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Efficient Environmental Monitoring through LoRaWAN IoT Solutions

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Abstract: The main objective of this paper is to present a new system for monitoring environmental conditions using LoRa (Long Range) technology for wireless communication in Internet of Things (IoT) applications. The system has been specifically designed to gather data on temperature and humidity in rural areas and transmit it to a central server for analysis and visualization. The system consists of three main components: sensor nodes, a LoRa gateway, and a cloud-based server. The sensor nodes are installed at specific locations and are equipped with sensors that collect data on environmental conditions. The collected data is then transmitted wirelessly to the LoRa gateway using LoRa technology. The LoRa gateway acts as an intermediary between the sensor nodes and the cloud-based server, receiving and forwarding the collected data to the server over the internet. Once the data reaches the cloud-based server, it is processed and analyzed to provide insights into environmental conditions. The proposed system offers several advantages over traditional environmental monitoring systems, such as low power consumption, long-range wireless communication, and the ability to support many devices. This system can be used in various applications such as agriculture, forestry, and weather monitoring. To summarize, the proposed system is a wireless environmental monitoring system that utilizes LoRa technology to collect and transmit data from remote rural areas to a cloud-based server for analysis and visualization. The system has several advantages over traditional environmental monitoring systems and can be used in various applications.

Keywords : Battery, TP4056, Solar Panel, ESP8266, DHT11, LoRa SX1278, OLED Display, IoT.

INTRODUCTION

The Internet of Things (IoT) has transformed the way we interact with the world, particularly in the context of environmental monitoring. However, IoT-based technologies are limited in their usefulness when network infrastructure such as GSM, CDMA, or LTE is unavailable, as they depend on internet connectivity. To address this issue, we propose a wireless sensor network architecture that operates without internet connectivity. The proposed architecture includes sensor nodes and a gateway and enables efficient transmission of sensor data over a wide range without relying on the internet. This paper presents a detailed study of an IoT-based environmental monitoring system that utilizes LoRa (Long Range) technology. LoRa technology is a low-power, long-range wireless communication technology that is well-suited for IoT-based environmental monitoring systems. Our proposed system comprises a network of wireless sensor nodes that are capable of measuring various environmental parameters such as temperature and humidity. The wireless sensor network includes a LoRa module that serves as the backbone of the system. This module, together with a microcontroller (ESP8266), transceiver, sensors (DHT11), and power source, makes the system suitable for remote data access in locations such as rural areas, forests, highways, and surveillance and monitoring applications. Additionally, the system's low power consumption is an added advantage. The sensor nodes transmit the collected data to a central gateway using the LoRaWAN (LoRa Wide Area Network) protocol. The gateway then processes and sends the data to the cloud for further analysis. This paper outlines the design and implementation of an IoT-based environmental monitoring system that employs LoRa technology. We comprehensively evaluate the system's performance, including its accuracy, reliability, and power consumption. Our findings demonstrate that the proposed system is a viable solution for real-time environmental monitoring applications, with potential applications in domains such as agriculture, smart cities, and industrial monitoring. To summarize, the proposed system is an IoT-based environmental monitoring system that utilizes LoRa technology to enable wireless communication over long distances, without relying on the internet. The system is composed of a network of sensor nodes and a gateway and is well-suited for remote data access in locations where internet connectivity is unavailable. The system's low power consumption, accuracy, reliability, and potential for real-time environmental monitoring applications make it an attractive solution for a wide range of applications.

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1. RELATED WORKS

Olakunle Elijah, Sharul Kamal Abdul Rahim, Vitawat Sittakul, Ahmed m. al-Samman, Michael Cheffena, Jafri Bin Din, and Abdul Rahman Tharek **"Effect of Weather Condition on LoRa IoT Communication Technology in a Tropical Region:**
Malaysia" In IEEE Access, Volume.9 ,2021 [1]
The study explores the influence of various environmental factors such as onboard and atmospheric temperature, relative humidity, and solar radiation on the LoRa communication link. The paper's authors carried out a detailed analysis of how these environmental factors impact the LoRa link in tropical regions, where the climate conditions are different from other regions. They analyzed the data collected from field measurements and simulations to assess the effect of environmental factors on the LoRa link's quality. Moreover, the paper provides an analysis of how rainfall conditions affect the LoRa link. The study found that the rainfall intensity in tropical regions significantly affects the LoRa link's quality, especially during heavy rainfall. The authors also compared the findings with those of similar studies conducted in different regions to provide a comprehensive understanding of the LoRa link's behavior in various weather conditions. Overall, the research paper contributes to the understanding of how environmental factors in tropical regions impact the LoRa link in a LoRaWAN setup. The study's findings are expected to provide insights for the design and deployment of LoRa-based IoT systems in tropical regions, helping to optimize the performance of these systems in adverse weather conditions.

Syazwan Essa, Rafidah Petra, M. Rakib Uddin, Wida Susanty Haji Suhaili, Nur Ikram Ilmi **"IoT-Based Environmental Monitoring System for Brunei Peat Swamp Forest"** In International Conference on Computer Science and Its Application in Agriculture (ICOSICA),2020 [2]
The article described a research paper that focused on developing an IoT-based environmental monitoring system for the Brunei Peat Swamp Forest. The forest is highly vulnerable to forest fires during hot and dry seasons, which can rapidly spread and pose a significant threat to the ecosystem. To mitigate the impact of forest fires, the authors proposed an IoT-based monitoring system consisting of sensor nodes that gather data on critical parameters such as temperature, water level, and soil moisture.The data collected by the sensor nodes is transmitted through a gateway and can be monitored in real-time on a dashboard. The water level sensor underwent several software tests to ensure data accuracy, and in-house testing confirmed that each sensor node could collect and transmit data to the dashboard, which can be viewed remotely by the public. The monitoring system allows for better data collection, coordination, and decision-making, which can help reduce the consequences of forest fires.The collected data can detect changes in temperature, water level, and soil moisture in real-time, which can help forest managers take timely and effective measures to minimize the risk of forest fires and protect the ecosystem. The proposed technology has the potential to play a significant role in forest fire prevention and control.

V.Raju, Mrs.T.Surya Kavitha**, "An Environmental Pollution Monitoring System using LoRa"** Published in International Journal Of Technical & Scientific Research -Vol.6, Issue II, 2017 [7]
The paper discusses the limitations of current automated environmental pollution monitoring systems and proposes a new system that overcomes these shortcomings. The new system is more accurate, cost-effective, portable, and compact, making it ideal for monitoring toxic gases in remote or challenging locations. The proposed system addresses the need for real-time data, which can be monitored continuously on a personal computer. This enables professionals to supervise and monitor environmental pollution in remote locations, making it a feasible solution for individuals struggling to gather data from remote areas. The proposed system is designed to be smarter, more efficient, and cost-effective than traditional systems. It provides a real-time solution that can be accessed and monitored easily, even in remote or challenging locations. The system's portability and compactness are key advantages, making it a highly desirable option for farmers and site operators who need accurate and continuous monitoring of toxic gases in remote areas. Overall, the proposed environmental pollution monitoring system is a more practical and effective solution that offers significant advantages over traditional systems, and can help ensure better management of environmental pollution in remote areas.

Zhi-Yang Su, Yi-Nang Lin, Victor R. L. Shen **"Intelligent Environmental Monitoring System based on LoRa Long Range Technology"** Published in IEEE Eurasia Conference in 2019. [6]
The research paper titled "Intelligent Environmental Monitoring System based on LoRa Long Range Technology" was published in the IEEE Eurasia Conference in 2019. The authors of the paper are Zhi-Yang Su, Yi-Nang Lin, and Victor R. L. Shen. The main aim of the research is to develop an effective environmental monitoring system using Long Range (LoRa) transmission technology that consumes less power. The system will be implemented in a densely populated large-scale campus and will use sensors placed at different locations to collect data on various environmental parameters such

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as temperature, humidity, suspended particles, carbon monoxide, carbon dioxide, wind speed, apparent temperature, and ultraviolet light in both indoor and outdoor environments. The transmission technology used will be LoRa 915 MHz, which will utilize the transmission module LRM001 developed by Liyatech. An industrial computer will serve as the Gateway, and the data from different detection points will be analyzed through C# Windows Forms. Hourly data will be uploaded to Microsoft Azure SQL Server, and the Server end will use ASP.NET technology to publish the website with the assistance of Google Map API to display the different detection stations' locations. This will enable users to investigate the environmental quality trend and carry out further analysis using Big Data.

3. METHODOLOGY

In this research we have developed an IoT based model for Environmental monitoring system.

The monitoring parameters are as follows:

1. Temperature Monitoring
2. Humidity Monitoring

BLOCK DIAGRAM:

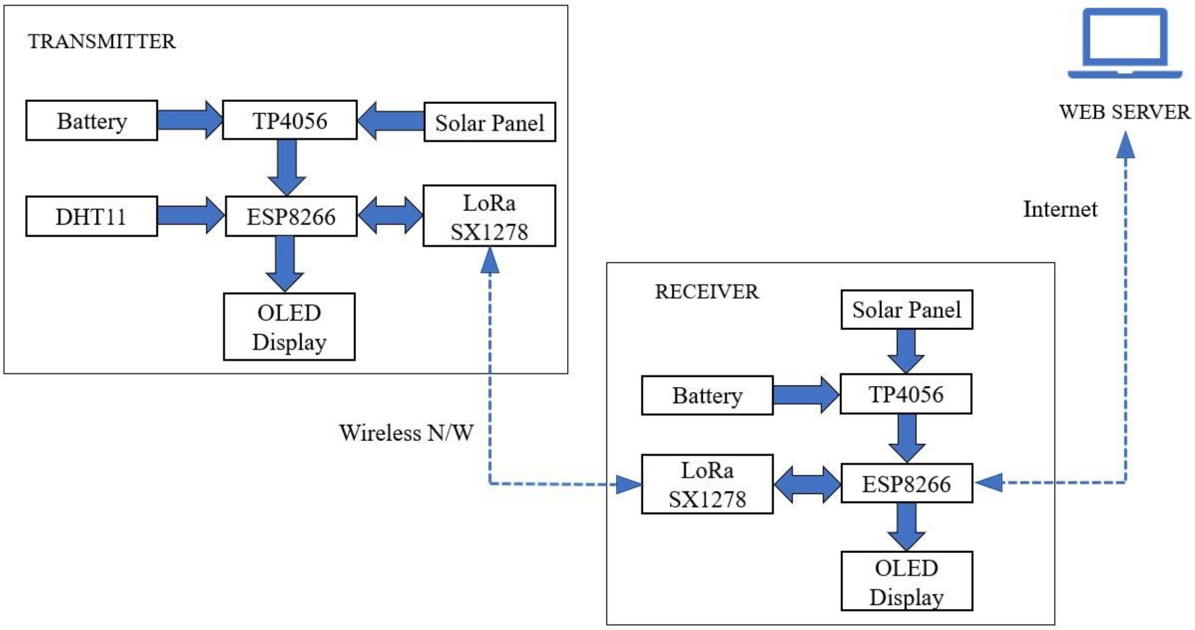

Fig.1 Block Diagram of the System

The following block diagram provides a detailed explanation of the intricate process involved in transmitting data from a sensor deployed in the environment to a cloud or web server through a LoRa (Long Range) communication system. The transmission process starts with the deployment of a sensor in the environment to collect relevant data. In this case, the sensor used is the DHT11, which is specifically designed to detect temperature and humidity levels. The device operates by constantly monitoring variations in its immediate environment, capturing them as electrical signals which are subsequently directed into a microcontroller - the ESP8266 - for further processing.The microcontroller, acting as a small computer, receives the data from the sensor and prepares it for transmission. The next stage in the data transmission process involves the use of a LoRa transmitter.

LoRa technology is a wireless communication protocol that facilitates low-power, long-range transmissions. It achieves this by utilizing spread-spectrum modulation, allowing it to transmit data over distances that would typically require much higher power consumption.. The transmitter sends the data from the microcontroller to the LoRa network, a collection of gateways that receives the data and relays it to the cloud or web server. LoRa technology is an ideal communication system for transmitting data over long distances, and it is especially useful in environments where traditional wireless

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technologies may not work. Once the cloud or web server receives the transmitted data, it processes, analyzes, and stores it for future reference. The data can be used for various purposes, such as monitoring the environment, tracking assets, and analyzing user behavior patterns. The transmission process described above is a crucial aspect of modern-day data collection and management. It enables organizations to make informed decisions based on accurate and real-time data. In summary, the LoRa communication system provides an efficient and reliable method of transmitting data from sensors in the environment to cloud or web servers for processing and analysis. This enables organizations to monitor their environments, track assets, and analyze user behavior patterns, among other applications.

CIRCUIT DIAGRAM:

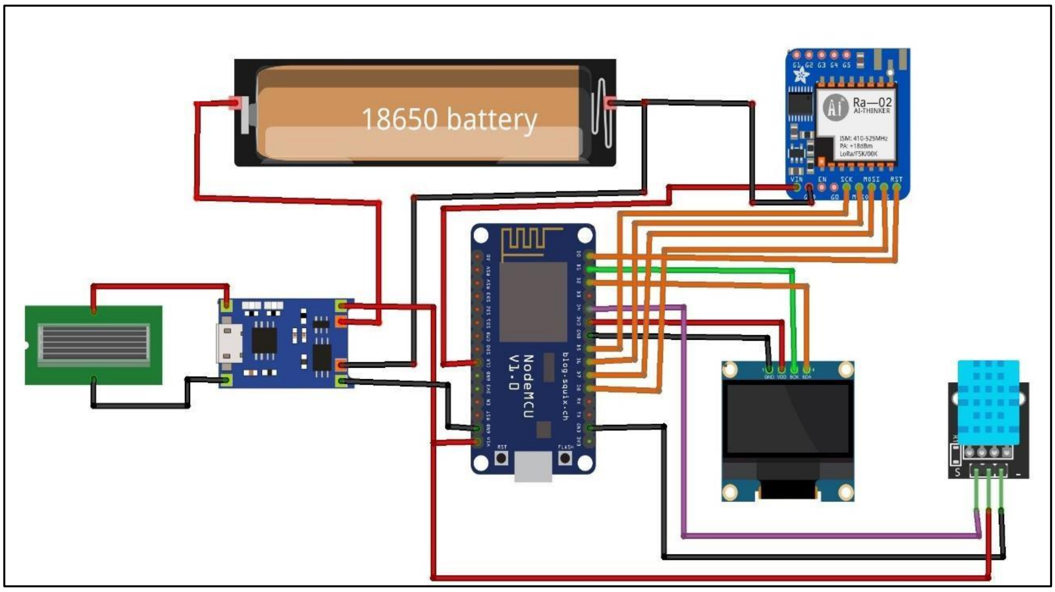

Fig. 2 Circuit Diagram of Transmitter Module

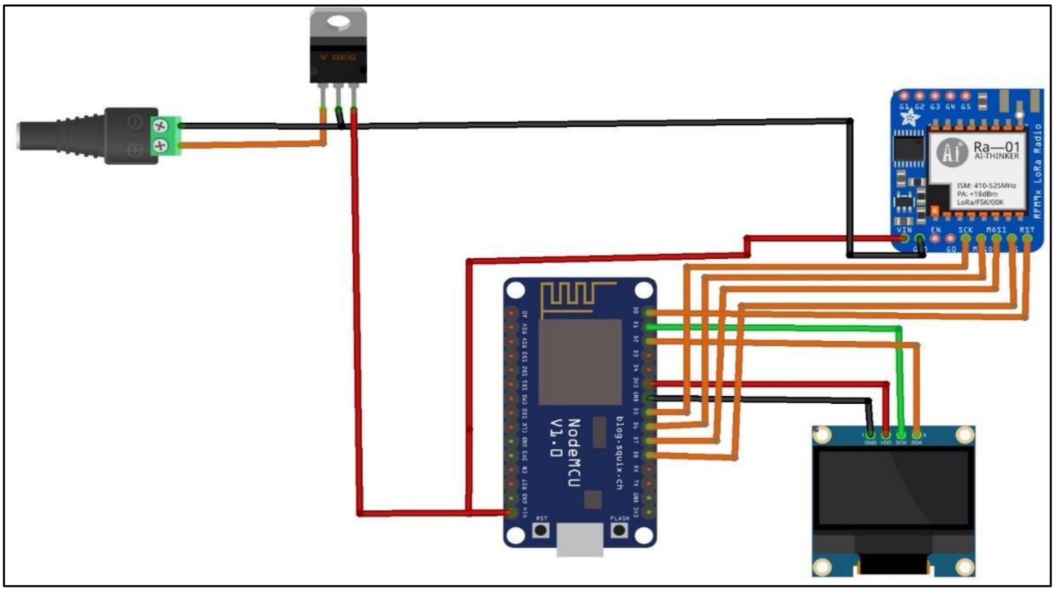

Fig. 3 Circuit Diagram of Receiver Module

HARDWARE DISCRIPTION:

ESP8266 – NodeMCU :

The ESP8266-NodeMCU is a microchip manufactured by Espressif Systems in Shanghai, China, designed to enable microcontrollers to connect to Wi-Fi networks and establish basic Transmission Control Protocol/Internet Protocol

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Fig.4 ESP8266

connections. This module is cost-effective and compact, making it a popular choice among developers. It comes with 64 KiB boot ROM, 80 KiB of user data RAM, and 32 KiB of instruction RAM pre-installed for optimal performance. The ESP8266NodeMCU supports Wi-Fi 802.11 b/g/n operating around 2.4 GHz, and it comes with 16 GPIO, Inter-Integrated Circuit (I²C), Serial Peripheral Interface (SPI), 10-bit ADC, and I²S interfaces with DMA. With this feature set, the module can communicate with other devices, sensors, and modules to create a wide range of IoT applications. The module can access external QSPI flash memory through SPI, supporting up to 16 MiB for enhanced storage. This external memory provides additional storage space for program and data storage, enhancing the module's capabilities for more complex applications.

Furthermore, the ESP8266-NodeMCU is equipped with a built-in memory ranging from 512 KiB to 4 MiB to further enhance its performance. This memory provides the necessary resources to store firmware, data, and other essential elements that help to boost the module's processing speed and overall performance. Overall, the ESP8266-NodeMCU microchip is an ideal solution for creating IoT projects that require a Wi-Fi connection. Its small size, extensive feature set, and built-in and external memory options make it a versatile and cost-effective option for developers.

LoRa Module Ra-02 SX1278 :

Fig.5 LoRa Module

The Ra-02 is a transmission module that utilizes SEMTECH's SX1278 wireless transceiver to establish wireless connections. It uses advanced LoRa spread spectrum technology and can communicate up to a distance of 10,000 meters (10 km). The module is resistant to jamming and features air wake-up consumption. The SX1278 RF module is designed primarily for long-range spread spectrum communication, and it can minimize current consumption.

DHT11 Sensor :

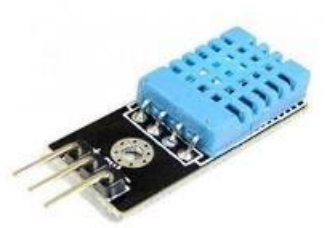

Fig.6 DHT11 Sensor

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The DHT11 is a simple and cost-effective digital sensor used to measure both temperature and humidity. It utilizes a capacitive humidity sensor and a thermistor to detect the temperature and humidity levels in the surrounding environment. Unlike other sensors that require analog input pins, the DHT11 provides a digital output on the data pin, which makes it easier to use. However, to obtain accurate readings, precise timing is required. The DHT11 sensor is equipped with a high-quality resistive-type humidity measurement component and an NTC temperature measurement component. It can interface seamlessly with an 8-bit microcontroller, ensuring high performance, quick response times, and anti-interference capabilities. Additionally, each DHT11 component undergoes rigorous laboratory calibration to guarantee accurate humidity measurement. The DHT11 sensor is an excellent choice for basic temperature and humidity measurement applications that require accurate readings, low cost, and ease of use. It is commonly used in environmental monitoring systems, HVAC systems, and home automation systems.

OLED Display :

Fig.7 OLED Display

The OLED displays discussed in this context are small in size, approximately 1 inch diagonally, but offer high legibility owing to OLED technology's high contrast. The display comprises an array of individual white OLED pixels, with each pixel controllable by the integrated controller chip. The OLED technology's self-illuminating property negates the requirement for a backlight, which is why the display has such high contrast. The breakout is versatile, supporting both SPI and I2C interfaces, and its interface can be selected by soldering two jumpers on the back. The OLED design is fully 5V-ready, with an onboard regulator and built-in boost converter. This feature makes it easy to connect the display directly to your 3V or 5V microcontroller.

Lithium-Ion Battery :

Fig.8 Lithium-Ion Battery

The 18650 Battery is a cylindrical lithium-ion cell that has gained widespread use as a reliable and rechargeable power source for a wide range of portable devices, including laptops, flashlights, power tools, and electric vehicles. Its model number is based on its dimensions, with the fifth digit indicating that it is a cylindrical cell. Its compact size, measuring 18mm in diameter and 65mm in length, makes it compatible with a variety of devices.

The battery features an internal protection circuit and has a maximum voltage of 4.1V when fully charged. During discharge, lithium ions travel from the negative electrode through the electrolyte to the positive electrode, generating a flow of electrons that can be harnessed to power devices. When recharged, this process is reversed, allowing for the battery to be reused. Lithium-ion batteries are renowned for their high energy density, which allows them to store more energy than other types of rechargeable batteries. They also exhibit minimal self-discharge, meaning they retain their charge for longer periods of time, and are not susceptible to memory effect, which is a phenomenon where batteries gradually lose their maximum energy capacity after repeated partial discharges.

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In summary, the 18650 Battery is a reliable and rechargeable lithium-ion cell that is commonly used in a wide range of portable devices due to its compact size, high energy density, and ability to retain its charge over time.

Solar Panel :

Fig.9 Solar Panel

Rather than using an AC power source, we have opted to power the hardware using a Lithium-ion battery. In order to recharge the battery, we have selected a 4V/1A solar panel and paired it with the TP4056 charging module. We specifically chose a solar panel with a small size that is compatible with the maximum charging current of the TP4056, which is 1 amp. It is important to note that the solar panel is not intended to be the primary source of power for the hardware, but rather it serves the purpose of recharging the battery. This approach offers a sustainable and eco-friendly way to keep the hardware operational without relying on traditional electricity sources. The battery can store energy from the solar panel and use it when needed, allowing the hardware to operate even in the absence of sunlight..

TP4056 Charging module :

Fig.10 TP4056 Charging Module

The TP4056 is an efficient charging module that has been specifically designed to charge Lithium-ion cells with a 3.7V rating. It is important to charge rechargeable batteries with the right voltage and current, as improper control can lead to damage and overcharging. The TP4056 charging module is a low-cost and reliable option that ensures better efficiency and durability. It is equipped with an automatic cut-off mechanism that stops charging the battery once it reaches full charge, preventing overcharging and any potential damage. Additionally, the module has a safety mechanism that disconnects the charging process if the battery temperature rises too high, which helps protect against thermal runaway. This charging module utilizes the constant current/constant voltage charging method, making it ideal for charging single-cell lithium batteries..

4. WORKING

Our proposed system involves the development of a low-power IoT device for transmitting data from non-network areas, such as rural areas or forests, to the cloud. To accomplish this, we will create a wireless sensor network (WSN) that consists of two modules. Module 1 will serve as the sender and will be responsible for sensing information from various sensors. This data will be processed using a microcontroller (ESP8266) and then transmitted to the receiver module via a Long Range (LoRa) module. The receiver module will act as a gateway and will receive the information transmitted by the sender. The microcontroller (ESP8266) on the receiver side will then transmit the data to the cloud using either GSM or WiFi technology to connect to the internet.

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To display real-time status on both the transmitter and receiver sides, low-power OLED displays will be used. Since a power source is not readily available on the transmitter side, a solar panel, charge controller (TP4056), and battery (2200mAh) will be used to power the device. The solar panel will have a small size of 4V, and the charge controller will ensure efficient charging of the battery while protecting it from overcharging. Furthermore, the data collected from the sensors will be stored in a database and analyzed using a web application. With the help of this application, users can view the collected data and gain insights into various aspects of the environment being monitored. Overall, this proposed system offers a reliable and efficient way of collecting and transmitting data from remote locations to the cloud, even in areas with limited power sources.

ADVANTAGES:

There are some advantages to using Smart Environmental Monitoring via LoRa-Enabled IoT Solutions:
1. Long Range
2. Low Power
3. High Scalability
4. Real time data monitoring
5. Cost effective
6. Data analytics

5. OUTPUT

The output of this project would be a working prototype of an IoT-based environmental monitoring system that uses LoRa technology for data transmission. The system would consist of sensors placed at different locations to collect environmental data such as temperature, humidity, air quality, water quality, soil moisture, and weather conditions. The data collected by these sensors would be transmitted to a central location using LoRa technology. The collected data would be stored and analyzed, and insights gained from the data analysis could be used to make informed decisions about environmental management. The system could also be used for early detection of environmental anomalies or hazards, allowing for timely intervention and mitigation measures. In addition to the hardware components, the project would also involve the development of software for data analysis and visualization. The software would provide a user-friendly interface to access the collected data and analyze it using various data analytics techniques. The results of the analysis could be presented in the form of charts, graphs, or other easily understandable formats.

output of this project would be a valuable tool for environmental management, providing real-time monitoring of environmental parameters in areas without traditional network access. It could also contribute to sustainable development by providing useful insights for decision-making in areas such as agriculture, water management, and urban planning.

6. RESULT

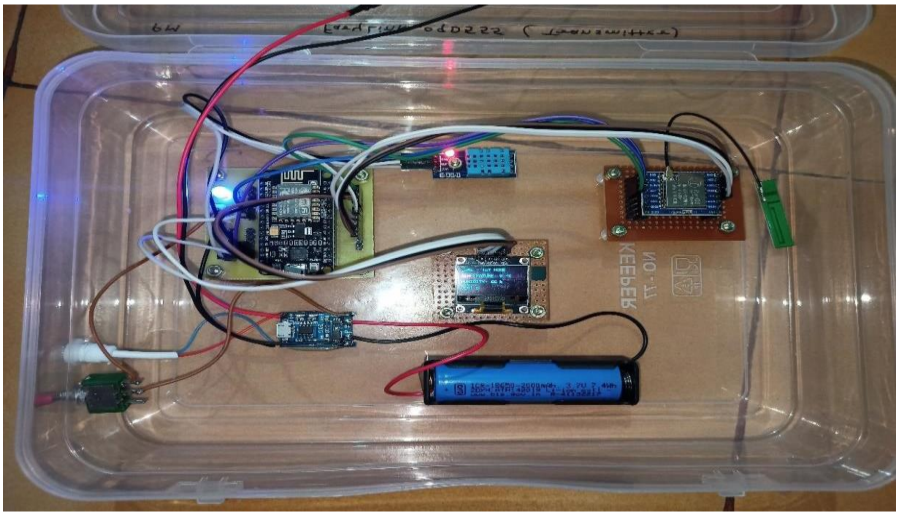


Fig. 11 Working State of Transmitter

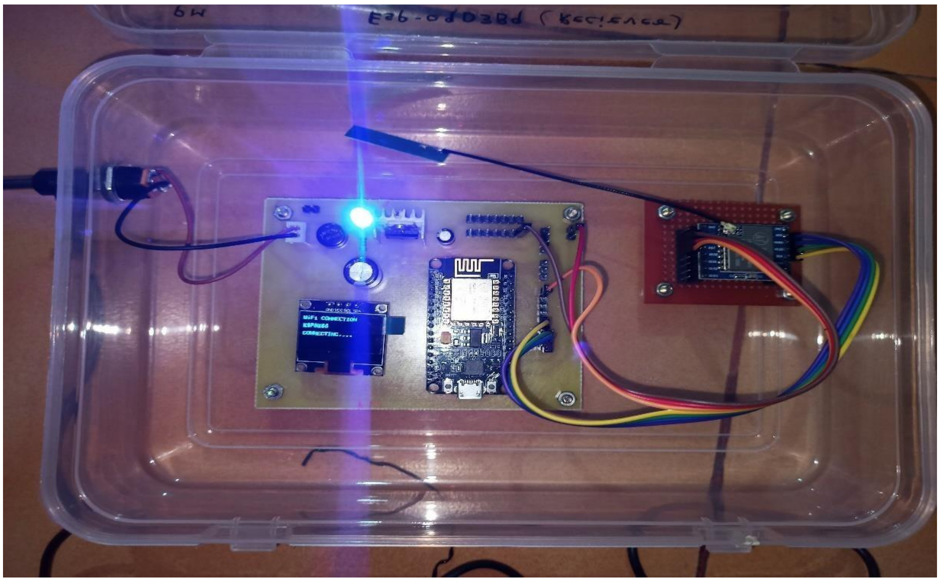
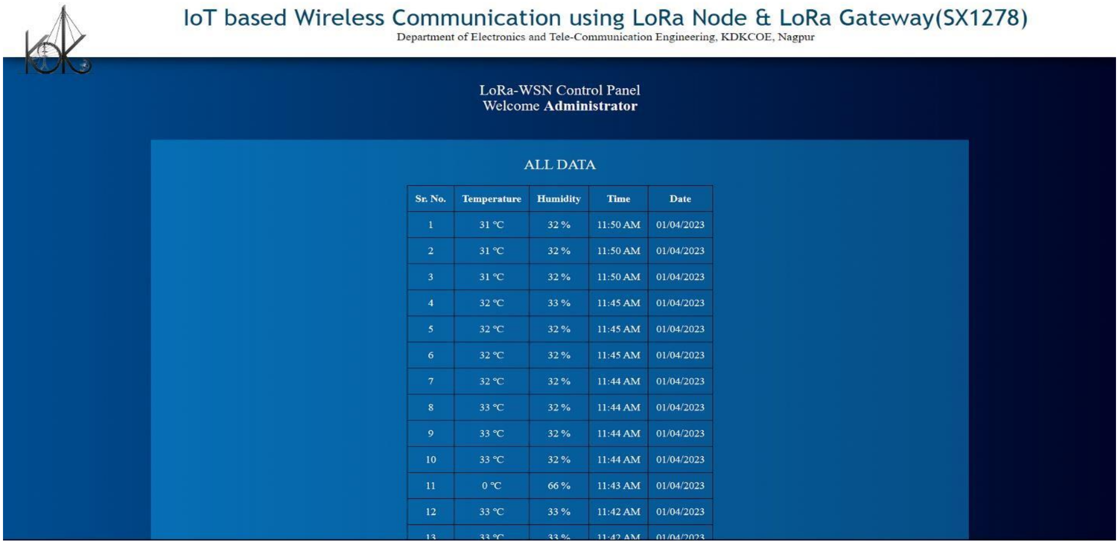


Fig. 12 Working State of Receiver



Sr. No.	Temperature	Humidity	Time	Date
1	31 °C	32 %	11:50 AM	01/04/2023
2	31 °C	32 %	11:50 AM	01/04/2023
3	31 °C	32 %	11:50 AM	01/04/2023
4	32 °C	33 %	11:45 AM	01/04/2023
5	32 °C	32 %	11:45 AM	01/04/2023
6	32 °C	32 %	11:45 AM	01/04/2023
7	32 °C	32 %	11:44 AM	01/04/2023
8	33 °C	32 %	11:44 AM	01/04/2023
9	33 °C	32 %	11:44 AM	01/04/2023
10	33 °C	32 %	11:44 AM	01/04/2023
11	0 °C	66 %	11:43 AM	01/04/2023
12	33 °C	33 %	11:42 AM	01/04/2023
13	33 °C	33 %	11:42 AM	01/04/2023

Fig. 13 Output on Website

7. CONCLUSION

In conclusion, the IoT-based environmental monitoring system that utilizes LoRa technology has numerous advantages over traditional monitoring systems, including long-range connectivity, low power consumption, high scalability, real-time data collection, and cost-effectiveness. The system has been shown to be a reliable and effective solution for monitoring various environmental factors and provides valuable insights that can inform decision-making and environmental management practices.

However, as with any technology, there are potential drawbacks to consider. These include limited bandwidth, interference, limited security features, distance limitations, limited functionality, dependence on gateway infrastructure, and reliance on battery power. Despite these challenges, the benefits of the system outweigh the disadvantages. It is ideal for deployment in remote areas where traditional infrastructure is not available and offers the flexibility and scalability necessary to monitor large areas effectively.

One of the key advantages of the IoT-based environmental monitoring system is its ability to operate for extended periods on a single battery charge. This feature reduces the need for frequent maintenance or replacement, making it more cost-effective and practical than other monitoring systems. In addition, the system can provide real-time data, allowing environmental scientists, policymakers, and other stakeholders to make informed decisions about managing and

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protecting natural resources. Looking to the future, there is significant potential for further research and development in this area. Future innovations could enhance the capabilities of the system, making it an even more powerful tool for environmental management. As environmental challenges continue to increase, the IoT-based environmental monitoring system using LoRa technology represents an essential step forward in our ability to monitor and manage the environment effectively.

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