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Review and Applications of Wireless Sensor Nodes for Environmental Data Monitoring and Analysis using Internet of Things

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Abstract: *The use of sensors in continuous monitoring of environmental data has the potential to provide sustainable solutions to the modern effects of extreme growth in industrialization, urban cities, and population, which pose a monumental threat to the environment. Big data generated from these wireless sensor nodes need to be cleaned and analyzed using the latest techniques of machine learning and data analytics. This work reviews the common Internet of Things architectures to monitor different environmental factors like temperature, humidity, air quality, and light sensors. These customizable sensor nodes can be used in various surroundings like agriculture fields, pollution control centers, waste management and thus help in the timely detection of unusual environmental parameters. This work also discusses in detail the most common system consisting of two sensor nodes and a gateway. The gateway collects data from sensor nodes at regular intervals and then shares that data for private channels so that we can analyze the data and make the appropriate decisions. The analysis follows the review of various applications. Analysis forms the basis of decision making which provides actionable items towards making a better environment. Finally, the steps involved in data analysis and decision-making are suggested.*

Keywords: Wireless Sensor node (WSN), Internet of Things (IoT), environmental monitoring

I. Introduction

The Internet of Things is the combination of embedded systems, which have sensors and actuators to interact with the physical world, and the internet, which provides ubiquitous remote and secure communication. In recent days technology advances help to grow the IoT domain rapidly. The fast- growing IoT field also has a few challenges such as sensing the physical world, connectivity issues, security, and power issues. IoT has tremendous potential to make the world a better place for the upcoming generations. The latest advances in IoT suggest promising improvements towards improving our lifestyle in the fields including but not limited to health monitoring, environment monitoring and management, agricultural improvements, parking management, and so on.

The global environment situation of the earth is becoming increasingly problematic and critical and there are a lot of parameters such as population, industrialization, which directly or indirectly affect the quality of the environment and results in a greater impact on the social and economic front of a human being. In order to provide the solution for a human to adapt to environmental change automated and continuous monitoring of the environment is needed. Environment monitoring can be defined as a rigorous process of sampling our most common environmental elements of air, water, and soil in order to study them, as well as derive necessary knowledge from this process and describe the quality of the environment. Temperature, Humidity, and CO2 are the basic parameters for most of these services. EMS has to play an important role in future smart cities for applications such as urban Air Quality, Weather forecasting, Protection of water supplies, etc

A wireless system is not only considered a single device but a collection of interdependent devices. The wireless sensor network is a self-configured network composed of a large number of sensors. WSNs provide an efficient and flexible monitoring system for indoor as well as outdoor applications. We implemented a star topology of WSN which contains two sensor nodes and one gateway device. Sensor node measures the surrounding temperature, humidity, and CO2 concentration in the environment with low power consumption, and transmits the collected sample readings to the gateway through Wi-Fi protocol.

After collecting sensor data from different sensor nodes, the gateway publishes the sensor node data on the cloud. The sensors are usually battery-powered which makes them readily portable.

Our review of various technical papers is summarized in the literature survey below. The various uses of WSN nodes in different fields can be found. The fields include precision agriculture, smart environment monitoring (SEM) systems using IoT, low-cost IoT sensors in environmental monitoring networks, etc.

II. LITERATURE SURVEY

In 2018, Jan Sramota, Amund Skavhaug, "RailCheck: A WSN-Based System for Condition Monitoring of Railway Infrastructure"[1], uses an autonomous, near-real-time system developed using IoT, WSN, and big-data processing. The performance of the system was potentially beneficial for the railway sector.

Vijay R. Shinde, Pankaj P. Tasgaonkar, R. D. Garg, [2]"Environment Monitoring System through the Internet of Things(IoT)", has developed a monitoring architecture using Raspberry Pi and IBM Cloud. The analysis helps in making helpful decisions.

In 2018, Dattatraya Shinde, Naseem Siddiqui[12], "IoT Based Environment change Monitoring & Controlling in Greenhouses using WSN" proposes a system that uses various sensors to check soil humidity and light. The system helps in maintaining the soil quality which is required to grow the particular crop properly.

In 2021, Ravesa Akhter, Shabir Ahmad Sofi [17], "Precision agriculture using IoT data analytics and machine learning", a thorough review on the use of IoT(sensors) and data analytics for precision agriculture was provided. We also understand the challenges faced by traditional farmers in adopting technologies to complement traditional farming.

In 2020, Ullo, Silvia L., and G. R. Sinha, "Advances in Smart Environment Monitoring Systems Using IoT and Sensors"[18], authors discuss how the advances in sensor technology, IoT systems make environment monitoring a truly smart monitoring system. We also find suitable standards for Wireless Sensor Nodes (WSN) discussed.

III. CASE STUDY AND PROPOSED ARCHITECTURE

We proposed the utilization of the Internet of Things to monitor diverse natural components like air quality, temperature, humidity, light, atmospheric pressure, rain, and dust. The architecture includes four parts, namely. sensor nodes, the gateway, cloud service, and a mobile application. The proposal suggests that sensor nodes are usually deployed in the fields to collect environmental data such as atmospheric pressure, light intensity, temperature, humidity, air quality, rain, dust, solar radiation, and fog. We are implementing two such nodes in our project work and one receiver as a gateway that will receive the data from WSN and send it to the cloud. A cloud service provider is used to channel the sensor values and store them.

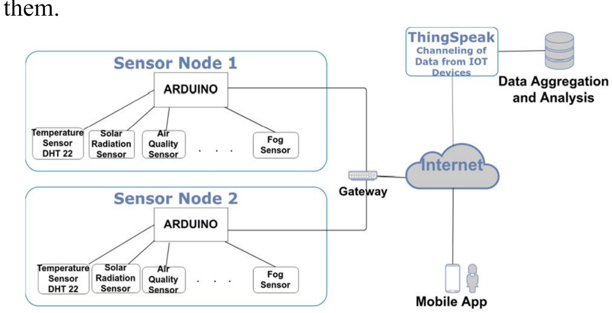

Figure 1: System Architecture

We calculated predicted values using the available dataset. The actual sensor data is used for comparison with predicted values. Mobile applications are also found to be an integral part of the IoT systems which allow end-users to view the data and perform further analysis. Thus, our system uses a similar mobile application that can be used to alert the stakeholders if environmental parameters cross safe predicted ranges.

3.1 Sensors

A. DHT22 Sensor - Digital Temperature and Humidity

The DHT22 combine the humidity sensor and digital temperature. A thermistor and a capacitive humidity sensor are used to measure the surrounding air. They give a digital signal on the data pin as output. DHT22 is suited for all kinds of harsh occasions because of its small size, low consumption, the long transmission distance of as long as 20m.

B. MQ-135 GAS Sensor - Air Quality Sensor

These sensors are used in air quality control sense for the system and are suitable for detecting NH3, NOx, alcohol, benzene, smoke, CO2, etc. It has lower conductivity in clean air. The conductivity of the sensor is higher along with the gas concentration rising when the target combustible gas exists.

C. Light Sensor

When there is no light, D0 output is high. When light intensity exceeds the threshold value, the module D0 output is low level. The module digital output D0 can be directly connected to the microcontroller. It can then detect high or low levels, which in turn can detect the environmental light intensity change.

D. BMP280 - Atmospheric Pressure Sensor

The BMP280 is an absolute barometric pressure sensor. It is the precision sensing sensor for measuring barometric pressure with ± hPa absolute accuracy, temperature with ±1.0°C accuracy, which is also low-cost.

E. GP2Y1010AU0F - Dust Sensor

GP2Y1010AU0F is a dust sensor that uses an optical sensing system. A phototransistor and an infrared emitting diode (IRED) are arranged diagonally into the device. The device detects the reflected light of dust in the air. It is very effective and thus used in air purifier systems. Additionally, it is smart to distinguish smoke from house dust by the pulse pattern of output voltage.

F. Rain Sensor

The rain sensor module is used for rain detection. It can be used for measuring rainfall intensity and as a switch when a raindrop falls through the rain board. This module also features a rain board and the control board, a power indicator LED, and an adjustable sensitivity through a potentiometer.

3.2 Wireless Sensor Node

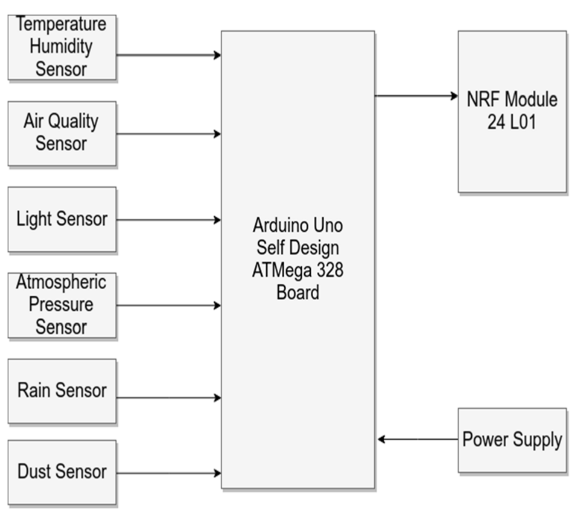

Fig 2. Wireless Sensor Node

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We are implementing two nodes in our project work and one receiver as a gateway that will receive the data from WSN and send it to the cloud. The WSN consists of the different environmental sensors discussed, which are connected to the ATmega328 based Arduino microcontroller. NRF module is a single-chip radio transceiver. The data from two deployed WSN will be sent to the gateway via the NRF module.

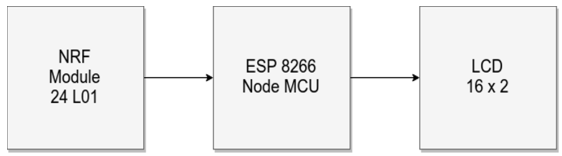

Fig 3. Receiver

Receiver uses the NodeMCU ESP 8266 platform for the development of IoT which will allow sending the data to the server. NodeMCU is an IOT platform that includes firmware running on ESP 8266 WiFi SoC from Espressif Systems and the hardware-based ESP-12 module.

3.3 ThingSpeak

ThingSpeak is an open cloud data platform where you can store and retrieve data.[14] ThingSpeak enables the creation of sensor logging applications, location tracking applications, and a social network of things with status updates. ThingSpeak acts as the IoT platform for data collection and data analysis that serves as a channel connecting sensor devices such as temperature and pressure sensors to collect data. ThingSpeak is very useful as the data collector which collects data from sensors of node devices and also enables the data to be analyzed by the software environment for historical analysis of data.

3.4 Machine Learning Model

A machine learning model is developed using the available dataset for temperature and humidity.[13] The details of the dataset are summarized in the following table:

Data collected	Temperature (°C),Relative Humidity
Start date	12/31/1978
End date	7/30/2014
Location Area (Nashik City)	North-east corner: 20.2219, 74.0938 South-west corner: 19.9007, 73.7422
Number of days(rows)	12929

The date-time variable is an independent variable and the temperature is considered the dependent variable. The temperature is predicted by using the available dataset. Reasons for using the linear regression model

- To include continuous and categorical independent variables.
- Multiple variables can be added to the model in the future
- Easy to implement for less amount training data Linear Regression though being the first step for statistical analysis yielded good results, as shown in the results section. The model fits perfectly and the coefficients obtained from regression were able to predict temperature for future dates.

3.5 Mobile Application

The measured parameters from the sensors are continuously updated and are thus viewed by the user using the Monitoring Application. Also the predicted values and actual values are shown on the mobile application. Notification service is used to indicate if values go beyond a safe range.

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IV. RESULTS

The following wireless sensor nodes were deployed:

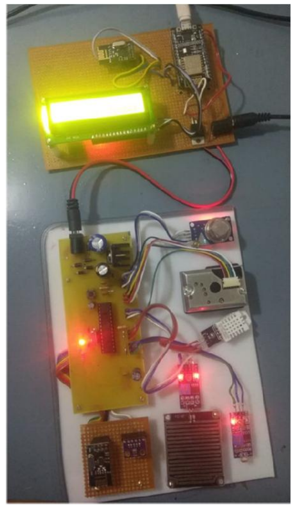
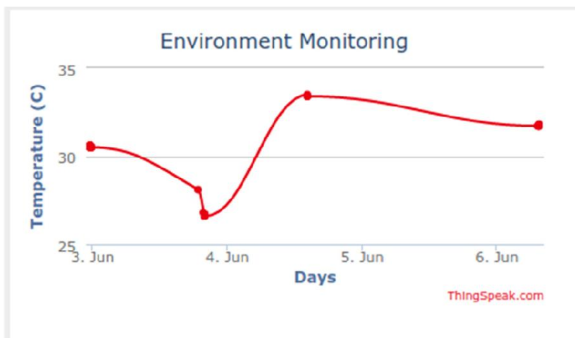
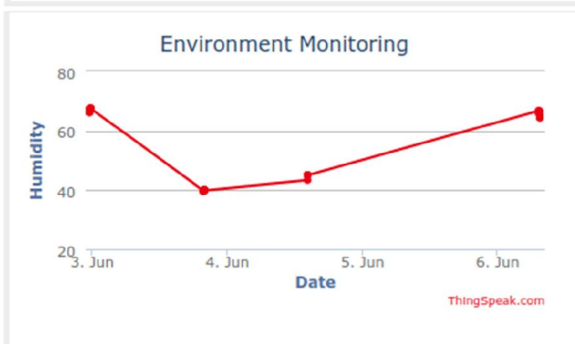


Fig 4. Receiver with LCD display and WSN mounted with environmental sensors

Graphs of collected data vs time received on the cloud service:





Temperature vs Year, linear regression model:

Temperature is predicted using a simple linear regression model specified by the following equation:

temperature = b * year + i

where b is the coefficient of the linear model and i is the intercept. After training the linear model we found out the values to be: b = 19.1773 and i = 0.0069

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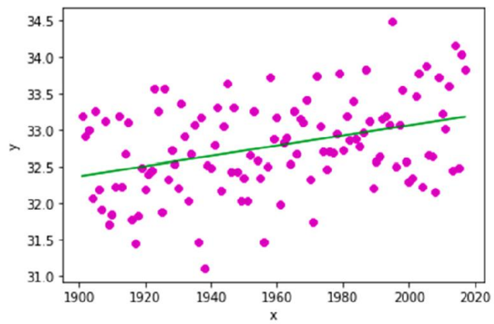

App screenshot:

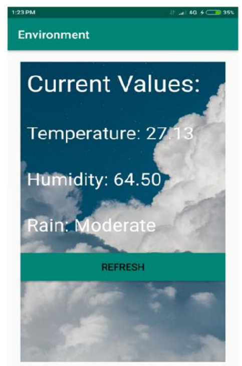

Fig. 5. App Screenshot

VI. Conclusion

This project has a multi-sensing capability that can monitor the environmental surroundings to provide alerts if the environmental conditions exceed the optimum range. The use of two nodes facilitates real-time values. Also, using more than one node gives us the flexibility to use this project in multiple surroundings. According to various applications, this project can be further modified to be used for industrial safety, campus monitoring, and environmental pollution detection.

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