USING LORA MODULES FOR IOT APPLICATIONS

Abstract

LoRa (Long Range) is a wireless data communication technology that uses a radio modulation technique that can be generated by Semtech LoRa transceiver chips used for the Internet of Things (IoT) and machine-to-machine (M2M) devices through the cloud. LoRa sensors have a wide range of compatibilities, allowing connectivity with various machines, devices and even animals and people. LoRa modulation provides a greater communication range with low bandwidths than other wireless data transmission technologies like cellular, WiFi, Bluetooth, or ZigBee. This paper introduces simple applications of LoRA modules – i) Configuring the devives ii) Testing LoRa as Transmitter and Receiver by sending a message iii) Sending a sensor data to a remote receiver iv) LoRa device used for detecting forest fire from a remote location.

Keywords: Lora Modules, IOT, Semtech LoRa.

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I. INTRODUCTION

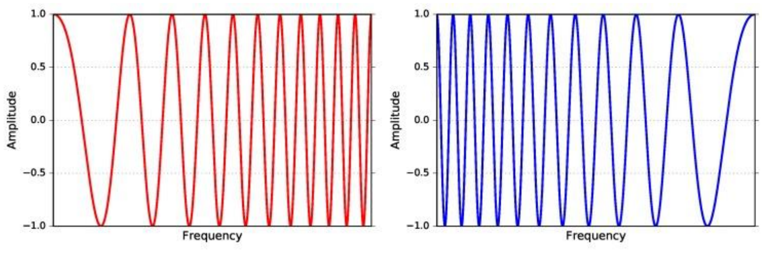
1. LoRa technology

LoRa technology provides long-range, low-power connectivity for various Internet of Things (IoT) and machine-to-machine (M2M) applications. It stands out for its ability to cover large distances while consuming minimal energy, making it well-suited for applications where devices are spread over wide areas and need to transmit data over extended periods. Cycleo, a company based in Grenoble, France has developed the technology, and later Semtech took over. LoRa technology operates in the sub-GHz frequency bands, specially the ISM (Industrial, Scientific, and Medical) bands: 433 MHz, 868 MHz, and 915 MHz, which offer better propagation characteristics compared to higher frequency bands.

Modulation means how analog or digital information are encoded onto a carrier signal. When analog information is encoded onto a carrier signal, three modulation types can be used: Amplitude Modulation (AM), Frequency Modulation (FM) and Phase modulation (PM). When digital information is encoded onto a carrier signal, three modulation types can be used: Amplitude Shift Keying (ASK), Frequency Shift Keying (FSK) and Phase Shift Keying (PSK).

LoRa is based on unique modulation scheme known as Chirp Spread Spectrum modulation (CSS). Chirp Spread Spectrum is a spread spectrum technique that uses wideband linear frequency modulated chirp pulses to encode information. Spread spectrum techniques are methods by which a signal is deliberately spread in the frequency domain. A chirp, often called a sweep signal, is a tone in which the frequency increases (up-chirp) or decreases (down-chirp) with time. These chirp signals are used as carrier signals where a message is encoded on. The chirp spread spectrum has a low transmission power requirement. It allows the signal to overcome interference and obstacles more effectively, thus enhancing the communication range. It also provides immunity to multipath and fading.

An example of such chirps is shown below:



(a) Up-chirp (b) Down-chirp

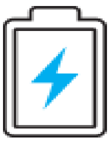
An advantage of this method is that the timing and frequency offsets between transmitter and receiver are equivalent, greatly reducing the complexity of the receiver design. The frequency bandwidth of this chirp is equivalent to the spectral bandwidth of the signal. The data signal that carries the data from an end device to a gateway is chipped at a higher data rate and modulated onto the chirp carrier signal. LoRa modulation also includes a variable error correction scheme that improves the robustness of the transmitted signal. For every four bits of information sent, a fifth bit of parity information is sent. In the LoRa system, a device that has some sensors and is equipped with a LoRa transceiver is called a node.

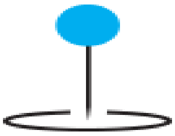
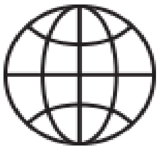
2. LoRaWAN

LoRaWAN (Long Range Wide Area Network) is an open networking protocol constructed on the foundation of LoRa technology that delivers secure bi-directional communication, mobility, and localization services standardized and maintained by the LoRa Alliance. It provides the infrastructure and communication framework necessary to connect and manage a large number of LoRa devices (nodes) within a wide geographical area. LoRaWAN is designed to optimize battery life, network capacity, and scalability, making it a best choice for IoT applications such as agriculture, industrial monitoring, smart cities, etc.. Security is a paramount consideration in IoT applications, and LoRaWAN incorporates various security measures. It employs end-to-end encryption, message integrity checks, and unique device identifiers to ensure the confidentiality and integrity of transmitted data. LoRa serves as the radio signal transporting the data, while LoRaWAN functions as the communication protocol governing and specifying how this data is transmitted within the network.

In conclusion, LoRa and LoRaWAN collectively offer a powerful solution for long-range, low-power IoT connectivity. The advantages of using LoRaWAN Wireless technology over Wi-Fi make it ideal for deploying IoT devices in large-scale applications, such as smart cities and industrial automation. As the IoT continues to grow, LoRaWAN is likely to become the preferred wireless communication technology for IoT applications.

II. FEATURES of LoRa:

Long Range		Extends its reach to over 10 kilometers in rural regions and penetrates dense urban or deep indoor environments.
Low Power		Consumes minimum energy, minimizing battery replacement costs

Secure		end-to-end encryption, mutual authentication, integrity protection, and confidentiality.
Standardized		The compatibility of devices and easy access to LoRaWAN networks facilitate the rapid deployment of IoT applications.
Geo location		Suitable for GPS-free tracking applications,
Mobile		Sustains communication with mobile devices without strain on power consumption.
High Capacity		It has the capacity to handle millions of messages per base station, meeting the demands of public network operators catering to expansive markets.
Low Cost		Low investment on infrastructure, battery replacement, and ultimately operating expenses

III. ADVANTAGES AND DISADVANTAGES OF LORA MODULE

1. Advantages

- **Long Transmission Distance:** The LoRa module is popular for its transmission distance which far exceeds other series of wireless modules, under the same power conditions.

- **Low Power:** The challenge of preserving low power consumption in wireless modules while simultaneously extending their transmission range is solved by the LoRa module. This achievement significantly contributed to its widespread popularity in the market.

- **Strong Anti-Interference Ability:** The LoRa module uses Spread spectrum modulation, a technique used in wireless communication to improve the signal's resistance to interference and to enhance its security forward error correction technology to detect and correct errors that may occur during the transmission of data.

- **High sensitivity:** In spread spectrum modulation, the signal extends over a wider range of frequencies than the minimum required for transmission. When operating at the same data rate a higher sensitivity than other modulation methods can be obtained. The higher the sensitivity, the longer the transmission distance the weaker the signal.

2. Disadvantages

- **Low Transmission Rate:** The benefit of an extended transmission range with LoRa modules often involves trade-offs in data transmission speed. As the transmission rate increases, the achievable transmission distance decreases. This is because higher rates make the signal more susceptible to weakening.

- **LoRa Module Price:** The LoRa module is relatively more expensive than other the RF modules. It is recommended to use the LoRa module as its performance of various parameters is much superior to all kinds of wireless modules.

IV. APPLICATIONS

LoRa and LoRa WAN technology will be an indispensable technology in near future in IoT deployments, some of the applications are listed as follows**:**

1. In Smart Cities
- Smart Lighting
- Smart Parking and Vehicle Management
- Facilities and Infrastructure Management
- Environmental (Air Quality) Monitoring
- Waste Management

2. For Industrial Use
- Equipment condition monitoring
- Predictive maintenance
- Warehouse management
- Remote monitoring of critical infrastructure

3. In Smart Homes
- Enhanced Security
- Home Automation with IoT-enabled Appliances
- Healthcare with Health Monitoring Devices
- Wearable Technology

4. In Agriculture
- Smart Farming and Livestock Management
- Monitoring Temperature and Moisture
- Water Level Sensors for Irrigation Control

5. For Healthcare
- Remote patient monitoring

- Asset tracking in healthcare facilities
- Medication adherence monitoring

LoRa devices are versatile and can be customized to suit the specific needs of various applications, making them a popular choice for many IoT projects. They excel in scenarios where long-range communication and low power consumption are crucial.

V. WORKING WITH LORA MODULES

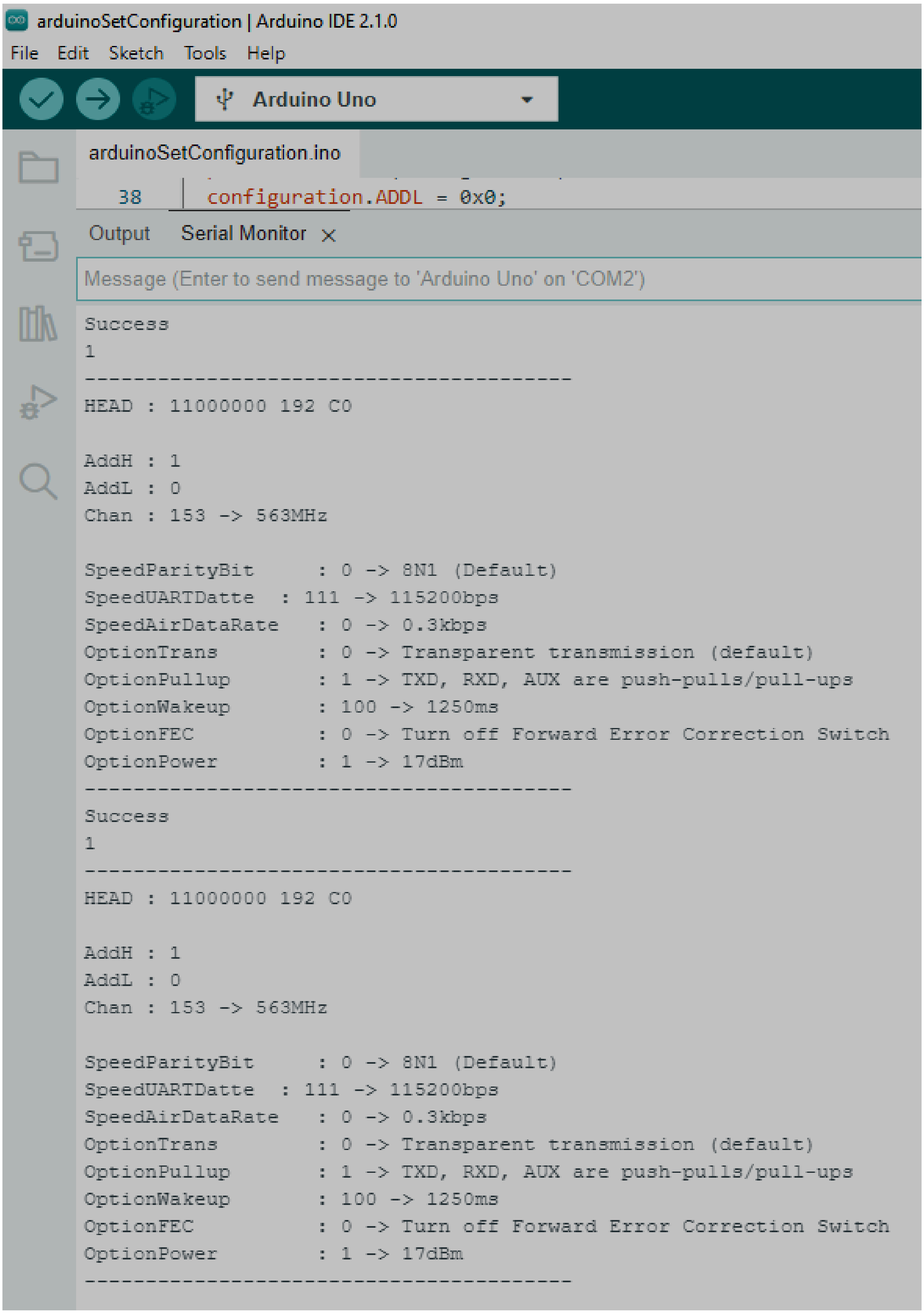
1. **Configuring the LoRa devices:** Arduino UNO and REYAX RYLR896 LoRa Module 866 MHz are used.

Figure 1: Lora modules used

Download the LoRa.h library for LoRa devices or LoRa_E32.h specifically for E32 LoRa devices

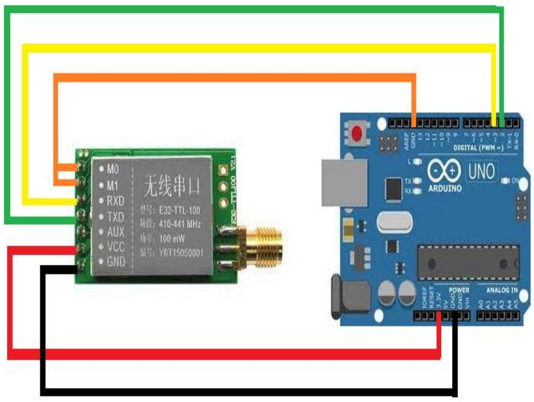
Go to the Example program in Ebyte LoRa 32 Library.

Note: To set configuration of EByte LoRa E32 , go to Set Configuration example which is available in Examples > E32 library. *The transmitter and receiver must have the same CHANNEL ADDL and ADDH*



2. **The below code is for sending and receiving Message between two E32 LoRa devices's which are kept at about 500m distance.**

The circuit connections for LoRa transmitter are shown below in fig.2



Arduino Uno
M0 to GND
M1 to GND
TX to PIN 2
RX to PIN 3
AUX is not connected
VCC to 3.3v/5v
GND to GND

Figure 2

```
// LoRa Transmitter scketch

#include  "LoRa_E32.h"
LoRa_E32  LoRaTX(2, 3);   // Configure without connecting AUX and M0 M1
//setup LoRa  module TX is pin2 and RX is pin3

void setup() {
Serial.begin(9600);         //  //initialize Serial Monitor
delay(500);
LoRaTX .begin();
Serial.println(" Sending  message!");
ResponseStatus  rs = LoRaTX.sendMessage("Hello everyone!");
Serial.println(rs.getResponseDescription());
}

void loop() {
if (LoRaTX.available()>1)
{
ResponseContainer rc = LoRaTX.receiveMessage();
if (Serial.available()) {
String input = Serial.readString();
LoRaTX .sendMessage(input);
}
}
```

Receiver Circuit

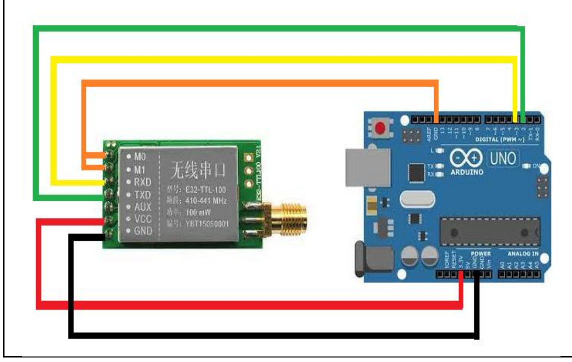
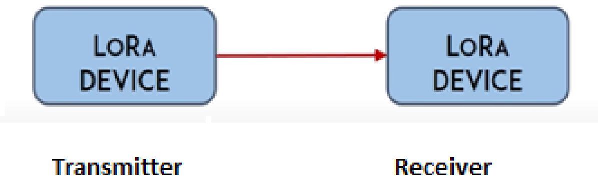
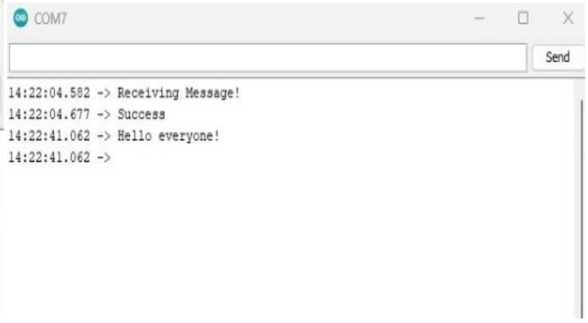
	Pin 3 to Rx of LoRa Pin 2 to Tx of LoRa

Figure 3: Receiver Circuit

```
// The LoRa Receiver Sketch
#include  "LoRa_E32.h"
LoRa_E32  LoRaRX(2, 3);

void setup() {
Serial.begin(9600);
delay(500);
LoRaRX.begin(); // //Send LoRa packet to receiver

}


void loop() {
if (LoRaRX.available()>1)
{
ResponseContainer  rc = LoRaRX.receiveMessage();
if (rc.status.code!=1){
rc.status.getResponseDescription();
}
else
{
Serial.println(rc.data);
}
}
}
```



Output at the transmitter and receiver



Display at the transmitter while sending a message   Output at the receiver after getting a message

Note: LoRa devices can be configured to transmit and receive data, it is referred to as transceiver.

3. Sending temperature sensor data to a remote receiver

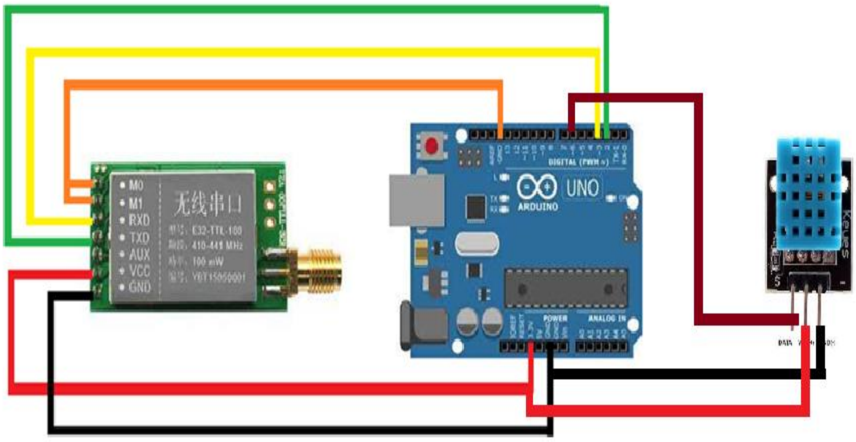


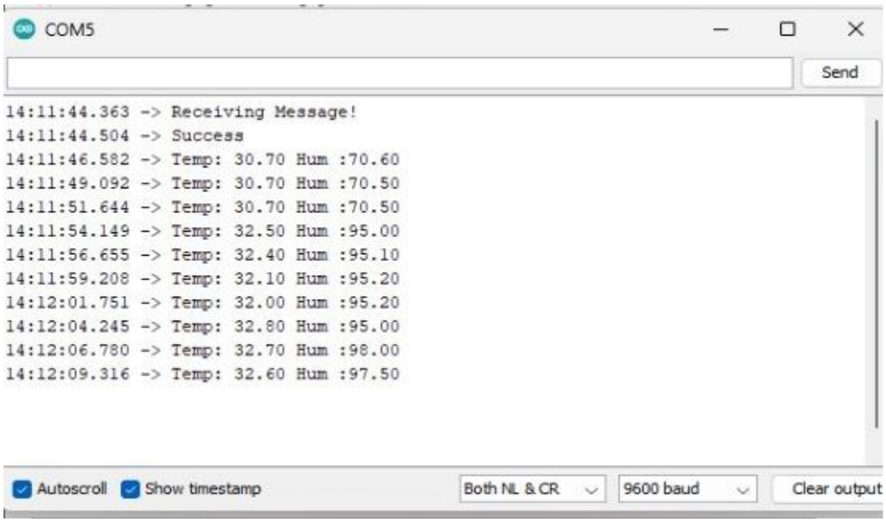
Figure 4: At the transmitter - Arduino Uno connected with Temperaure sensor

```
// Program at the transmitter side

#include "LoRa_E32.h"
#include "DHT.h"
DHT dht(6,DHT11);
LoRa_E32  LoRaTX(2, 3);

typedefstruct  struct_message {
String a;
String b;
} struct_message;
```

```
struct_message myData;

void setup() {
Serial.begin(9600);
delay(500);
dht.begin();
LoRaTX.begin();
Serial.println("Sending message!");
ResponseStatus   rs = LoRaTX.sendMessage("Hello everyone!");
Serial.println(rs.getResponseDescription());
}

void loop() {
float temp = dht.readTemperature(); //reads temperature
float hum = dht.readHumidity(); //reads humidity
myData.a = temp; //stores float value as string
myData.b = hum; //stores float value as string
LoRaTX.sendMessage("Temp: ");
LoRaTX.sendMessage(myData.a);
LoRaTX.sendMessage(" Hum :");
LoRaTX.sendMessage(myData.b);
delay(1000);
}
```

Receiver circuit is same as in fig3

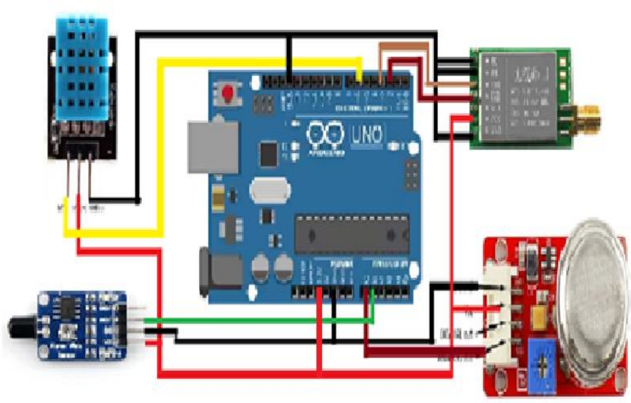
```
// Program at the receiver

#include  "LoRa_E32.h"
LoRa_E32 LoRaRX(2, 3);
voidsetup() {
Serial.begin(9600);
delay(500);
LoRaRX.begin();
}

voidloop() {
if (LoRaRX.available()>1)
{
ResponseContainer  rc = LoRaRX.receiveMessage();
if (rc.status.code!=1){
rc.status.getResponseDescription();
}
else
{
Serial.println(rc.data);
}
}
}
```

Output at the receiver with temperature and humidity values

4. **Use case: Forest Fire Detection using LoRa Device:** The objective of this initiative is to facilitate the prompt identification of forest fires, which aims to the detect forest fire natural, to avoid damage to the natural resources. The circuit setup shown below as in fig.4 succeeds in detecting (or/and predicting) the occurrence of the fire without any delay using LoRa communication system. This project makes use of sensors and Arduino boards based on Wireless Sensor Network (WSN) to achieve this task. In this project, temperature sensor, IR sensor, Gas sensor are interfaced to Arduino to detect any increase in the concentration of gases, detect flames and measure temperature changes produced from the fire. The values are taken from the Sensors and are transmitted through the LoRa module connected to Arduino Uno board and sent to a remote receiver.

   The system can be improvised to station many such WSN nodes at various locations to detect the fire as fast as possible and send notification to the fire units. Both local and global fire alert can be provided, very low cost implementation, also camera based detection can be provided as fail safe in case sensors malfunction. A database can be created at the receiver for analysis.



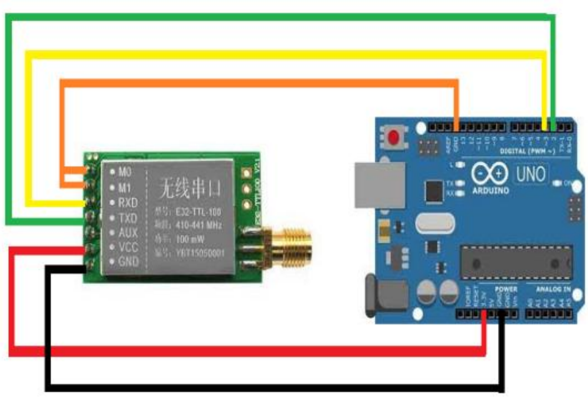
LoRa E32 E32-TTL-100
Arduino UNO
M0 to GND
M1 to GND
TX to PIN 2
RX to PIN 3
AUX is Not connected
VCC to 3.3v/5v
GND to GND

Figure 4: Connection diagram at the transmitter with temperature sensor, flame sensor and smoke sensor connected to Arduino Uno and LoRa device

```
//  Program to measure temperature, humidity values  and
//  monitor presence of smoke/ flame and transmit to a remote receiver

#include  "LoRa_E32.h"
#include "DHT.h"
DHT  dht(6,DHT11);
int Flame = 7;
int Smoke = 8;
LoRa_E32   LoRaTX(2, 3);
Typedefstruct   struct_message {
String a;
String b;
String c;
String d;
} struct_message;
struct_message  myData;

voidsetup() {
Serial.begin(9600);
delay(500);
pinMode(Smoke, INPUT);
pinMode(Flame, INPUT);
dht.begin();
LoRaTX.begin();
Serial.println("Sending  message!");
ResponseStatus  rs = LoRaTX.sendMessage("Hello everyone!");
Serial.println(rs.getResponseDescription());
}

void loop() {
float temp = dht.readTemperature(); //stores float values as string
float hum = dht.readHumidity();
 Smoke = digitalRead(8); //reads smoke
 Flame = digitalRead(7); // reads flame
delay(1000);
myData.a = temp; //converts float value to string
myData.b = hum;
LoRaTX.sendMessage("Temp: ");
LoRaTX.sendMessage(myData.a);
LoRaTX.sendMessage(" Hum :");
LoRaTX.sendMessage(myData.b);
if(Smoke == 0)
 {
LoRaTX.sendMessage(" Smoke Detected "); //prints as output if smoke detected
 }
else
{
LoRaTX.sendMessage(" No Smoke Detected "); //if not detected
}
```

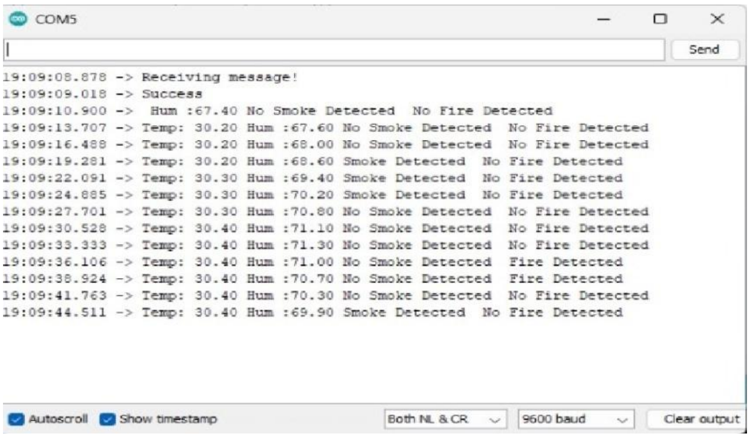
```
if(Flame == 1)
{
LoRaTX.sendMessage(" Fire Detected "); //prints when fire is detected
}
else
{
LoRaTX.sendMessage(" No Fire Detected "); //when fire is not detected
}
delay(1000);
}
```

At the receiver (Fig.5)



Pin 3 to Rx of LoRa
Pin 2 to Tx of LoRa

```
// Program at the receiver to display the values received

#include "LoRa_E32.h"
LoRa_E32 LoRaRX(2, 3); (3 to RX of Lora, 2 to TX of LoRa)

void setup() {
Serial.begin(9600);
delay(500);
LoRaRX.begin();
}
void loop() {
if (LoRaRX.available()>1)
{
ResponseContainer rc = LoRaRX.receiveMessage();
if (rc.status.code!=1){
rc.status.getResponseDescription();
}
else
{
Serial.println(rc.data);
}
}
}
```



Output at the receiver with temperature-humidity values, fire and smoke alerts

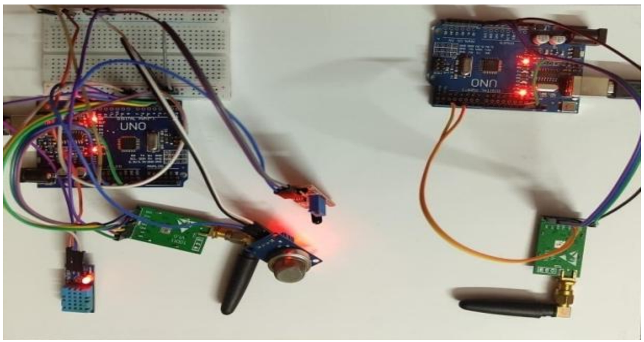
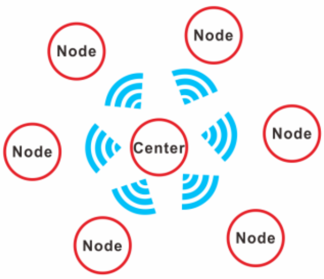


Figure 6: Picture of the Transmitter and Receiver Circuits

VI. FUTURE SCOPE

Wireless multi-point sensing or measurement system using LoRA modules: Sensing equipment cannot be directly connected to the network, and can only be connected to the center through wired or radio frequency, and the center communicates with the network to upload data. This method has a low cost. However, due to the same frequency interference of radio frequency communication, multiple sensing devices cannot communicate with the center at the same time, otherwise data will be lost. An effective scheduling algorithm for the communication between the sensing devices and the center is required to ensure Stable and reliable data transmission.



A wireless multi-point sensing measurement system.

The node collects sensor data and uploads the data to the center at regular intervals. After receiving the data, the center uploads the data to the server. The data can be saved in a database for predictive maintenance or /and disaster management. ESP boards with LoRa Connectivity can be used instead of a separate Arduino Uno boards with a LoRa Module.

VII. CONCLUSION

In conclusion, Lora devices have emerged as a promising technology for long-range, low-power, low data rate and secure data communications. LoRa can be used for point to point communication or in a network; LoRa can be especially useful to monitor sensors that are not covered by Wi-Fi network and that are several meters apart.

While there may be some limitations to consider, such as network congestion and limited bandwidth, the advantages of Lora devices render them a valuable asset in the IoT era. As technology continues to advance, the use of Lora devices is expected to grow, bringing new possibilities and innovations to numerous sectors, ultimately leading to increased efficiency, improved decision-making and enhanced connectivity. Overall, Lora devices have proven to be a reliable and efficient solution for long-range communication needs, offering tangible benefits to businesses and society alike.

REFERENCES

[1] LoRa and LoRaWAN: A Technical Overview by Semtech Corporation https://www.semtech.com/lora
[2] ESP32 with LoRa using Arduino IDE – Getting Started https://randomnerdtutorials.com/?s=LoRa+
[3] Kia C. Wiklundh Understanding the IoT technology LoRa and its nterference vulnerability, Proc. of the 2019 International Symposium on Electromagnetic Compatibility (EMC Europe 2019), Barcelona, Spain, September 2–6, 2019.
[4] Nur-A-Alam, M. Ahsan, M. A. Based, J. Haider, and E. M. G. Rodrigues, “Smart monitoring and controlling of appliances using lora based iot system,” Designs, vol. 5, no. 1, Mar. 2021, doi: 10.3390/designs5010017.
[5] K. M. Babu et al., “FOREST FIRE DETECTION USING Lora,” JETIR, 2020. [Online].: www.jetir.org.
[6] S. Lora, “LoRa ® APPLICATION BRIEF SMART HOME & BUILDINGS HOW A LoRaWAN-BASED FIRE DETECTION SYSTEM WORKS.” [Online]. Available: www.lora-alliance.org.
[7] K. Ram Prasanna, J. M. Mathana, T. A. Ramya, and R. Nirmala, “LoRa network based high performance forest fire detection system,” Mater. Today Proc., vol. 80, pp. 1951–1955, Jan. 2023, doi: 10.1016/j.matpr.2021.05.656.
[8] Electromagnetic Compatibility Society., and Institute of Electrical and Electronics.
[9] About LoRa Alliance® - LoRa Alliance® (lora-alliance.org)
[10] The Arduino Guide to LoRa® and LoRaWAN® | Arduino Documentation

