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Effective Communication System for Disaster Management Using LoRA

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ABSTRACT- Disaster Management leads to address various issues like floods, cyclones, fire etc. Different regions are vulnerable to different disasters due to its geo-climatic condition and varied landscapes. Our project addresses this critical need through LoRA based simplex communication system using Arduino Uno and LoRA RA-02(433MHZ). It is designed for extremely affordable and minimal power needs. It allows victims to broadcast SOS message with GPS coordinates to stationary receiver nodes up to 10km away. By restoring basic communication, we can bridge the deadly silence between victims and rescuers when every minute counts.

Keywords- LoRA, FSK modulation, LNA, crystal Oscillator, monopole antenna.

I.INTRODUCTION

Natural and man-made disasters frequently cripple conventional communication networks, leaving affected populations isolated when they need help most. Earthquakes, tsunamis, and hurricanes regularly devastate regions across Southeast Asia (Indonesia, Philippines), the Pacific Rim (Japan, Chile), and the Caribbean, while conflict zones in Africa (Sudan, Somalia) and the Middle East (Syria, Yemen) experience prolonged network blackouts. Even developed nations face vulnerabilities - Hurricane Katrina (2005) disabled 70% of cell towers in New Orleans, and the 2011 Tōhoku earthquake disrupted Japan's infrastructure for weeks. These breakdowns create deadly information gaps where victims cannot call for help, and responders lack situational awareness. Traditional radios like walkie-talkies have limited range, while satellite phones remain prohibitively expensive for widespread deployment.Unlike cellular networks, LoRa's long-range, low-bandwidth protocol penetrates dense urban rubble and remote terrain. Field tests in simulated disaster zones achieved 92% message reliability despite obstructions. Portable wireless nodes can be installed in the disaster area and survivors can connect to these nodes using Wi-Fi devices and communicate their needs. The victim's messages are communicated to the rescue team using LoRa technology. A prototype system is constructed to evaluate the function of the network and its performance.

The RMS value, phase angle, and frequency of the voltage, active and reactive power at specific points can also serve as monitoring signals for the micro grid control systems [1]. Furthermore, instantaneous values of voltages at the terminals and the feeder are needed for synchronizing within the system [2]. It is expected that in the near future automated operation of micro grids can be achieved [3] by monitoring the system through various sensors, analyzing the collected sensor data and integrating the results into an advanced control scheme, and passing the control commands back to the nodes. Ref. [4] presents LoRa's use in monitoring patients with mental health issues. The works reviewed above demonstrate various systems where LoRa technology has been applied for communication and data transfer. The motivations for proposing the LoRa-based communication system include: 1) low cost, 2) acceptable communication range, 3) low energy consumption, and 4) high possibility of using in remote areas where other forms of communication, such as the internet and cellular networks, do not exist.

The main objective of the proposed LoRa-based communication system in this paper is to achieve data transfer from the nodes to the private server through the gateway, which is a one-directional data transfer.

1.1 LoRaWAN and LoRa technology

The LoRaWAN protocol is a low power wide area network (LPWAN) designed for wireless connection of equipment to the internet [5] to achieve

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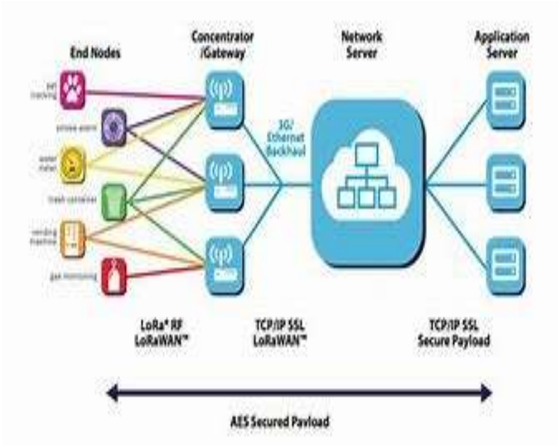
bi-directional communication between nodes and servers.



The communication between nodes and the gateway is achieved by the Physical Layer LoRa communication system. The gateway functions more like a router that relays the data received from various nodes to the Server

LoRa is the physical layer or the wireless modulation used in creating a long-range communication link [5]. Most of the known wireless communication technologies use frequency shift keying (FSK) modulation at the physical layer [5] to achieve low power communication. LoRa, on the other hand, makes use of the Chirp Spread Spectrum Modulation (CSS) technique, which can achieve both low power and long-range communication. The chirp spread spectrum for message modulation works with chirps whose frequencies increase or decrease linearly over a certain amount of time [5]. LoRa operates in the free spectrum band (ISM), for example, at 868 MHz and 915 MHz band for Europe and USA, respectively [5]. It has a low data rate of up to 50 kbps [6], and bandwidth capabilities of 125 KHz, 250 KHz, and 500 KHz [7]. Conventionally, it uses a sweep tone, which increases (up chirp) or decreases (down chirp) in frequency over time for message encoding instead of the pseudorandom binary sequence used by the well-known direct-sequence spread spectrum (DSSS) [8]. The modulation technique employed in LoRa spreads the message (signal) over a wide bandwidth, which makes it less affected by noise and interference [8]. Other low power communication systems do not have this feature by default. A LoRa transceiver can decode transmission 20 dB below the noise floor, making very long-distance communication at low power consumption possible.

Four important parameters control LoRa communication, which need to be well adjustable to achieve peak communication. These parameters are: 1) Transmission Power: is typically between 2 dBm and 14 dBm although it can be adjusted between –4 dBm and 20 dBm. This parameter has a direct impact on the system energy consumption and the range of the signal coverage [9]. 2) Spreading Factor (SF): is concerned with how many bits are encoded in each symbol, which can be set from 6 to 12. The range of signal and signal-to-noise-ratio are both increased by an increased spreading factor. However, it has a reducing effect on the transmission rate when the energy consumption is increased. 3) Bandwidth (BW): LoRa operates on the bandwidths of 125 KHz, 250 KHz and 500 KHz. 4) Coding Rate (CR): is the amount of forward error correction (FEC) that is applied to the message for protection against interference [10]. Therefore, an equation that states the transmission rate of the LoRa system is stated as follows:

$$TR = SF \times BW/2^{SF} \times CR \qquad (1)$$

where, TR is Transmission Rate, SF is Spreading Factor, BW is Bandwidth, and CR is Coding Rate.

It showed that the LoRa modulation had high immunity to Doppler effects, and can be used in satellite communication systems in orbits above 550 km with little or no restrictions. Ref. [9] proposes that LoRa’s performance can be enhanced by applying message replication and using LoRa gateways with more diversified antennas. Furthermore, [10] states that the mass produced LoRa kits have also reduced the communication strength of the LoRa system. Therefore, a customized LoRa transceiver should be designed in order to achieve improved characteristics, such as increased sensitivity and improved immunity to interference. In the recent past the improvement in LoRa’s scalability has been closely dependent on the variation of the Spreading Factor (SF) as mentioned in [11].

1.2 LoRa software implementation

LoRa communication is implemented on the software platform using open source codes available on GitHub. Various forms of software codes are made available in GitHub for easy design of automation systems. This alone contributes greatly to the low cost feature of the LoRa technology. The nodes are configured with various programming languages, such as C, C++ and Python. The nodes send processed sensor data to the gateway, through which the data can be forwarded to a network server.

II DESIGN OF THE PROJECT

The **LoRa RA-02** (433 MHz) is a low-power, long-range RF module based on Semtech's **SX1278 chip**, implementing LoRa (Long Range) modulation for IoT and M2M applications. It operates in the **433 MHz ISM band**, offering superior penetration in dense environments compared to higher frequencies (868/915 MHz).

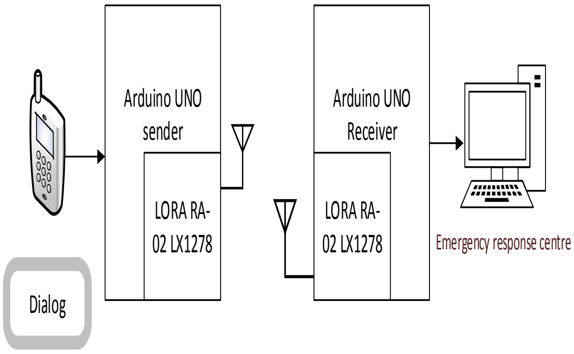


Fig.1 Signal Transmission through LoRA module

LoRa nodes are basically Semtech SX1276 transceivers that operate at the ISM frequency bands (868, 915, 433 MHz) of various regions of the globe. The nodes can send and receive data over the frequencies with capabilities to directly connect with sensors through microcontrollers, which makes them very reliable for communication. LoRa nodes can connect to a large number of sensors, which are employed to measure various physical data such as voltage, current, temperature and pressure. There is one limitation that the LoRa node can only communicate with a node that is set to the same frequency. In microgrids, the LoRa node will basically fit into the end-nodes that are connected to various DG units for data acquisition through sensors and microcontrollers. The acquired data is then sent out at a fixed frequency. A LoRa node has the capability to operate with open source microcontrollers such as the Arduino Uno, Arduino Mega or ESP 32 to process the acquired data. There are three classes of LoRa nodes (Class A, B, and C) based on their capability of enabling bi-directional communication. In particular, Class C allows for a seamless bi-directional communication [12]. In this paper, this class of LoRa node is employed. The whole process of data acquisition and transmitting can be programmed on the end-node on the Arduino Integrated Development Environment (IDE) by coding.

Fig.2. LORA RA-02 SX1278

2.1 Key Components

Component	**Function**
SX1278 Transceiver	Implements LoRa/FSK modulation with -148 dBm sensitivity (LoRa mode).
433 MHz RF Front-End	Includes PA (Power Amplifier), LNA (Low-Noise Amplifier), and impedance-matching circuits.
SPI Interface	Enables communication with microcontrollers (Arduino, ESP32, etc.).
TCXO (Crystal Oscillator)	Provides stable frequency reference (±10 ppm tolerance).
RF Switch	Automatically switches between Tx/Rx modes.
Built-in Antenna Connector	SMA/IPEX connector for external antenna (λ/4 monopole recommended).

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The module integrates these critical components:

2.2 Modulation Techniques

The LoRa modulation is also known as CSS modulation (Chirp Spread Spectrum modulation). In this LoRa modulation technique, spreading of the spectrum is obtained by generating a chirp signal that varies continuously in frequency. Due to this, the timing offset and frequency offset are equivalent between the LoRa transmitter and receiver parts. This simplifies the receiver design by avoiding complex algorithms. Moreover, the frequency bandwidth of the chirp is equivalent to the spectral bandwidth of the LoRa modulated signal. It's a robust modulation technique compared to other spread spectrum techniques such as DSSS. It addresses all the issues encountered in DSSS and at the same time provides a low-cost and low-power-based solution. It's also known as CSS modulation due to the Chirp Spread Spectrum technique employed.

$Rb = SF * (1/[2^{SF} /BW])$ bits/sec

Where:

SF = Spreading factor

BW = Bandwidth of modulation

2.3 Pin Configuration & Functions

The RA-02 has 16 pins **(2×8 layout). Key pins:**

Pin	Name	Function
1	GND	Ground
2	VCC	Power input (3.3V–5V DC)
3	SCK	SPI clock input
4	MISO	SPI Master-In-Slave-Out
5	MOSI	SPI Master-Out-Slave-In
6	NSS	SPI chip select (Active LOW)
7	DIO0	Interrupt pin for RxDone/TxDone events
8	RESET	Module reset (Active LOW)
9-16	RF & Antenna	Antenna output (50Ω impedance; connect to λ/4 monopole or SMA antenna).

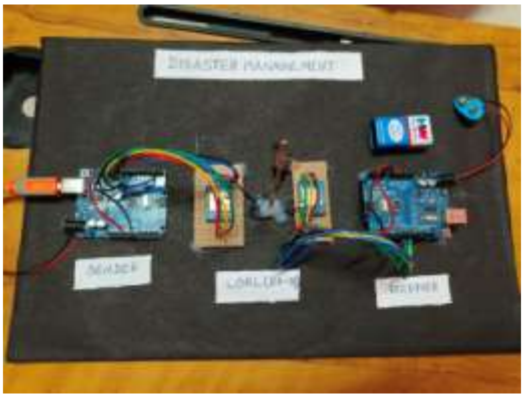

Fig.3. Circuit connection

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III HARDWARE AND SOFTWARE

3.1 Hardware Specifications

1. Ra-02 SX1278 (410 MHz – 525MHz) LORA module
2. Arduino UNO
3. Charging Module
4. 433 MHz Antenna (λ/4 monopole, ~16.5 cm).

Key Components of Arduino UNO

Component	Description
ATmega328P MCU	8-bit AVR microcontroller (16 MHz, 32KB Flash, 2KB SRAM).
USB-to-Serial Converter (ATmega16U2)	Enables USB programming and communication.
Voltage Regulator	Converts input voltage (7-12V) to stable 5V/3.3V.
16MHz Crystal Oscillator	Provides clock signal for the MCU.
Reset Button	Restarts the program execution.
Power LED & Pin 13 LED	Indicates power status and debugging.
ICSP Headers	For direct programming without USB.

The Arduino UNO can be powered in **three ways**:

1. **USB (5V)** – From a computer or power bank (500mA max).
2. **Barrel Jack (7-12V DC)** – Ideal for motors/servos.
3. **Vin Pin (7-12V)** – Directly from a battery or adapter.

The digital pins in Arduino UNO can read/write **digital signals** (HIGH/LOW) and some support **PWM (Pulse Width Modulation)**. The pin details are given in the following table.

Pin	Primary Function	Special Functions
0	RX (Serial Input)	UART communication (USB programming)
1	TX (Serial Output)	UART communication
2	Digital I/O	External Interrupt (INT0)
3	Digital I/O	PWM (~), External Interrupt (INT1)
4	Digital I/O	-
5	Digital I/O	PWM (~)
6	Digital I/O	PWM (~)
7	Digital I/O	-
8	Digital I/O	-
9	Digital I/O	PWM (~)
10	Digital I/O	SPI SS (Slave Select)
11	Digital I/O	SPI MOSI (Master Out Slave In)
12	Digital I/O	SPI MISO (Master In Slave Out)
13	Digital I/O	SPI SCK (Clock), Built-in LED

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PWM (~) Pins (3,5,6,9,10,11): Generate analog-like signals (0–5V) for dimming LEDs or motor control.

A type of radio antenna that includes a straight rod shape conductor that is perpendicularly mounted above a ground plane is known as a monopole antenna. This antenna is a simple and single-wire antenna, mainly used for both transmitting & receiving signals, so broadly used in wireless communication systems. In a monopole antenna, the conductor rod works like an open resonator mainly for radio waves & oscillates by standing voltage & current waves through its length. The antenna's length is simply determined depending on the desired radio wave wavelength. The monopole antenna frequency range is from 1.7- 2 GHz, with a 3.7 dBi average gain.

3.2. Software details

Arduino IDE (Integrated Development Environment) is a software platform used to write, compile, and upload code to Arduino boards. It provides a simple interface for coding in a language similar to C/C++, specifically designed to interact with Arduino hardware.

Advantages of Arduino IDE are as follows
Beginner-friendly
Quick setup and deployment
Massive community support
Extensive documentation
Open-source and free to use

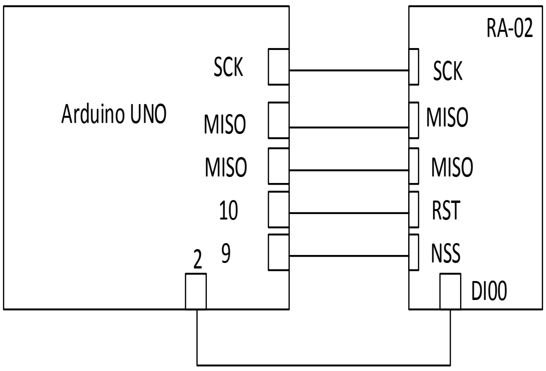

Fig. 4. Circuit connection of Arduino UNO with LoRA module

The above figure shows the connection between Arduino UNO and the LoRA module which is having multiple input and single output.

IV TESTING OF THE PROJECT

Fig.5. Testing

In disaster scenarios where conventional communication infrastructure fails, our **modular simplex radio system** provides a critical lifeline. This system enables victims to **broadcast their precise GPS coordinates and casualty status** using low-power LoRa (Long Range) technology, operating on the **433 MHz frequency band** for maximum penetration through rubble and dense terrain.

Victim-Side Communication

Pocket-sized **LoRa-GPtransmitters** (waterproof & shockproof) allow survivors to send:Victim can broadcast Exact location and Number of injured/stranded people urgency level (e.g., "trapped," "medical emergency")

Rescue Team Intelligence

Centralized **LoRa NODE is capable** to receive signals up to **10 km away**, even in urban collapse zones.
Critical injuries (via pre-set emergency codes)
Structural risks (e.g., fires, flooding)
Assessment of **resource allocation** guides teams to deploy:
Medical supplies (based on injury reports)
Heavy equipment (for collapsed buildings)
Evacuation routes (updated in real-time)

4.1 Applications

A. Home Automation

Smart lights, temperature control (using relays & sensors).

B. **Robotics**

Motor control (via L298N driver) & obstacle avoidance (ultrasonic sensors).

C. **IoT Prototyping**

Data logging (with SD cards) or LoRa-based communication

4.2 Cost of the Component

NAME OF THE COMPONENTS	QUANTITY	AMOUNT IN (Rs)
Ra-02 SX1278 (410 MHz – 525MHz) LORA module	2	1200
Arduino UNO	2	1000
Battery 9V	2	50
433 MHz Antenna (λ/4 monopole, ~16.5 cm).	2	100
TOTAL		**□3350**

V CONCLUSION

Thus the prototype model developed is compact and convenient tool in disaster management. The victims' data would be broadcasted repeatedly to ensure the reception at emergency support. The low cost implemented prototype is feasible for mass production and practical utilization.

VI FUTURE WORK

- To design the duplex communication to acknowledge the victim on message reception and to deliver first aid instruction as future upgrades.
- In future, the power optimization of circuit shall prolong the backup of the circuit since the power supplies will be down in disaster times.

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