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Design and Feasibility Analysis of a LoRa Based Communication System for Disaster Management

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***Abstract*— In the context of earthquake and flood disasters, effective communication remains a pivotal concern due to the vulnerability of conventional networks. In this paper a system has been designed and investigated to deploy LoRa based mesh networks in disaster-stricken areas using amphibious rovers. The system was tested in urban environments as well as in simulations using the Meshtasticator simulator and Okumura-Hata path loss model. Critical parameters such as communication range, SNR (Signal to noise ratio), RSSI (Received Signal Strength Indicator) rate, data transmission speed, bandwidth, frequency, and delay have been evaluated. The measured outcomes of this study were compared with other existing technologies proposed for disaster communication and management, indicate that fast deployment of Meshtastic LoRa is more reliable for operating at lower frequencies and hence for long-distance communication compared to other existing disaster communication technologies. The results of this study indicate the proposed system can operate at about 2-6 times the range with acceptable performance parameters and superior uptime. These findings not only enrich the discourse on disaster management strategies but also offer insights into crafting adaptive, feasible and resilient communication systems.**

***Index Terms*— LoRa, disaster, mesh, rover, amphibious, SNR, RSSI, Wi-Fi, Bandwidth**

I. Introduction

The concept of natural disaster is used to describe the occurrence of widespread destruction caused by a natural calamity, such as a flood, mudslide, or earthquake, when standard precautions against such events were ineffective or impossible to implement. It is crucial to take action to recover from the devastation inflicted by the unforeseen event. Emergency squads across the world had to carry out difficult rescue operations as a result of the sudden occurrence and characteristics of several major-to-giant earthquakes from 2010 to 2023 in places like N Sumatra, Indonesia (Mw8.6), Central Chile (Mw8.3), the Kuril Islands of Russia (Mw8.3), Honshu, Japan (9.1), and the Syrian border of Turkey (7.8) [1]. In the same time span, occurrences of floods have been observed in different regions including Alberta (2013), Italy (2013), United Kingdom (2014), Morocco (2014), and more [2][3][4][5]. Bangladesh and Pakistan were notably impacted by floods in 2022 among the Southeast Asian nations. Beginning in early June of that year, the nations were hit by torrential rain and nonstop downpours, which caused one of the greatest floods in recorded history. In Pakistan, more than 1700 deaths were recorded due to the floods [6]. In Bangladesh, despite having 12,000 shelters all over the country capable of accommodating 5 million people, only 472,856 people have been taken to around 1,605 shelter centers during the recent Sylhet region flood [7]. With thousands in various unions struggling to access essential humanitarian aid and shelter due to severe communication and power disruptions. Numerous people have perished or been seriously injured as a result of these incidents all around the world. As a result, rescue missions to save people in a disaster have become concerning over the years.

Md. R. Hoque et al. examined the implementation and current status of e-health systems in these two countries. It identifies the major challenges, including infrastructure deficiencies, lack of trained personnel, and policy issues. The study highlights the potential of e-health to improve healthcare delivery through information and communication technology (ICT), while also discussing the progress made by both public and private sectors. The findings suggest that while e-health systems face significant obstacles, targeted improvements could enhance their effectiveness and accessibility. Both the improvement of healthcare and the challenges address the issues faced in disaster scenarios [8].

During the past decade, numerous proposals have been made for improving communication during and after a disaster, including a Drone Assisted Emergency Ad-hoc Network [9], a smartphone-based self-rescue system called RescueMe [10], a system referred to as TeamPhone that aids smartphones in communicating in the event of a disaster recovery [11], and a hybrid cellular-MANET architecture that uses functioning cellular base stations if they have not been collapsed [12].

This study offers a method for disaster management to facilitate rescue efforts through the use of Mesh networks, which can establish a connection even when the main

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infrastructure is down. The goal of a mesh network is to provide complete wireless coverage (radio) throughout an entire region. LoRa, a low-power, long-range modulation method, has been used in the development of the network in this study. A LoRa mesh network is a group of interconnected mesh nodes that function as a single, powerful radio network. In addition, a wireless communication device employing LoRa modulation will enable end-to-end communication. In the event of a crisis, many individuals may not have access to a mobile phone, and there might be places where it is challenging to reach out for assistance. A rover will transport the communication gadget, which the trapped people may then use as a GPS by retrieving it. This tool will make it possible to conduct a rescue operation for those who are stranded. Furthermore, having a smartphone on hand will facilitate communication between the rescue center and the victim. The rover used in this system can move both on land and in water with obstacle and human detection capabilities. Because of the technological progress made and the practical implementation of the project, lives can be saved by locating survivors and facilitating effective communication with other devices and rescue teams in the event of a disaster.

The following sections of the study will offer the system architecture and describe the experiments conducted at American International University-Bangladesh that validate its robustness and precision.

II. LITERATURE REVIEW

For a long time, researchers have worked to develop communication technologies that would aid in search and rescue operations for disaster recovery. Z. Lu et al. [11] in their study proposed a platform for communications during disaster recovery and named it TeamPhone. Within this system, smartphones are paired and cooperate to offer data communications. In cases where there is limited or no infrastructure, TeamPhone allows data communications among rescue personnel by utilizing the WiFi and cellular modules of smartphones to integrate cellular networking, ad hoc networking, and opportunistic networking.

IoT based tracking solutions like in [12] are being researched to use tracking features in a variety of networks and situations. The system uses NodeMCU, GPS, and GSM modules to track and send real-time location data to a Firebase server. It employs Bluetooth for short-range connectivity and GSM for long-range communication. The Android app integrates Google Maps API to display real-time locations and includes features like geofencing, manual and automatic tracking modes, and offline tracking capabilities. The primary goal is to enhance safety and security through affordable and efficient monitoring solutions.

The paper in [13] presents the design and development of a smart biofloc system for fish farming, leveraging IoT, image processing, and renewable energy. The system uses various sensors to monitor water quality parameters such as pH, TDS, and temperature, and communicates data via the BLYNK IoT platform to smartphones for remote monitoring. An innovative underwater fish weight measurement method using image processing in MATLAB is introduced, enhancing accuracy and minimizing fish stress. The methods used for image processing and object & people recognition can be used in disaster scenarios to more accurately identify objects in suboptimal scenarios. The research by Ganesh et al. [9] uses a drone that utilizes the Ubiquity Network to further simplify the rescue procedure. The architecture proposed in this study allows drones to build a mesh network, which victims can use to inform first responders of their position and current state. The UbiQNet architecture in this paper is made possible by a DJI drone and an ESP-based system on chip. In [10], Cong Pu and Xitong Zhou introduced RescueMe, a smartphone-based self-rescue system aimed at improving disaster relief operations. The core idea behind RescueMe is that smartphones carried by survivors trapped in disaster-stricken areas form a one-hop network to efficiently send distress signals to nearby rescue teams. When seismic activity is detected, these smartphones automatically switch to self-rescue mode and enable communication among all nodes, enhancing the effectiveness of rescue efforts.

Many studies are evident to show the applicability of MANET-based architecture as a remedy for network disruptions in disaster-affected areas. Verma and Chauhan [15] modeled a hybrid cellular-MANET architecture that, ignoring a network outage, makes use of existing cellular base stations. The article also provides a routing method for this emergency situation that makes good use of devices' communication and power reserves. Furthermore, to aid the volunteers during catastrophes, Lien et al. [16] suggested a MANET-based emergency communication and information system called P2Pnet. In the hours and days following a natural disaster, a communication system like Walkie-Talkies can be invaluable; this paper presents the design of a subsystem of P2Pnet, such a system. The purpose of the system is to facilitate communication needs immediately following a natural disaster. The framework in [17], harnessed the power of MANET (Mobile Ad-Hoc Network) technology to establish a robust backup framework for facilitating communication between individuals in situations where traditional infrastructure proved either unavailable or unreliable. This innovative MANET-based solution created a decentralized network without a central core or conventional infrastructure, enabling everyday smartphones to establish dynamic connections. Consequently, the SPAN project leveraged the widespread prevalence of smartphones to deliver resilient communication capabilities precisely when they were needed most.

A work in [18] was conducted by Khazmir Camille Valerie G. Macaraeg et al. from the Advanced Science and Technology Institute, Department of Science and Technology, Quezon City, Philippines, implemented a device that used a modified Ad-hoc On-demand Distance Vector (AODV) routing protocol to enable mesh networking with LoRa. The particular protocol used the Received Signal Strength Indicator (RSSI) as the routing metric. They evaluated the performance of the system using Packet Delivery Ratio (PDR) and successfully created a device that could form a LoRa mesh network and send messages through it. In [19], Noraini Azmi et al. from Universiti Sultan Zainal Abidin (UniSZA), Terengganu, Malaysia, created a board that combined wireless

Wi-Fi technology using ESP-32 and LoRa modules on a single PCB that would be used for various purposes. Apart from LoRa, the integrated ESP chip enabled data to be forwarded to the cloud or a server from where it could be further processed, as the SoC themselves are not suitable for power-hungry applications. This was ultimately used to monitor indoor air quality; however, it can be used for other purposes as well.

Apart from communication, one of the main concerns when it comes to automated disaster recovery strategies is sealing the robot's body because, in some cases, it would be operating on water. In this context, the application of silicone is particularly noteworthy. The article by Hannu Teisala et al. [20] examined the characteristics of silicon glue. On most surfaces, silicone will stick. The exceptional thermal stability, electrical and thermal insulation, and water repellency of these materials were emphasized as their distinctive qualities. It has been demonstrated that applying heat to oxide surfaces causes them to form firmly bound polymer brushes. This contributes to silicone's exceptional liquid-repellency and its low contact angle hysteresis of less than or equal to 10° for a range of polar and nonpolar liquids. By contrast, the water contact angle hysteresis of other hydrophobic coatings, such as Teflon and fluorosilanes, is usually between 20 and 30°. Top coatings for medical devices, electronics, solar cells, optical lenses, window panes, release layers for sticky labels, containers, and food packages are some examples of the many uses for silicones in the construction, automotive, and paper industries. Silicone glue was found to be used in the development of the miniature floating robotic platform named Lily in the work by Haghighat et al. [21]. The outside of the robot is a sturdy, water-resistant 3D-printed shell. Properly encapsulating the electronics while retaining the ability to disassemble, repair, and reassemble the device rapidly was a critical component of the design. The top and shell of the platform were sealed using silicone paste, taking into consideration the material's exceptional water repellent properties.

The studies mentioned above demonstrate various efforts to improve communication during a disaster. Based on the severe consequences of such situations, in this paper, we attempted to incorporate LoRa for communication during disasters which has not been studied before. Since LoRa is a low power-consuming modulation technique, we believe it will be suitable for efficient disaster management concerning communication.

III. SYSTEM ARCHITECTURE

The system follows a multi-layered structure that can be implemented with existing search and rescue teams with potentially minimal training required. The system implements a basic amphibious search rover, which can be replaced by drones, other rovers, and complete rescue teams with customized equipment depending on the situation. The search device (i.e., the amphibious rover) can then deploy or 'hand over' off-grid communication devices using LoRa as the physical layer from the OSI model, with Meshtastic as the firmware [22].

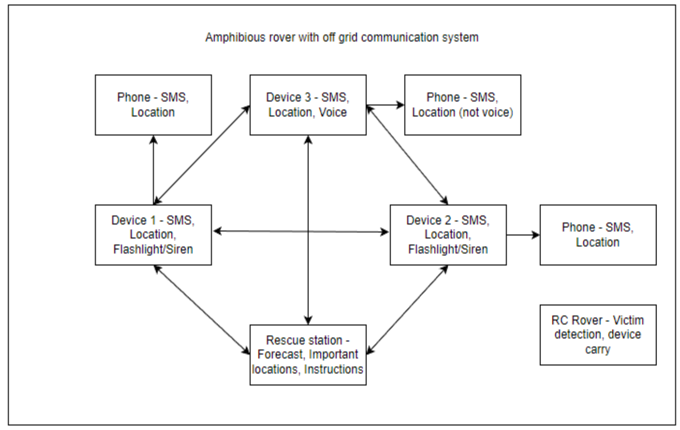

Fig. 1. Block Diagram for the rescue system implementation.

The model for establishing communication is illustrated in figure 1. In the event that there are several devices, the model is meant to work such that they are connected to one another. The devices would then facilitate peer-to-peer SMS and location sharing between the rescue station and the victims. In scenarios involving multiple trapped survivors, they have the capability to establish connections with each other, thereby streamlining the rescue process. Using this system, the rescue victims can then establish long-range communication with rescue parties and each other in order to receive instructions regarding safety while transmitting their location at same time.

A. *Rover*

The primary purpose of the rover is to find victims and deliver individual communication devices to them, such that they can receive detailed instructions on emergency survival procedures until rescuers can find them. To achieve this, the rover uses a camera with object detection capabilities so that a victims can be detected & obstacles can be avoided. Alternatives to rovers can be quadcopters in operations where long operating times are not mandatory, due to the trade-off between battery life and speed for quadcopters [23].

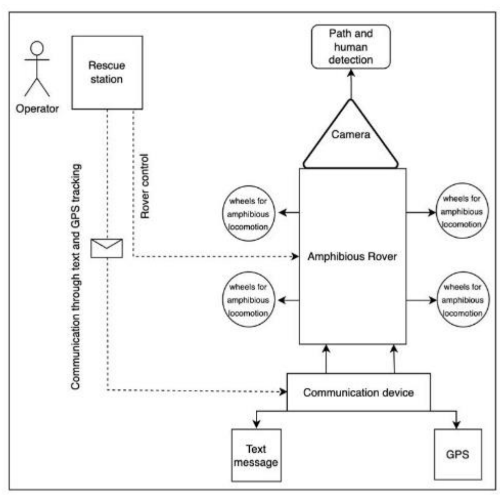

Fig. 2. Amphibious Rover operation flowchart

The design allows for the rover to locomote on both land and water while carrying communication devices for deployment. In Figure 2, the presented flowchart illustrates the operational procedures of the amphibious rover. The rover is equipped with a communication device designed to enhance the versatility of the LoRa communication range. The survivor's devices get into the range of LoRa modules, and they gain access to communicate with the rescue team. The rover is also outfitted with a camera, contributing to effective control and obstacle avoidance measures. Each rover can safely carry two to four communication modules to be picked up by individuals in strategic locations.

B. Communication Devices

After the communication device has been handed to a victim, it will continually transmit the victim's location to the rescuers and other peers, even if the victim starts relocating to a different place away from the rescue rover. Furthermore, it will be able to send and receive text messages with the help of a smartphone or PC.

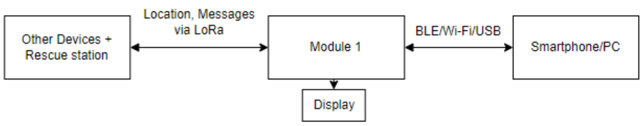

Fig. 3. Communication Device Block Diagram

The flowchart describes the individual processes involved in the use of the communication device. The device can connect to a smartphone or personal computer via Bluetooth Low Energy, Serial (USB), or Wi-Fi and communicate with other devices via LoRa. A display can also be fitted to view additional data and be of use without connecting to a smart device.

A combination of active deployment of this system to complement dedicated rescue teams can ensure faster recovery of victims affected by floods, earthquakes, and other disaster scenarios.

IV. ROVER MODELING

Figures 4.1 and 4.2 are the 3D models created in Blender that show the concept behind the amphibious rover. The wheels have rudders attached that extrude outward. The sealed chamber at the bottom houses the motors, and the internal circuitry along with power source are placed in the upper chamber.

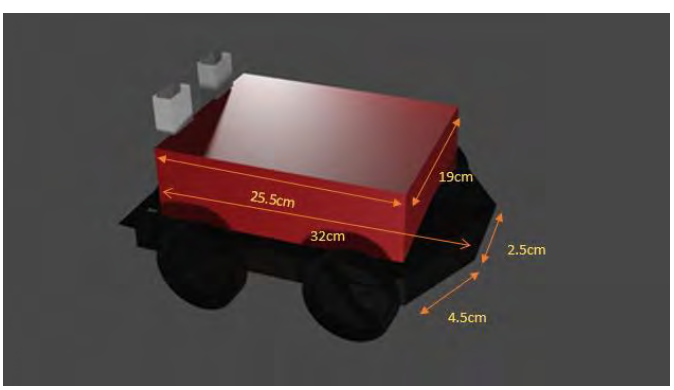

Fig. 4.1. 3D design of the amphibious rover

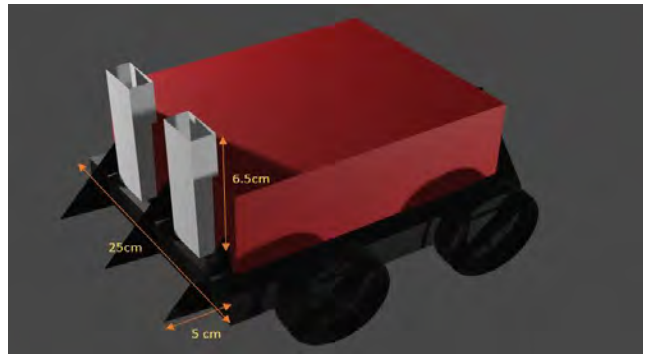

Fig. 4.2. 3D design of the amphibious rover

Two holders for carrying the LoRa-based communication devices are shown. The total volume of the rover is as shown:

Top chamber volume:

$$V_1 = lbh_1 \quad (1)$$

$$V_2 = \frac{1}{2}(a+b)h_2 \quad (2)$$

$$V = V_1 + V_2 \quad (3)$$

Where l = 25.5cm, b = 19cm, h_1 = 6.5cm, a = 2.5cm, and h_2 = 2 cm. Therefore, the total volume of the rover chambers equals V = 3149.25 + 21.5 = 3170.75 cm^3, or 3.17075 x 10-3 m^3.

Calculating the buoyant force and comparing it with the downforce (weight) of the rover proves theoretically that the rover will be able to float in water:

$$F_b = -\rho g V \quad (4)$$

Where F_b = buoyant force, ρ = fluid density = 997 kg/m3, g = acceleration due to gravity = 9.81 m/s, V = displaced fluid volume = 3.17075 x 10-3 m¬3. Therefore, F_b = 306N. Measured weight of the rover including all circuitry

W = 200N. Thus, Fb – W = 106N which is enough to partially submerge the rover for the rudders to work [24].

V. HARDWARE IMPLEMENTATION

A. Rover

Making the amphibious rover as small as possible was a primary design consideration. Consequently, maintaining an even distribution of weight was imperative in order to achieve buoyancy on the surface of the water. The optimal proportions for the body area were determined to be 25.5x19 square centimeters, taking into account the dimensions of circuits and batteries. In order to support the weight of the rover, four wheels with a diameter of 9cm were attached. In relation to the fundamental aspect, wheels are constructed with integrated propellers in order to achieve optimal efficiency during water travel. The rover is equipped with two chambers located at the rear, measuring 6.5 cm in length, specifically designed to accommodate the device. The selection of PVC board as the material for the rover's body was based on its durability and lightweight properties, making it highly suitable for the intended function. The rover weighed 2 kg in total. The following figure shows the primarily constructed rover body. The prototype rover can be controlled via a web application that connects directly via 2.4GHz 802.11 b/g/n Wi-Fi standard. Different ways of locomotion and connecting to the rover may also be explored.

The internal structure of the rover was divided into two compartments. The motors are situated in a separate compartment that is physically isolated from the upper body where the circuits are located, thereby preventing water penetration. In addition, to ensure that water does not enter and damage the internal circuits, silicone glue was utilized to cover any gaps between the compartments [20, 21]. The effect of the glue can last up to 20 years when applied correctly [25]. This design feature is essential to enabling the rover's functionality in aquatic environments.

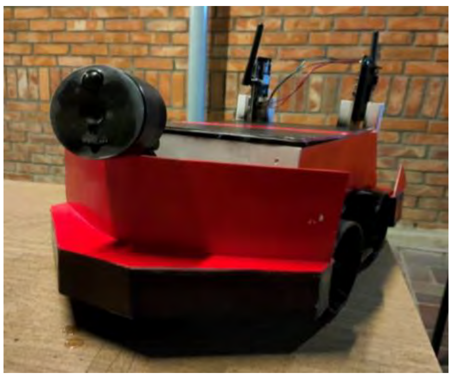

Fig. 5. Final Rover Prototype with communication devices

The completed model is displayed in figure 5. Both the camera and the communication equipment are in place. The objective of the camera is to identify and detect the existence of people through the utilization of infrared radiation while being monitored by human operators. Upon reaching a victim, the communication device located in the back of the rover can be retrieved and utilized to facilitate the establishment of communication.

Fig. 6. The rover floating in the water

Figure 6 validates the theoretical calculations that affirm the rover's buoyancy in water. The depiction illustrates the rover afloat on the water surface, substantiating the accuracy of the calculated buoyant force compared to the gravitational downforce (weight) of the rover. This visual representation serves as empirical evidence supporting the calculated predictions, showcasing the rover's successful flotation in water.

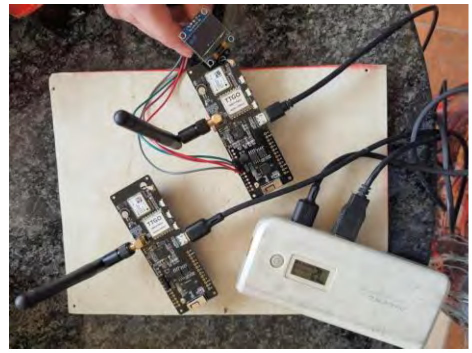

Fig. 7. Communication device model setup

In Figure 7, the setup of the TTGO T beam devices is shown. The setup involves a strategic arrangement where one device is powered by a portable power bank, seamlessly integrated into the amphibious rover. Simultaneously, the second device was kept with the rescue team, playing a crucial role in establishing a robust network connection between the survivor and the rescuer. The OLED display provides a clear platform for the presentation of information and confirmation at the survivor end. A total of three communication devices, one at the rescuer end and two for the survivor end has been shown and evaluated.

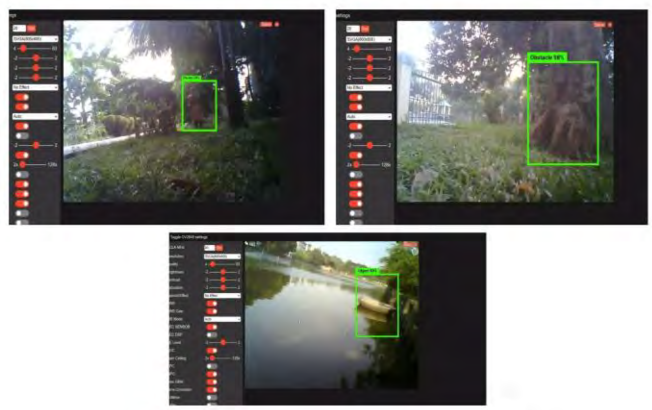

Fig. 8. The Rover camera detecting person, obstacle and objects.

The images demonstrate that the camera employed is equipped with advanced features like object, obstacle, and human detection, enhancing its functionality and effectivity.

B. *Communication Device*

The ESP32 based LILYGO TTGO T-Beam was used as the primary piece of hardware to install Meshtastic Firmware on. As it includes a built-in GPS module, Bluetooth connectivity, and supports antennas at 868MHz, it could be used to configure prototypes accordingly. An OLED display was also attached to the module and can be used to show transmissions from the rescue parties as well as transmit the victim's GPS location. The device itself displays further information, such as the distance, signal strength, and approximate direction of another device, as can be seen in figure 8. These different functionalities can be viewed directly using buttons built into the communication devices.

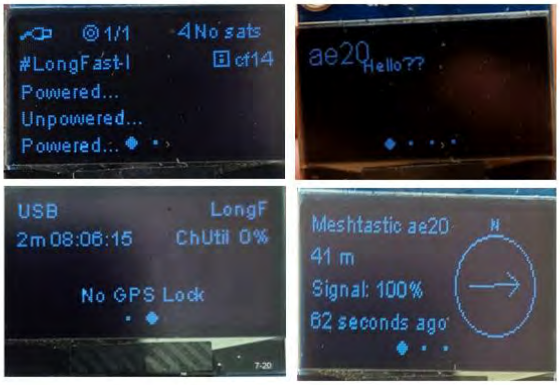

Fig. 9. OLED Display outputs for the communication device

A smartphone or personal computer further enhances the features of the devices by connecting via Bluetooth and can be used to send messages as well as view a live map, which can be used as a two-way tracking device in case the victim can reach rescue organizations and safe houses. The application may be installed in advance or provided as the rover detects people. In case of issues, redundancy is provided as the Meshtastic web client can be accessed via a Wi-Fi hotspot, Bluetooth, or Serial (USB) via the Web Bluetooth API or Web Serial API. Support is primarily available in Chromium based browsers. [26].

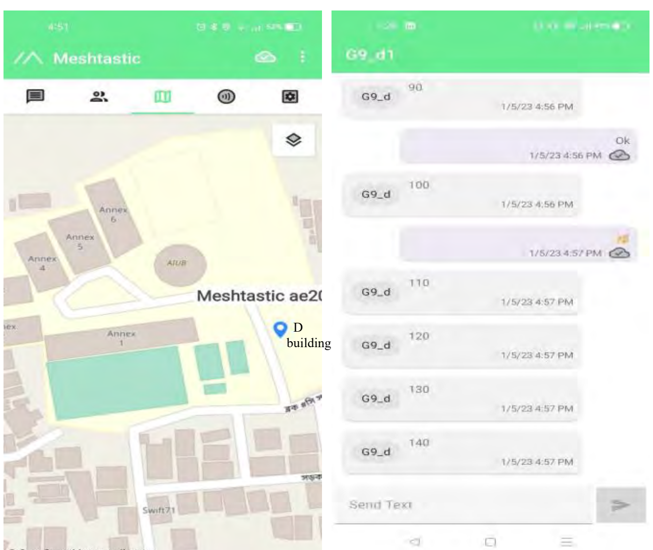

Fig. 10. Text communication and GPS tracking through Meshtastic App

The text messages delivered during the testing process on the university campus are shown in Figure 9. It is clear that the experimentation was carried out inside the campus's D building, which is indicated on the map. The location was chosen as a testing site because the building does not guarantee a constant network supply. The messages in the chat window demonstrate that the device was able to send them with a minimum delay. In the process of testing, areas with and without obstacles were covered. In addition, experiments were carried out at various levels to evaluate its suitability for use in the event of an earthquake inside the ruins of buildings. The messages were sent and received without any issues.

VI. RESULTS AND ANALYSIS

To find out if the deployment of LoRa based communication devices and the Meshtastic firmware is suitable for disaster communication and management, several tests were conducted, relating to signal strength, range, battery life, and comparisons with other similar projects. The practical tests have been carried out for 2 hops with 3 TTGO T-beams as each node, to demonstrate the mesh network performance over a realistic scenario.

A. SNR and RSSI against distance

In order to determine the Signal-to-Noise Ratio (SNR), we determined the power of the signal and the power of the noise. The formula for SNR in dBm as used in the communication device is:

$$\text{SNR (dBm)} = 10 * log\left(\frac{Signal\ Power\,(mW)}{1mW}\right) \tag{4}$$

RSSI (Received Signal Strength Indicator) quantifies the received signal's intensity. Its calculation involves the transmitted power, antenna gain, and path loss.
The theoretical formula of RSSI is:
RSSI = Transmit Power + antenna gain − path loss

For dB conversion,

$$RSSI\,(dB) = 20\,log\,(RSSI) \tag{5}$$

The device uses dBm as an absolute measure of the received signal power in milliwatts. The closer it is to 0dBm, the better the signal quality. As per the inverse square law, the electromagnetic radio wave intensity from a point source diminishes with increasing distance. Consequently, signal power weakens, leading to a decline in SNR. Thus, with an increase in distance, path loss increases, consequently deteriorating RSSI values.

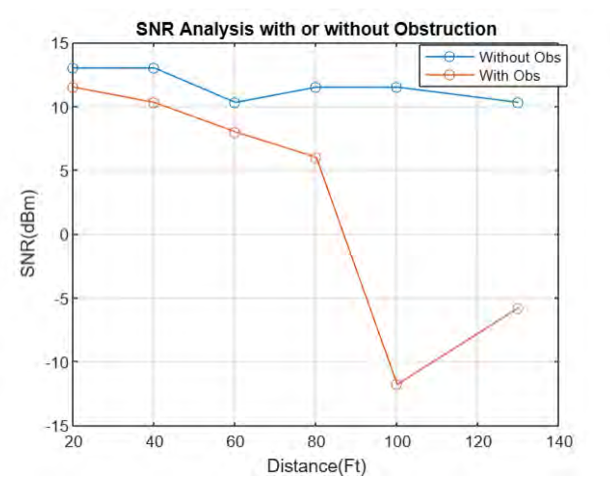

Fig. 11. SNR analysis with and without obstacle

The graph above shows the variation in SNR of the device for line of sight (orange) and with obstacles (blue). It can be clearly noticed that the SNR for line of sight is better than with obstacles. Both have similar trends throughout the analysis that are high at smaller distances but get constant at greater distances.

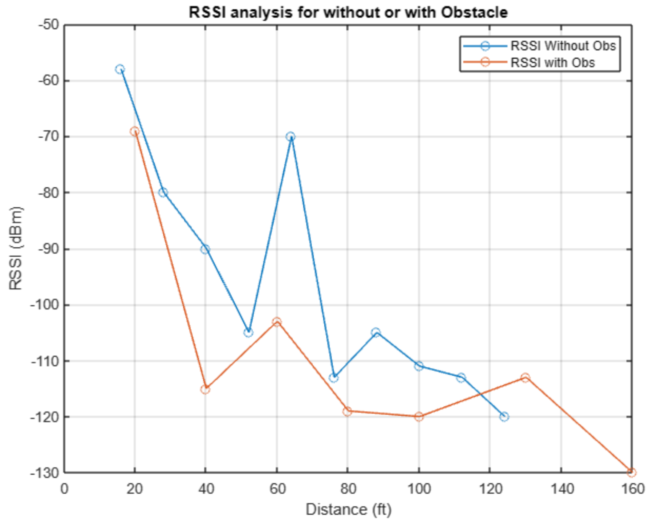

Fig. 12. RSSI variation with and without obstacles

The Received Signal Strength Indicator, or RSSI, is another measure to indicate signal strength. RSSI values closer to zero indicate a good signal and so denote poor signal strength when they are farther than the x axis. This device consistently exhibits a stronger Received Signal Strength Indicator (RSSI) in obstacle-free conditions. However, as the device encounters obstacles, its signal strength diminishes. For the obstacle test, the obstructions were 2 feet of concrete roofing applied at heights of 10 feet each.

B. Simulated results

Due to constraints in testing space, simulations were carried out to find the theoretical limits of the proposed solution and to compare the performance of Meshtastic in disaster scenarios with other proposed technologies. We have used Meshtasticator, a discrete-event simulator for LoRa that uses the Meshtastic routing algorithm and local nodes. The Okumura-Hata model for small and medium sized cities was chosen as the suitable pathloss model as the physical tests have been conducted in a similar environment. The spreading factor primarily tested was SF11 due to the relevancy for long range capabilities at higher spreading factors [18].

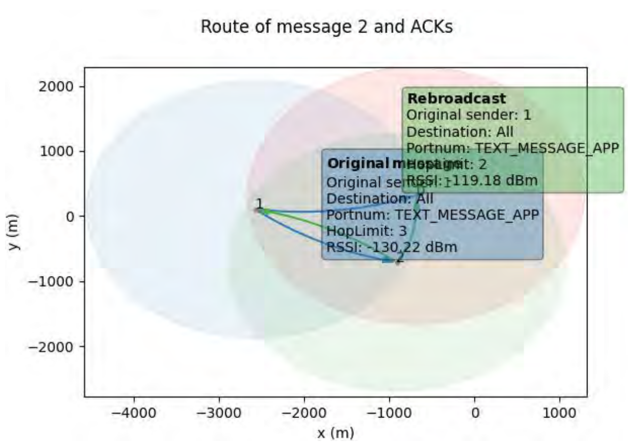

Fig. 13. RSSI values and area coverage with 3 nodes

From Fig. 13. the simulations show an expected RSSI value between 120dBm to 130dBm for a distance of approximately 1.5km and shows each device can effectively cover an area of more than $6km^2$. Successful transmission path of messages with 3 devices and 2 hops have been shown.

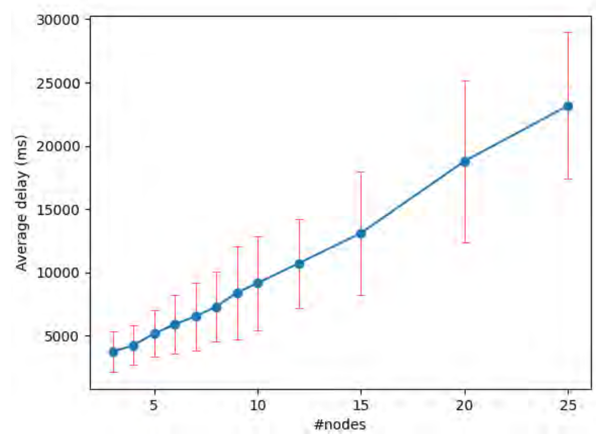

Fig. 14. Average delay vs no. of nodes

Fig. 14. shows the average delay along with the standard deviation for reception of messages between each device as the number of devices increases. Therefore, the number of devices used must be carefully selected according to parameters such as area coverage, number of people and average delay.

C. Comparisons against other similar solutions

In disaster-affected areas where reliable communication is crucial, Meshtastic LoRa surpasses other solutions in several aspects. Operating at a lower frequency (868 MHz), LoRa excels in long-distance communication, crucial when infrastructure is compromised. Its superior obstacle navigation and signal propagation range make it ideal for challenging environments [26]. With a coverage of up to 15km compared to 1.2km at best for Wi-Fi based solutions, LoRa effectively bridges communication gaps over larger disaster-affected areas [27][28]. Despite a lower Received Signal Strength (-118 dBm), LoRa demonstrates enhanced sensitivity, operating effectively in weak signal conditions [29][30][31]. Compared to technologies like Wi-Fi direct mesh, used in [32][33][34], LoRa mesh provides better stability at much longer ranges as can be seen from the graphs, at the cost of having a lower operating bandwidth, which further allows better battery life and only allows emergency communications with basic location services.

LoRa prioritizes range over data speed, strategically opting for lower bit rates. This approach results in less attenuation (signal loss) and interference, contributing to more reliable communication over longer distances. Lower bit rates necessitate less bandwidth, enabling signals to travel extended distances with reduced signal loss and interference. While LoRa operates at a low bandwidth, its robustness during infrastructure failures makes it more reliable compared to MANET based frameworks with both p2p and cellular technologies or Wi-Fi mesh [14][15][34]. The narrow bandwidth ensures quicker, energy-efficient data transmission, contributing to sustainability and cost-effectiveness. LoRa's lower data rate prioritizes range over speed, beneficial for concise transmissions and infrequent packet delivery, particularly in densely built areas [35]. Its lower power consumption enhances sustainability and reliability in disaster areas, ensuring extended battery life and accessibility in remote locations [36]. Overall, LoRa's practical advantages make it a preferred choice for effective communication networks in disaster relief efforts.

Compared to [32], scalability is not an issue in this project, as projects like BeWare drains more battery from smartphones due to the additional background processes of smartphones along with power hungry technologies & frameworks such as cellular MANET or p2p cellphone Wi-Fi. As a separate device is being used here and connecting usually through Bluetooth Low Energy, TTGO with Meshtastic can be used for a much longer period of time. The TTGO t-beams tested had a battery life of over 28 hours per device, a 400% higher uptime compared to similar proposed solutions shown above.

LoRa based systems for similar situations have also been developed like in [18] where a modified ad hoc on-demand distance vector protocol (AODV) was used to create mesh networks. The AODV protocol can operate at a maximum spreading factor (SF) of 9 while the Meshtastic Flood routing can operate at a higher spreading factor of 11 with acceptable RSSI levels, showing a measurably better performance per device. This allows it to work at almost twice the range at 1.5km vs 800m with AODV LoRa mesh routing.

Hence, LoRa Meshtastic with TTGO can be justified for simplicity, extended range, and effective obstacle navigation make it an efficient and practical choice for addressing communication needs in disaster-affected areas, outperforming Wi-Fi in these critical scenarios.

VII. CONCLUSION

The primary aim of this paper was to investigate the feasibility of employing a LoRa-based communication system for disaster management and to propose a reliable rescue model. From both the testing and simulations Meshtastic LoRa with Flood Routing and TTGO modules deployed quickly with operational rovers provides an approximate 2 to 6 times increase in usable range and a 4x higher uptime per communication device compared to other similar solutions, although bandwidth is capped at 1kbps in most practical scenarios. This, combined with the Meshtastic routing protocol that uses a flood routing approach, can provide reliable text-based communication and location tracking while sacrificing bandwidth. The solution proposed by this project also works with RSSI values unusable with other forms of radio or microwave modulation at similar distances. Further discussion in this domain might include an investigation of voice transmission over LoRa and the integration of different autonomous locomotion systems to deploy communication devices.

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