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LoRa BASED SMART CITY AIR QUALITY MONITORING SYSTEM

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Abstract: The transformation of cities into smart cities is being done these days. Smart city initiatives responding to environmental problems such as air pollution ensure clean air. This paper introduces an automatic air quality monitoring system that monitors environmental conditions in real time. This proposed system is based on IoT technology and embedded systems. This system also includes electronic devices such as sensors to sense the environmental conditions and the Arduino Uno board for the system's performance. A LoRa module is introduced in this system for communication over long ranges. The communication modules such as Bluetooth, Zigbee, and Wi-Fi also can be used but LoRa is introduced in this system to communicate at long ranges. Bluetooth, Zigbee, and Wi-Fi are tended to be used for short-range communications as compared with the LoRa module. This project is a LoRa-based smart city air quality monitoring system the main purpose of this system is to monitor smart city environmental conditions such as temperature, humidity, rain, and pressure, and detect light and pollutants in the air. The values of these environmental parameters are stored on a cloud server that uses the LoRa Gateway for communication. Data can be monitored by the user from the cloud server and values are displayed in the form of graphs or tables.

Keywords: Sensors, LoRa, Internet of things, Arduino.

1. INTRODUCTION:

These days, the implementation of IoT applications has been affected in all domains. The IoT applications introduced till now have been implemented in real-time like controlling, managing, and monitoring the day-to-day usual actions of humans, environmental parameters, or animal moments. These IoT applications have made the life of humans easier than before. Many environmental monitoring systems have been proposed to measure and control the parameters.

Humans have been trying to analyze the environment for many years. So many things have been invented to measure the various parameters of the environment. For example, humans developed thermometers, barometers, and pyrometers to measure temperature, atmospheric pressure, and solar radiation. However, some legacy tools still need to be used locally. On the other hand, the invention of IoT has made everyday scenarios easier. The procedure to measure the environmental parameters also becomes easier than before. In this proposed system, the measurement of the environmental parameters will become easier as we have included the LoRa module along with the IoT system. This helps us to communicate in the long range. In this system, transmitters are placed at different locations to monitor environmental parameters at different locations. The transmitter contains various sensors used to measure environmental parameters such as rain, light, temperature, and humidity. This system is proposed for smart cities to make the life of city citizens more convenient.

In Section 2 of this white paper, we did some research on the system. The working of the system is provided in section 3. System implementation and design are provided in Section 4. System results and discussion are provided in Section 5. And finally, Section 6 completes the thesis.

2. Literature Review:

Many recent applications have been introduced to measure various air parameters and remotely monitor air quality. IoT has made people's lives more convenient by introducing these applications. This application monitoring also includes websites, software, or mobile applications for visualizing received values or monitoring systems. An indoor air quality monitoring and control system which was Wi-Fi enabled is introduced in the year 2017 by Xiaoke Yang, Lingyu, and Jing Zhang. this indoor air quality monitoring system is based on IoT smart home architecture, designed to monitor indoor air quality, The raspberry Pi and numerous sensors were employed as hardware, and Excel was used for the software processing. The indoor environment is assessed based on the experimental results. This system is helpful to improve the living quality in all residences and maintain good indoor air quality. This is also helpful for children and people with allergies caused by the air.

A LoRa-based low-power real-time air quality monitoring system using LPWAN was introduced by Sujuan Liu, Chuyu Xia, and Zhen Zhen Zhao in the year 2016. This is an air quality monitoring system used to monitor outdoor air quality—this LoRa-based real-time project. To monitor the area approximately 2 km LoRa has been used. The transmission power used here is only about 110 mA. This is low cost compared to other wireless technology. Here, a single-chip microcontroller and several air pollution sensors are used. This is a solar PV-battery-based system. GUI is also used in this system. Four electrochemical sensors were used to make the air quality data more stable and accurate. In this system, the measuring and monitoring of gas concentration and PM concentration were done.

Giovanni B. Fioccola and his team from Napoli, Italy have introduced a system to measure and monitor cloud-based air quality and IoT based. They named this system Polluino. The monitoring of air pollution is done via Arduino and air quality sensors. They also stored the data by establishing a cloud platform. A comparison between two cloud computing services models and between two IoT communication protocols is performed. This approach led to a power saving of up to 47%. This Polluino prototype is helpful in terms of both cost and performance.

An embedded system model for air quality monitoring is introduced by Sneha Jangid and Sandeep Sharma. This system is presented to facilitate the assessment of health impacts caused due to indoor as well as outdoor air pollutants and can intimate the human prior about the risk he/she going to have. This is focused on the context of allergic patients. The tool will inform them that they can secure themselves without experiencing the risk factors. The equipment is based on the microcontroller equipped with a gas sensor, optical dust particle sensor, and humidity and temperature sensor. These monitor the pollutants in the air parameters and store them in the tool which is monitored by the user.

An IoT-based mobile air pollution monitoring system is introduced by Swathi Dhingra and her group which named it as IoT-Mob air. In this system, a three-phase air pollution monitoring is introduced. The IoT Kit was prepared using sensors, Arduino, and a Wi-Fi module. It is most useful for smart cities. In this system, the pollution level of the entire route is predicted, and a warning is displayed if the pollution level is too high.

In 2016, Rao et al. We propose a weather monitoring system that utilizes IoT. The system measures environmental parameters such as temperature values, light intensity, and CO content. Similarly, in the same year, a weather visualization system based on a wireless sensor network was introduced by Ram and Gupta. The latter was able to record temperature, light, and humidity values from the environment. The values are sent to his web page for monitoring by the user.

In 2017, Kumar and Jasuja teamed up to propose a new system based on IoT technology, including a Raspberry Pi board. The system measures ambient temperature, carbon monoxide, carbon dioxide, pressure, and humidity to assess air quality.

In 2018, Reddy et al. Introduced a low-cost weather monitoring system that utilizes IoT technology. The system uses multiple sensors to detect ambient air conditions, including hydrocarbons, sulfur dioxide, nitrogen oxides, and more. When hazardous gas is detected, the system will trigger a warning alarm and send an SMS to the end user. Historical measurements were saved in the database.

In late 2019, Durrani et al. Introduced an intelligent weather station for monitoring weather parameters. Different sensor nodes are deployed to collect data from different locations in this system. Data is sent to the cloud. In addition, machine learning algorithms can be used to predict future station weather.

3. WORKING:

Air pollution has become a growing concern in recent years due to its determinantal effects on health and our environment. This problem is especially present in urban outskirts due to heavy traffic and industrial emissions. Studies show that the air in our homes is even more polluted than the air outside.

This project presents a real-time, long-range system for monitoring air pollution in both indoor and outdoor environments. The system implements a wireless sensor network using Lora Long-Range, Wide-Area Networking Protocol (WAN) technology for data communication between all nodes and sensors. The system consists of sensor nodes located at a certain distance from the gateway that measures the concentration of VOCs (volatile organic compounds), carbon dioxide (CO2), and PM (particulate matter). Increased Ranges achieved are up to 900 meters and results can be viewed via a web-based client BlynkIoT. My experiments on Lora WAN transmission have shown that Lora WAN technology works well in air pollution systems, especially long-distance transmission.

The sensors are connected to the NodeMCU (ESP-WROOM-32) and it is connected to the LoRa module and the power supply board. This connection is made as the transmitter section it is connected to the antenna the receiver section also contains an antenna, LoRa module, and the NodeMCU (ESP8266MOD) the transmitter is taken as the sensor node and placed at different places in the smart city the sensor node antenna is communicated with receiver antenna which is called as the gateway. The data will be received by the gateway with the help of the transmitter and receiver LoRa module and sent to the cloud to monitor it remotely in the application BlinkIoT.

The temperature, and Humidity sensor, rain sensor, LDR sensor, and Air quality sensor are connected to the NodeMCU ESP-WROOM-32, and the LoRa module is also connected to the NodeMCU. We have taken NodeMCU ESP-WROOM-32 at the transmitter side and NodeMCU ESP8266MOD at the receiver side. Both transmitter and receiver LoRa Ra-02 are connected to the NodeMCUs at the transmitter and receiver sides.

The code is written in the Arduino IDE for the sensor node and the sensors to measure the environmental parameters.

The measured environmental parameters data are sent to the gateway (receiver) from the sensor nodes (Transmitter) by using transmitter and receiver LoRa modules. The received data is sent to the cloud using a Wi-Fi ESP8266 module. The data can be monitored in the BlynkIoT application remotely in both mobile and web dashboards.

The results will appear in gauge and graphical form. The temperature is shown in °C, humidity appears in %, light resistance appears in %, the air quality appears in ppm up to 1000 units of measurements, and the rain sensor result is it turns into blue colour when it rains and it turns white when there is no rain.

4. SYSTEM IMPLEMENTATION:

This proposed paper is designing and implementing a LoRa-based smart city air quality monitoring system. The system consists of several sensor nodes used to measure environmental parameters such as temperature, humidity, rain, light resistance, and airborne contaminants. A transmitter is created by connecting all the sensors, a NodeMCU board, and a LoRa module. These sensor nodes read pollutants in the environment. These sensor nodes are placed in various locations. Data from each sensor node is sent through the LoRa module to the LoRa gateway to the receiver, transferred to the cloud, sent to BlynkIoT's web server, and accessed by smartphones over the internet.

4.1. Transmitter section:

This transmitter section consists of a LoRa module, a NodeMCU ESP-WROOM-32, and sensors for measuring air quality, rain, light resistance, temperature, and humidity. The DHT11 temperature and humidity sensor is used in this system to measure air temperature and humidity. The temperature is measured in °C and the humidity is measured in %. The MQ135 sensor is an air quality sensor for detecting harmful contaminants in the air. The air quality is measured in PPM up to the value of 1000. A rain sensor is used to detect rain. A NodeMCU ESP-WROOM-32 is used to process sensor readings according to pollutant parameters.

NodeMCU ESP-WROOM-32

The system uses a LoRa module as a communication medium between the transmitter and receiver parts, acting as a LoRa gateway. The LoRa module is used here for long-range communication and consumes very little power.

Each transmitter is assigned an address number. Transmitters transmit sensor data with addresses. Recipients use these address numbers to identify the source of the data sender.

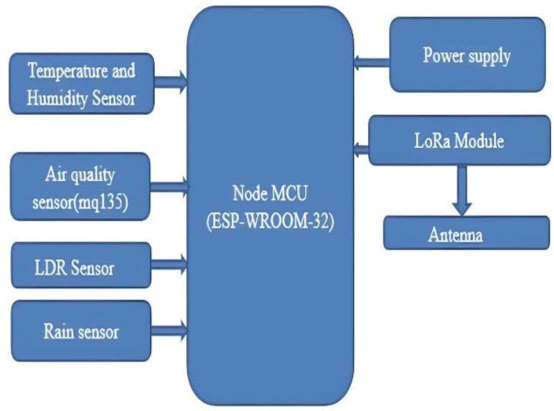

Figure 1: Transmitter Section.

4.2. Receiver section:

This section receives data from the transmitter section and forwards it to the BlynkIoT server. The receiver part consists of a NodeMCU (ESP8266), the LoRa module, and the receiver antenna. The NodeMCU board connects to Wi-Fi networks via the ESP8266 module, making it suitable for data transfer to the cloud.

The receiver identifies the source of the data received from the sender. The received data is forwarded to BlynkIoT servers. The receiver receives data from various transmitter sections and transfers it to the BlynkIoT cloud server, where users retrieve the information via their mobile phones.

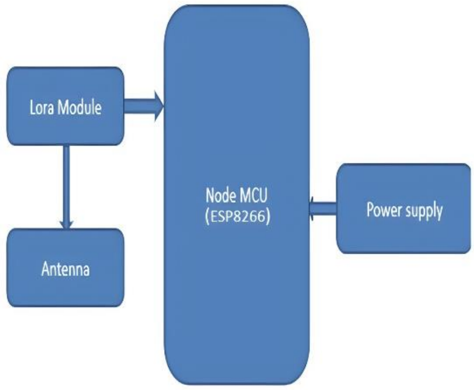

Figure 2: Receiver Section.

4.3. Software Requirements:

The proposed system requires code for the sending node to collect the data and send it to the receiver. The recipient also has to transfer the data to the cloud on her server. Therefore, a separate code was also developed for the receiver. Data from the receiver to the cloud server is transferred via WLAN. Data is visualized in gauge and graphical format in the BlynkIoT server.

The software used for the system is the Arduino IDE. Send and store data using the BlynkIoT server as a cloud and display data on your phone.

4.4. LoRa Specifications:

LoRa was introduced as a modulation technology in 2010 by the French start-up Cycle, which was acquired by SEMTECH in 2012. LoRa's sensitivity reaches up to -148 dBm with a diffusion factor of 12. A typical range for LoRa is 3 km in urban areas and 14 km in rural areas. LoRa technology offers numerous solutions. LoRa's battery life is up to 10 years. LoRa modules can connect to many end devices and offer Class A, Class B, and Class C based on different power consumption and delay capabilities. Class A offers the lowest energy consumption. A battery-powered class B device with a controlled delay downlink to ensure efficient power consumption. The Category C device will continue to communicate and listen on the second RX2 until the end node device starts sending another message. This category is designed for manually loaded devices.

LoRa Module

5. FUTURE SCOPE:

Proposed pollution monitoring system. Overcame many of the shortcomings of the conventional Pollutant measurement system that also relies on radio transmission technology within 100 meters of Coverage such as Zigbee and Wi-Fi. The proposed system is a low-cost system, with no phone/data charges, etc. The cellular system, small in size, and long-range is sent in real-time. Based on the practical examination. This system has been proven both indoors and outdoors ability to detect contamination and classify the degree of contamination. Compared to other wireless transmission technology, the technology is very suitable for air pollution systems, especially for long-distance transmission. Future studies may focus on improving the coverage. LoRa technology by adding a gateway to data traffic-crowded areas. Also, new types of sensors can be added to detect other related types of gases.

6. RESULT AND DISCUSSION:

There have been numerous devices for air quality monitoring. In all cases, the reliability of those used devices is not satisfactory and also shows different performances for laboratory and real-life scenarios. The LoRa devices with gateways and servers have been introduced and they have been helpful in fully covering the city area for monitoring air quality. This massive connectivity of several types of devices is proof of its scalability. Moreover, the cost of Lora WAN technology devices is made affordable to the customers. This use of wireless sensor networks using the LoRa module made the applications more flexible for monitoring remotely. In this regard, LoRa technology offers better performance.

The received data is sent to the receiver station from the transmitter section using the Lora module the received data is sent to the user's mobile and stored in the cloud from the receiver section. The data can be viewed in the BlynkIoT application on both mobile and web dashboards.

6.1. Circuit:

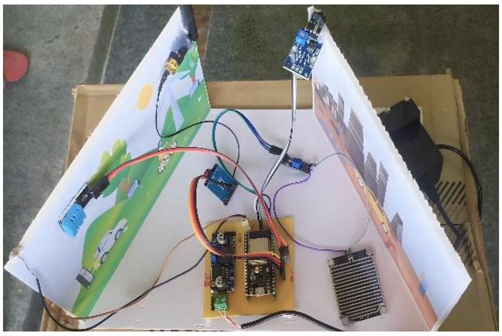

Figure 3: Transmitter Section

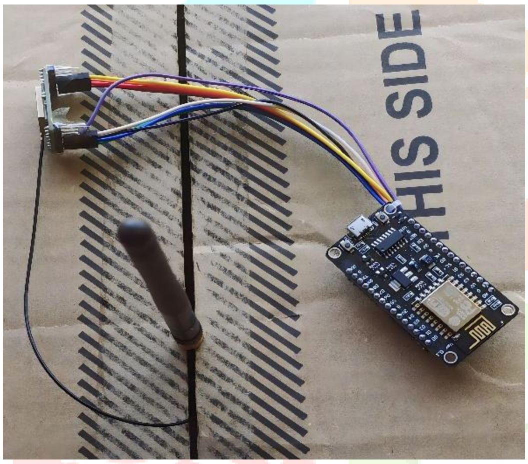

Figure 4: Received Section

6.2. Result in Mobile Dashboard:

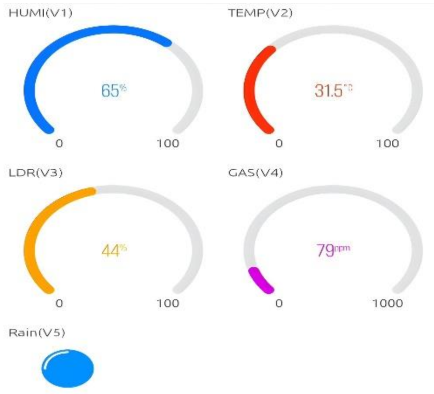

Figure 5: Gauge Representation of results of sensors.

Figure 6: Graphical representation of sensor results.

6.3. Result in Web Dashboard:

Figure 7: Gauge representation of sensors.

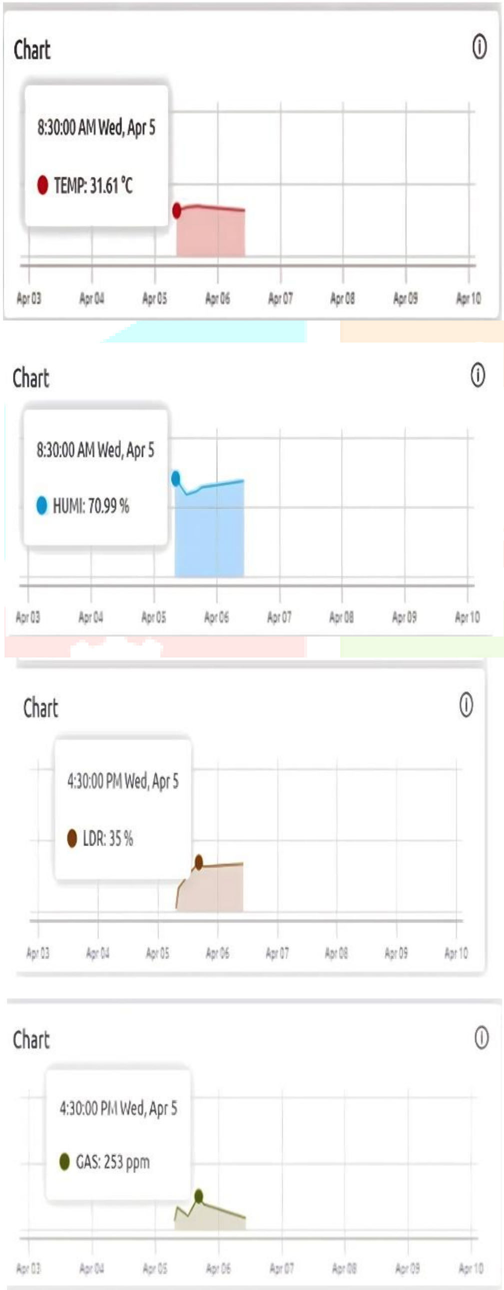

Figure 8: Graphical representation of sensor results.

7. CONCLUSION:

This air quality monitoring system is based on LoRa in this system, we have worked well to detect atmospheric changes. Change of exposure to CO, CO2, and PM. We have also detected the change in air Temperature and Humidity. The atmospheric pressure, rain, and environmental light intensity are also measured. Data from the sensor node is sent to the gateway and forwarded to the Blink IoT server. The communication system between transmitter and receiver has been tested with both outdoor and indoor scenarios. In the testing process, the transmitter was placed outdoors and the receiver has placed indoors and the transmitter was placed indoors to test the indoor environment parameters. Both transmitter and receiver devices can communicate up to long distances to 3 kilo meters.