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Implementation of Automated and Decentralized Pollution Monitoring System with Lo-Ra WAN

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Abstract

This paper proposes an IoT and Blockchain based distributed system for automated measuring and detection of air pollution. Comparable state of the art solution requires human interaction to assess the data or require high power consumption or space requirements or they are based on centralized architecture. The proposed pollution monitoring system here, on one hand, employs Lora to address the high-power consumption and low range transmission challenges of IoT protocol. On the other hand, it is designed to be fully decentralized by using the Ethereum block chain to store and retrieve the data recorded by IoT sensors. The IoT sensors used for this work are DHT11 (Temperature and Humidity sensor), MQ135 (Carbon-di-Oxide sensor) and MQ3 (Nitrogen-di-Oxide sensor). The Arduino NANO collects this information and transmit it to the receiver module using the Lo-Ra gateway. The receiver side has a Arduino UNO which is used to store this data in the block chain. Observation on four different types of sensors for temperature, relative humidity, Nitrogen-di-oxide (NO2), Carbon-di-oxide (CO2), revealed in high accuracy with the expected timelines of measurement of non-falsified experimental values collected and can be used as reliable evidence of presence of pollution.

1. Introduction:

Exponential global population growth since 1950 has raised serious environmental issues such as global warming and natural resources depletion. Drinkable water sources, clean air, wild life and human beings life are endangered by civilization and current industrial activities [1]. Even though some international authorities or even public and independent communities spent lots of effort in protecting the Earth from human-activity-triggered environmental problems, still there is a need for human-independent solutions which, automate the process of monitoring water and air quality to use the results of monitoring as a drive against pollution generators. State-of-the-art pollution measuring and monitoring solutions are based on applications which, require direct human interaction and they are designed based on centralized architectures which, mandate users to communicate with a central entity for storing and retrieving data known as, Trusted Third Parties (TTP)[4]. Main problems with previous solutions can be listed as implementation cost, high space requirements, mobility, human-interaction, centralization, high power consumption, lack of public access, and solutions that can support higher ranges of communications without the need for human interaction in reading the data captured by sensors[7]. In this work, to solve the problem of single point of failure (centralization) a block chain-based solution is proposed which, automatically integrates the data received from IoT sensors into the Ethereal Block chain (BC). BC provides solutions for storing back-linked blocks of data in a decentralized and distributed fashion [3]. For the first time, by using BC-based applications, trust to validity of stored data without the need for a centralized authority became possible. Also, the data in BC is publicly accessible. In design and implementation details of the proposed pollution monitoring system is explained [12-17].

2. Existing system:

In the existing system, GSM based environmental monitor system is implemented and SMS gateway is used for updating the server and the block chain technology is implemented for secure data transfer and monitoring.

3. Proposed System:

In the proposed system Lo-Ra and IoT based pollution monitoring system is implemented for industrial and environmental conditions. The sensor node is used for collecting the information and the block chain technology is implemented. In the block chain each node generates a key and the key is randomly changed for the security purposes and the sensor value is sent to the receiver node. The master continuously sends the frame of command to node for getting the sensor information, and the sensor node send the data to the master using the Lo-Ra protocol. The IoT sensors used for this work are DHT11 (Temperature and Humidity sensor), MQ135 (Carbon-di-Oxide sensor) and MQ3 (Nitrogen-di-Oxide sensor).

4. Block Diagram:

In this project, Arduino mega and Arduino based microcontroller is used, here the Arduino mega is 8bit microcontroller, and Arduino is 8bit Microcontroller. Arduino mega microcontroller is act as gateway and Arduino Microcontroller act as data Node. The master continuously sends the frame of command to node for getting the sensor information, and the sensor node send the data to the master using the LoRa protocol

Transmitter System

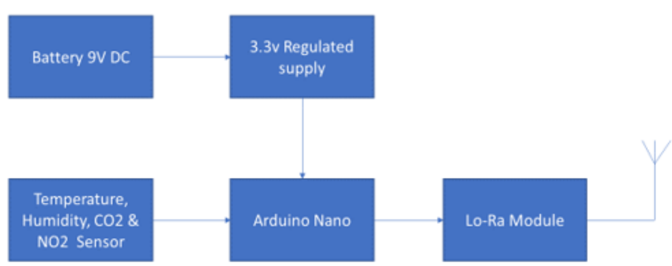

Fig 1: Transmitter block

Receiver System

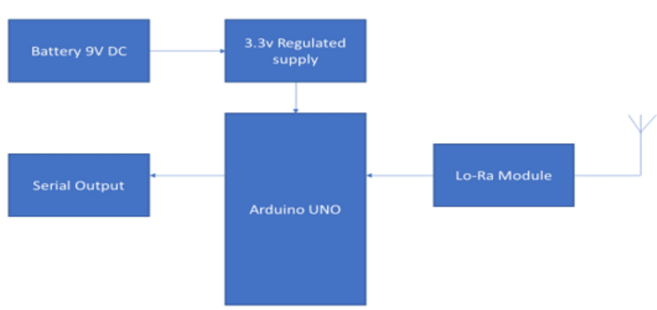

Fig 2: Receiver block

For collecting the data from the IoT modules, three sensors are connected to an Arduino NANO board. This module transmits the data which is then uploaded into the BC using Lo-Ra gateways. The implemented PMS provides IoT sensors connected to Lo-Ra boards (Lo-Ra sensor nodes) connected to

BC with an ELC installed on the Lo-Ra sensor nodes. In this approach an Arduino Uno is accompanying a Raspberry PI 3 (RPI) with inbuilt Wi-Fi module for connecting to the internet.

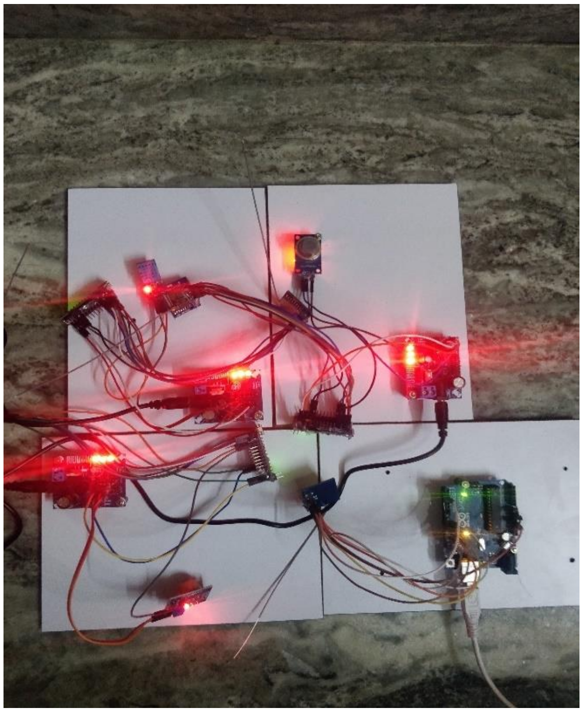

Fig 3: Experimental Setup

The RPI is used as a platform for ELC and Arduino Serial port communication. A JavaScript file running on the RPI and with help of NodeJS collects the recently received data by The Things Network (TTN). TTN decrypts the encrypted data sent from the Lo-Ra sensor nodes. Once the data is transacted by the ELC, it is available on the BC and the pollution data will be accessible over the BC network and in the PMS monitoring web page. A SC is developed to check the data received by sensors. Thresholds of the variables in SC are set according to the pollution standards. The ranges of pollution standards used in the SC can be specified depending on the regional standards during SC deployment. The developed SC is presented which includes functions for each measured factor of pollution with which, only violated values in the received data are detected and sent to the BC.

Program logic (Rx System):

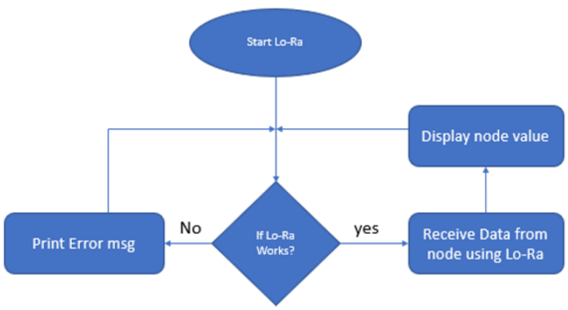

Fig 4: Flow chart of receiver System

Program logic (Tx system):

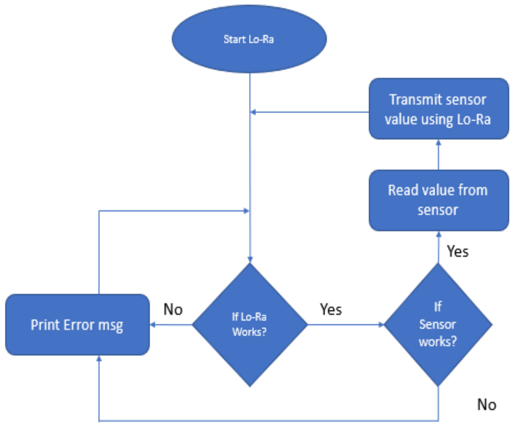

Fig 5: Flow chart of Receiver

The monitoring web application used for extracting data from BC and monitor them for further analysis accordingly. The web server stores all the data received by sensors, not only the violated data (the data which is out the standard range). This implementation decision was made to provide an additive trust, and also for increasing the functionality of the application by having all the data in hand to monitor every country and every city in the world based on both pollution generation and the standard thresholds.

6. Implementation

For collecting the data from the IoT modules, three sensors are connected to an Arduino NANO board. This module transmits the data which is then uploaded into the BC using Lo-Ra gateways. The implemented PMS provides IoT sensors connected to Lo-Ra boards (Lo-Ra sensor nodes) connected to BC with an ELC installed on the Lo-Ra sensor nodes. In this approach an Arduino Uno is accompanying a Raspberry PI 3 (RPI) with inbuilt Wi-Fi module for connecting to the internet.

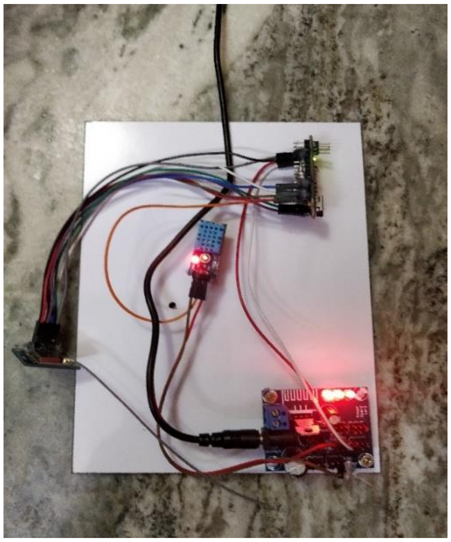

Fig 6: Temperature/Humidity module

The RPI is used as a platform for ELC and Arduino Serial port communication. A JavaScript file running on the RPI and with help of NodeJS collects the recently received data by The Things Network (TTN). TTN decrypts the encrypted data sent from the Lo-Ra sensor nodes. Once the data is transacted by the ELC, it is available on the BC and the pollution data will be accessible over the BC network and in the PMS monitoring web page.

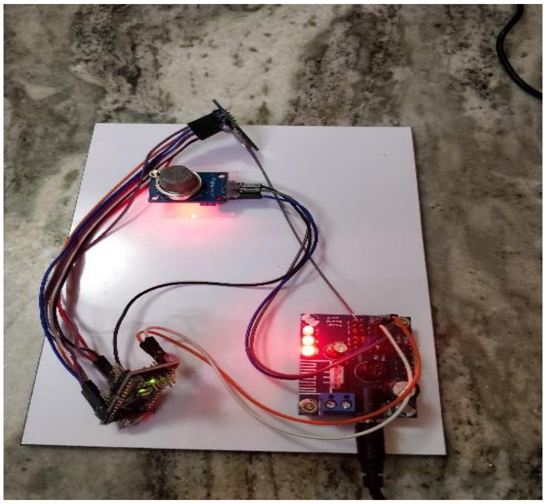

Fig 7: Carbon-di-Oxide module

A SC is developed to check the data received by sensors. Thresholds of the variables in SC are set according to the pollution standards. The ranges of pollution standards used in the SC can be specified depending on the regional standards during SC deployment. The developed SC is presented which includes functions for each measured factor of pollution with which, only violated values in the received data are detected and sent to the BC.

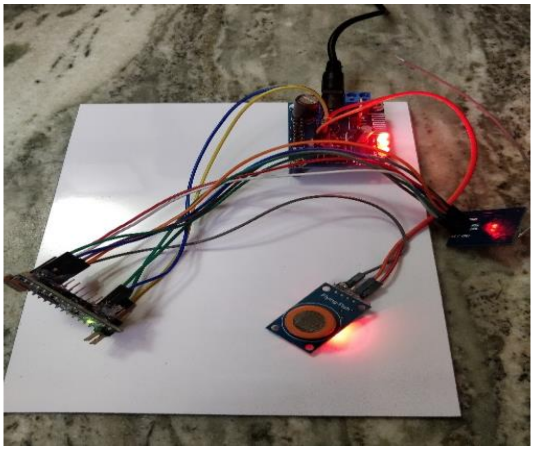

Fig 8: Nitrogen-di-Oxide module

The monitoring web application used for extracting data from BC and monitor them for further analysis accordingly. The web server stores all the data received by sensors, not only the violated data (the data which is out the standard range). This implementation decision was made to provide an additive trust, and also for increasing the functionality of the application by having all the data in hand to monitor every country and every city in the world based on both pollution generation and the standard thresholds.

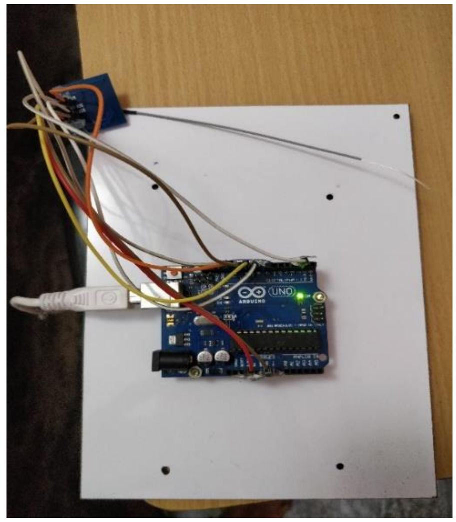

Fig 9: Receiver module

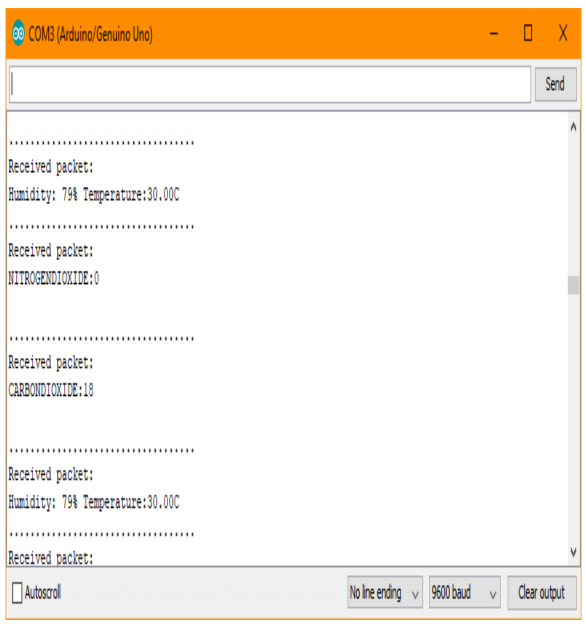

Fig 10: Output taken at Sathyabama College

7. Conclusion

A power-efficient, long-range communication enabled, automated, and decentralized IoT and BC-based pollution monitoring system is introduced, The proposed system on one hand, leverages the unique nature of BC by providing tamper resistant decentralized and trustable distributed systems, and on the other hand, employs Lo-Ra WAN communication protocol to provide long range and low power enabled communication. This helps in communicating with IoT sensors in environment far from gateways. For the first time, through this work ELC is deployed on Lo-Ra gateways which is a great advantage in combining IoT-based applications and BC-based systems.

The values observed while the device was placed in Chennai central railway station were as follows Carbon-di-Oxide: 24, Nitrogen-di-Oxide: 0, Temperature: 32 and Humidity: 86. The high value of Carbon-di-Oxide is due to the fact that the railway station is a highly dense area with lot of people moving from place to place and also due to the vehicles coming to drop the passengers at the railway station. Since the station is nearer to the sea the humidity level is also fairly high. The values observed while the device was placed in CMBT were as follows Carbon-di-Oxide: 22, Nitrogen-di-Oxide: 0, Temperature: 33 and Humidity: 72. The high value of Carbon-di-Oxide is due to the fact that the CMBT bus stand is a highly dense area with lot of people moving from place to place. Since the bus stand is far from the sea the humidity level is fairly low when compared with the levels observed at the railway station. The values observed while the device was placed in sathyabama college were as follows Carbon-di-Oxide: 25, Nitrogen-di-Oxide: 1, Temperature: 30 and Humidity: 79. The comparatively low value of Carbon-di-Oxide to the railway station, CMBT and airport is due to the fact that the sathyabama college is a moderately dense area with students and teachers being the only people present and the movement of only battery operated vehicles so there is minimal presence of Carbon-di-Oxide. Since the college is closer to the ECR beach the humidity level is fairly high. The values observed while the device was placed in Chennai airport metro were as follows Carbon-di-Oxide: 22, Nitrogen-di-Oxide: 1, Temperature: 33 and Humidity: 76. The high value of Carbon-di-Oxide is due to the fact that the airport is a busy place with lot of foot traffic. The presence of Nitrogen-di-Oxide might be due to the exhaust of planes.

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