2414A 2.4GHz 14dBi [7]

Figure 3

Transportation Crane [17]

Figure 4

GPS System [18]

Figure 5

Energy consumption (joules) vs Number of Nodes

Figure 6

Packet delivery ratio (%) vs Number of Nodes

Figure 7

Pause time Vs Packet Delivery Ratio

Figure 8

Delay vs Speed

Figure 9

Delay vs Pause Time