"   Utilizing Internet of Things (IoT) technology for monitoring air quality   through the detection of particulate matter, with data processed and stored on cloud servers using the Online Think speak platform"

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Abstract

This paper presents a platform that uses Internet of Things (IoT) and cloud computing technologies to monitor both interior and outdoor pollution, enabling environmental quality assessment at any time and in any location. The system captures data at regular intervals from multiple locations inside and outside a room, providing valuable information for characterising the current conditions. Monitoring and reporting environmental factors such as gas levels, particulate presence, temperature, and humidity, the Pollution Monitoring System exemplifies the efficient application of technology. However, communication between sensing hardware devices and MQTT software protocols for online monitoring on any cloud platform presents a number of obstacles. To address these issues, IoT-enabled hardware devices are programmed to measure various air quality metrics and transmit the data to Thinkspeak analytics and the Cloud Platform for accounting and graphical representation. The system employs the MQTT protocol to establish communication between hardware devices and the cloud server. The primary objective of this research is to develop an Internet of Things-based air quality monitoring system that is both real-time and cost-effective. The system employs a dust level or particulate matter sensor for monitoring dust levels, while DHT11 sensors measure temperature and humidity. In addition, an ATmega328 controller with a NodeMCU ESP8266 development board equipped with a WiFi module is used to transmit readings to a ThingSpeak web channel platform, enabling immediate and real-time air quality display. The concentration level is graphically monitored through channels on ThingSpeak to facilitate remote communication. A threshold value has been established, so when pollutant levels reach high concentrations, the graphical curve rises to represent the increased particulate concentration level. Using NodeMCU and ThingSpeak, the study effectively designs a low-cost air quality monitoring system.

Keywords: *IoT, ThingSpeak, NodeMCU, ESP8266, DHT11, ATmega328, MQTT.*

1.1 Introduction

Indoor air quality refers to the environmental conditions within buildings and public facilities that can affect the respiratory and psychological health of individuals. Historically, monitoring indoor air quality was not a priority for public buildings such as retail centres, hospitals, banks, restaurants, and schools. However, the COVID-19 pandemic has highlighted the significance of indoor air quality due to the virus's rapid dissemination and negative effects. In contrast to external air, indoor air is continuously recirculated, resulting in the accumulation of contaminants that can contribute to viral transmission. There are numerous commercial methods for monitoring air quality, typically involving gas and particle sensors. This study proposes a cost-effective method for creating a standard pollution monitoring device using wireless technology, specifically the Internet of Things (IoT) and the cloud.

The paper describes the development of a cloud-based IoT system for air quality monitoring, accessible via a web interface or a cloud server. Air quality monitoring is a global concern for governments and individuals alike. Globally, governments have invested substantial resources in policies and solutions to address the issue of deteriorating air quality. Particulate matter emitted by industries, automobiles, equipment, waste recycling, industrial operations, and households causes air pollution. Heavy metal particles, carbon monoxide, ozone, carbon dioxide, nitrogen dioxide, suspended particulate matter, hydrogen fluoride, and sulphur oxides are among the notable pollutants. The release of these pollutants into the atmosphere has severe health and environmental effects.

1.2 MQTT Protocol:

MQTT is an OASIS standard for Internet of Things (IoT) communications. It is meant to be a very lightweight publish/subscribe message transport for connecting remote devices with a small amount of code and minimal network traffic. MQTT is currently utilised in numerous industries, such as automotive, manufacturing, telecommunications, oil and gas, etc.

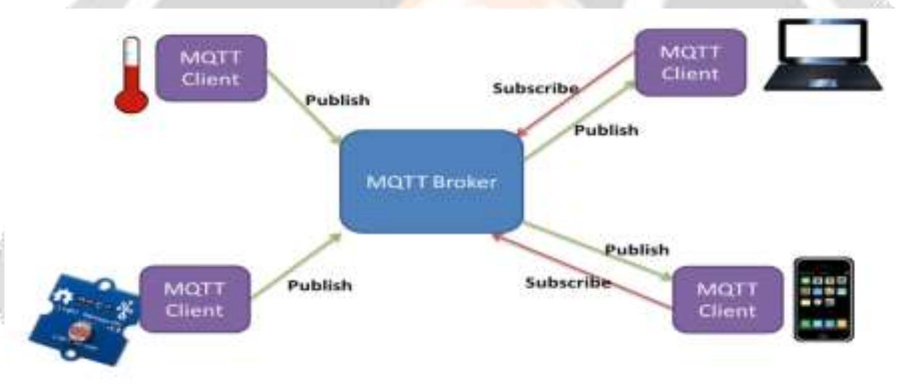

Fig :MQTT Publish/Subscribe Architecture

The primary advantages of MQTT are as follows:

1. Lightweight and efficient, reducing client and network bandwidth requirements.

2. Enables bidirectional communication between devices and servers, including the ability to broadcast messages to groups of items.

3. Scales effectively to handle large numbers of items.

4. Provides different Quality of Service (QoS) levels to ensure message reliability.

5. Supports persistent sessions, minimizing reconnection time over unstable networks.

6. Offers message encryption using TLS and supports client authentication mechanisms.

MQTT is a binary protocol where control components are represented as binary bytes instead of text strings. It employs a command and acknowledgment format, meaning that each instruction is accompanied by an acknowledgment.

1.3 System Structure:

Figure 1 depicts the implementation's architectural design. The six-pin pointed dust sensor GP2Y1010AU0F is utilised by the system to detect environmental contamination. Additionally, a DHT11 sensor is employed to measure the temperature and humidity of the environment. The GP2Y1010AU0F and DHT11 sensors are both connected to the atmega328 microcontroller, which is serially connected to the NodeMCU-12E ESP8266. The ESP8266 is additionally connected to the MQTT broker, which also functions as the results display mechanism. The analogue data are measured by the keen dust sensor GP2Y1010AU0F and then transmitted to the subscriber via the MQTT broker. The system can be divided into two sections: the first portion comprises the sensors and microcontroller, while the second section comprises the MQTT broker and the output display. As a network gateway, the ESP8266 NodeMCU-12E serves as the interface between the Sharp dust sensor (GP2Y1010AU0F) and the DHT11 temperature and humidity sensor.

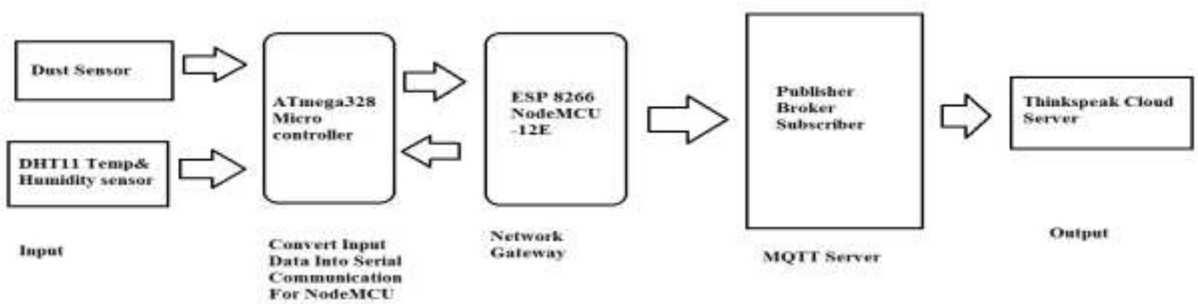

Fig : System Architecture

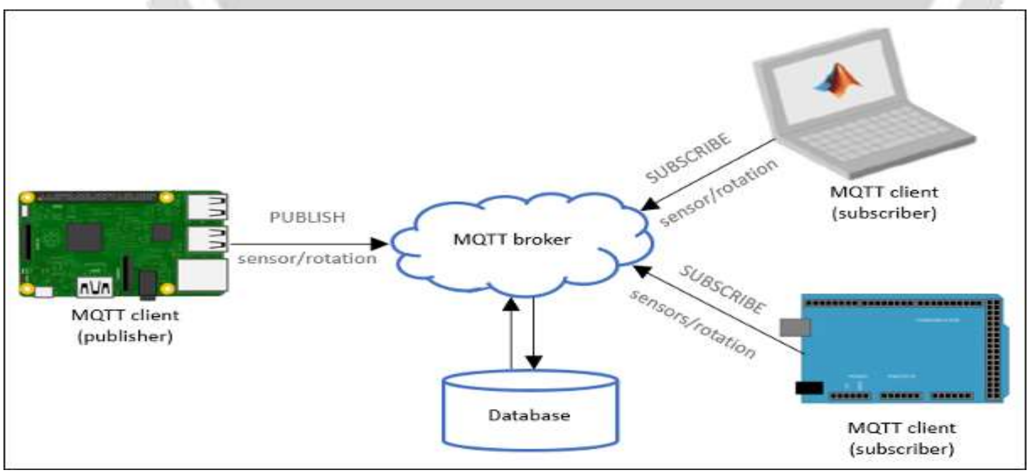

Fig: MQTT Basic Communication

1.4 ThinkSpeak

ThingSpeak is an open-source software platform that enables internet-connected devices to communicate. Ruby is the programming language used to implement it. This platform simplifiees data access, retrieval, and archiving by offering an API for devices and social network website integration. ThingSpeak was initially introduced in 2010 by ioBridge to facilitate IoT applications. MATLAB, a numerical computation programme from MathWorks, has been integrated into ThingSpeak. This integration enables ThingSpeak users to analyse and visualise submitted data using MATLAB without requiring a distinct MathWorks MATLAB licence. ThingSpeak has been featured in articles on "Maker" websites such as Instructables, Codeproject, and Channel 9.

Fig: Example OfThinkspeak Channel

1.5 Objective of the Paper:

1) The purpose of this study is to develop an Internet of Things-based real-time air quality monitoring system.

2) Utilising the Cloud Server for Real-Time Data Feeding, Monitoring, and Logging.

3) Utilising MQTT for Internet Communication.

4) Directly interfacing external sensors and hardware with a cloud server in order to interact.

LITERATURE REVIEW

2.1 BACKGROUND

Ravi Kishore Kodali and Borade Samar Sarjerao,**2017**,National Institute of Technology Warangal,The suggested pollution monitoring system is built around a WiFi microcontroller ESP8266 nodemcu, a sharp dust sensor GP2Y1010AU0F (for particle measurement), and a MQ-7. Sensors for measuring carbon monoxide and the MQTT protocol ESP8266, GP2Y1010AU0F sharp dust sensor, and We constructed a low-cost MQ-7 (carbon monoxide) sensor. Implementation and maintenance, portability, and ease of use The subscriber can view the polluted content simply utilising a web browser. application for mobile A straightforward pollution monitoring system (particulate) measuring matter and carbon monoxide levels) device based on ESP8266 nodemcu microcontroller with MQTT protocol with A price of less than $40 has been provided.

JunHo Jo , ByungWan Jo , JungHoon Kim , SungJun Kim, and WoonYong Han,2020,Department of Civil and Environmental Engineering, Hanyang University, 04763 Seoul, Republic of Korea 2Smart IS, 22101 Incheon, Republic of Korea,,The creation of an IoT-based indoor air quality monitoring systems is reported in this research. Experiments were carried out. done in order to validate the air quality measuring equipment A platform-based technique proposed by the Ministry of Korea's environment. We tested the precision of indoor air quality. quality control and desired performance of the device. Experiments utilising the platform were also conducted. carried out and exhibited appropriate performance and convenience of the platform for monitoring air quality Several The platform's accomplishments included the following: (1) The indoor air quality may be efficiently checked Using IoT and the cloud, you may access information from anywhere and in real time. Technology of computation;(2) For platform and data security, the platform used Amazon Web Services as a certified web server; (3) the Smart-Air device has an expandable interface, and the web server is also easily extendable, allowing easy application to various environments through the addition of appropriate sensors to the device or the installation of more Smart-Air devices in appropriate monitoring locations.The gadget and platform will be tested further in the future. The experiment in this study focuses on validating the device's dependability and deploying the platform, where further experiments are required to assure data correctness over lengthy time periods. A ventilation system can also be linked to the platform. As a result, when the air quality is poor, the system can function automatically to enhance it.

T.Veeramanikandasamy, Gokul Raj.S, A.Balamurugan, A.P.Ramesh, Y.A.Syed Khadar,2020,One of the most significant risks in many sectors is air pollution. It is essential to monitor and guarantee that the workplace is safe and free of pollution. This IoT-based air quality monitoring and control system employs an embedded system to continuously maintain air quality in industrial workplaces and to show the measured air quality index (AQI) on the ThingSpeak IoT platform and the Virtuino mobile app display. It supports new technologies by monitoring real-time environmental data such as CO, CO2, and ammonia gas concentrations, particulate matter PM2.5 and PM10 in air, and temperature-humidity. The data is kept in the cloud server and may be sent to the user through e-mail.The system has maintained the air quality index (AQI) in the workplace if the threshold values for gas concentrations and PM are exceeded. This technology will eliminate the source of explosions and fires caused by gas leaks. Real-time air quality monitoring and control system based on IoT to decrease detrimental impacts in the industrial workplace.

Anabi Hilary Kelechi1, Mohammed H. Alsharif, Chidumebi Agbaetuo, Osichinaka Ubadike1 Alex Aligbe1, Peerapong Uthansakul, Raju Kannadasanand Ayman A. Aly,2021,This study successfully developed a low-cost air quality monitoring system design using Arduino and ThingSpeak, demonstrating that an air quality system can be constructed utilising low-cost technologies, such as Arduino and ThingSpeak. The project was tested in several areas, including unit, sub-unit, system, acceptability, and programme testing. In all testing settings, the system operates admirably. This method may be used to create a smartphone app that can be simply deployed to monitor air quality across the spectrum, ultimately benefiting public health.

Chaitra N, Bhavana S, Vilas Reddy D N, Nikhil AS,2020,Temperature, pressure, humidity, and, most crucially, PM2.5 AND PM10 detection play a vital part in residential, industry, and air quality monitoring. The system we are constructing is very modest when compared to prior and current air excellence intensive automobilee plans. This design provides the benefits of stability, low power usage, and self-sufficiency. Users may watch real-time information and track changes in the data. This design will also be useful for checking the atmospheric conditions in a specific area, which are difficult for humans to measure. By using trending approaches, this solution contributes to quality of life support.

3 PROBLEM IDENTIFICATION

3.1 Problem Statement

The importance of air quality in terms of human safety, security, and health cannot be overstated. Despite the fact that expanding large-scale manufacturing and urbanisation produce enormous cities, these activities have a number of negative environmental effects.

Similarly, the deterioration of air quality in several Indian cities is a problem. Particulate matter (PM2.5) is the leading cause of air pollution, causing asthma and other respiratory disorders.

According to one study, those who inhale airborne particles are more likely to develop lung cancer than those who are exposed to passive smoking.

3.2 Followings are the Points for the Problem Statement:

a) Previously in the past data's has to be fed in the website manually for analyzing purpose.
b) Online Live Data Monitoring is not Available.
c) Hardware and Internet Interface is Challenging and Future Promising Task.
d) For Live Data Feeding and Graph Analysis and Internet Communication MQTT Protocol based Publisher,Subscriber,Broker is need.
c) Cloud Space server is need for the Interaction.

4.METHEDOLOGY

4.1 Methedology

The objective is to collect data from sensors and relay it to the user whenever the user desires to examine particulate matter data (GP2Y1010AU0F sharp dust sensor) and carbon monoxide level (MQ-7). The Esp8266 NodeMCU-12E microcontroller functions as a gateway server for Wi-Fi Internet connectivity. It operates as a network with command over the sensors that provide updates on the particulate matter concentration (PM 2.5), carbon monoxide concentration, and component condition. Transport layer security (Security Protocol) protects the data.For this investigation, we employed a GP2Y1010AU0F pointed dust sensor (which detects analogue values) and a DHT11 (which measures both Temperature and Humidity). Additionally, the data is persistently stored on the MQTT Server. The advantage of combining the MQTT protocol with the Secure Socket Layer (SSL) cryptographic protocol is that no erroneous data is stored alongside the necessary data, and security is maintained.

4.2 Methods used For this Study is as Follows:

1) For controller programming, employ the Arduino Ide Embedded Programming Platform.

2) The canonical programming languages for the Arduino Ide software are C and C++.

3) Communicating with the Thinkspeak Cloud Server through MQTT Protocol Header Files.

4) The Arduino IDE software was used to programme an ATmega328 programmable hardware microcontroller.

5) The Thinkspeak Cloud Server is utilised to monitor and log IoT Controller NodeMCU data.

6) ESP8266-based NodeMCU Hardware Controller, Foot IoT Communication

7) Connecting the NodeMCU Controller to the internet by means of a Wi-Fi signal.

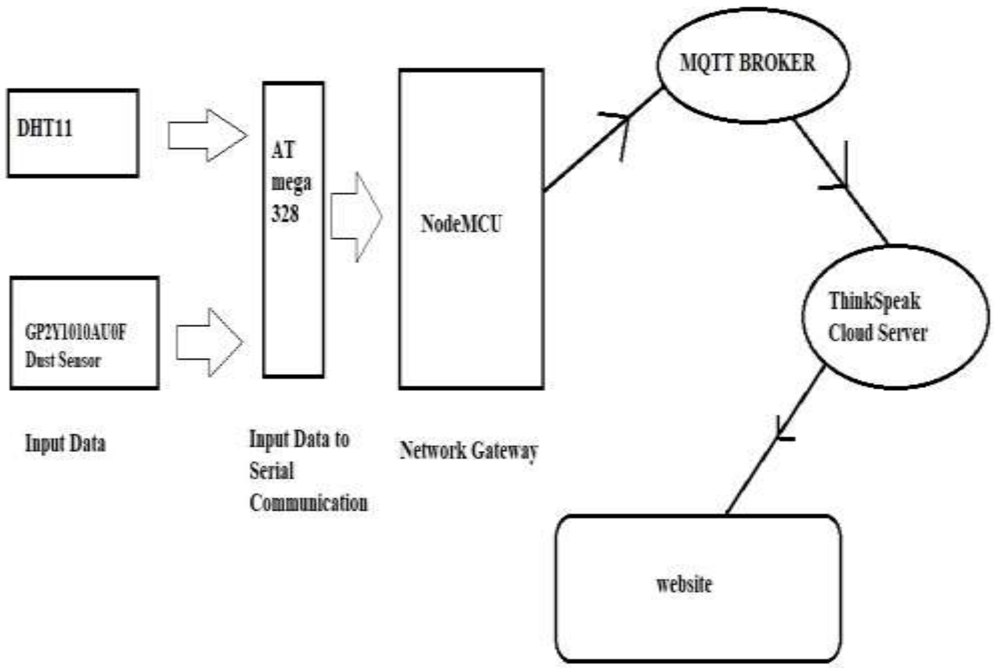

Fig : Block Diagram Explanation Of system

4.3 Working Procedure:

1) DHT11 measures ambient temperature and humidity, while Dust Sensor (GP2Y1010AU0F) measures dust levels between 0.1 and 0.10 mg/m3.

2) The Atmega328 Microcontroller is used to receive sensor data and calculate the surrounding parameters based on the computations in the Header File.

3) Utilise the serial Communication Programme to transmit the output data to the NodeMCU.

4) NodeMCU receives serial communication and separates data from characters.

5) Determine the particular character sign and filter the data.

Convert the character to an integer using logical operations.

7) Connect using the configured wifi id and password.

8) Upload the data to the Thinkspeak Server by utilising the Thinkspeak Header File.

9)All programming is done in C and C++ using the Arduino IDE software.

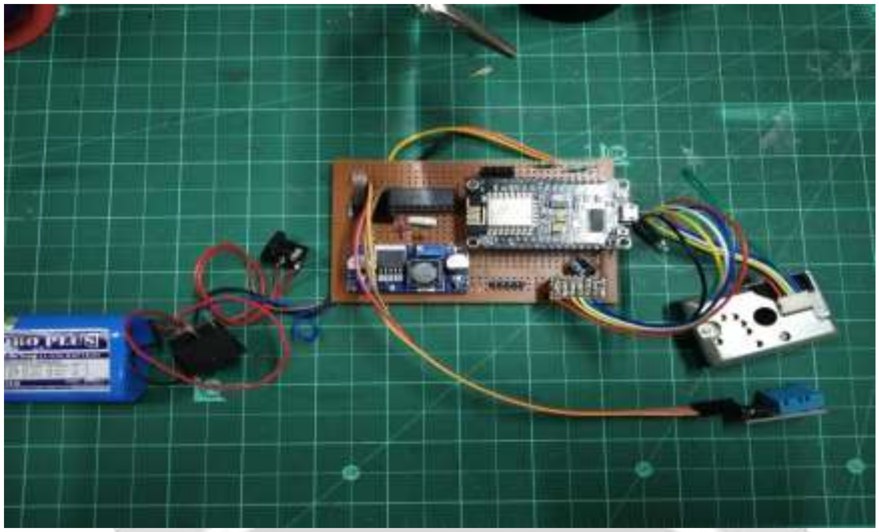

Fig : Real Combined Circuit with ATmega328 ,NodeMCU,Dust Sensor,DHT11 Temp and Humidity sensor

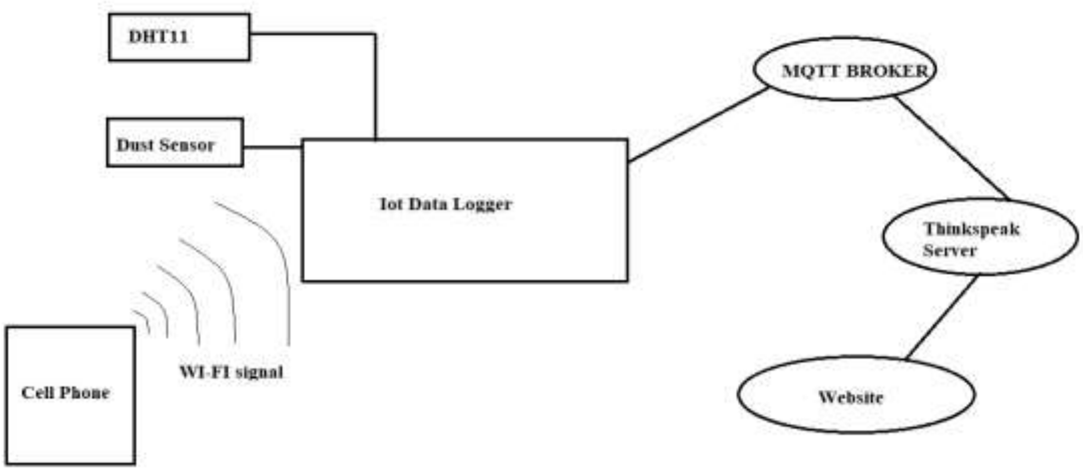

Fig: Block Diagram For Wi fi Communication

5.RESULT

5.1 Result

As from the above Programming the Output Received in the Thinkspeak Server as Followings:

1) Temperature Data
2) Humidity Data
3) Dust Level Concentration

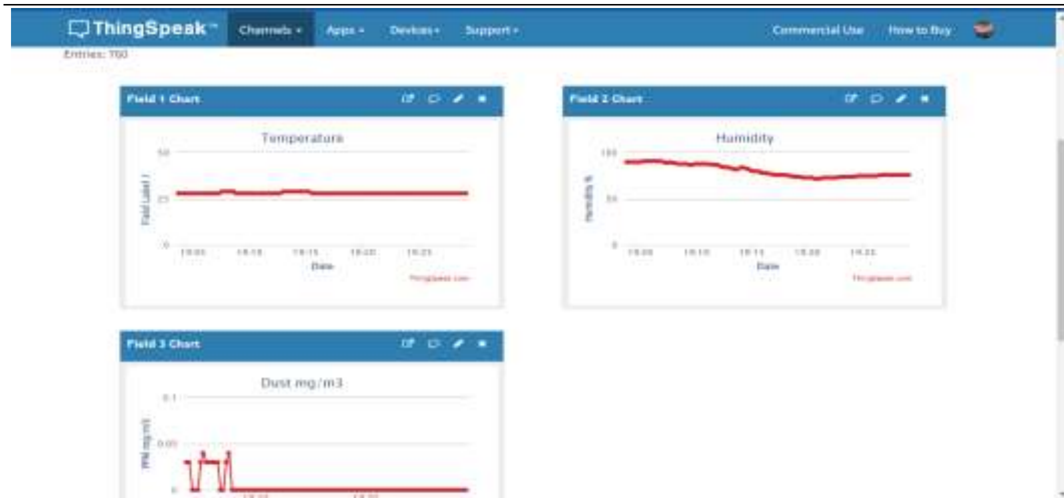

Fig : ThinkSpeak Server all Sensors Data Outputs

Connection established successfully in between NodeMCU Hareware and Thinkspeak Cloud Server.The Result Output Obtained From the Programming and Real Time Data Monitoring of Sensors Output From Iot based hardware NodeMCU is shown Below.

1) Surrounding Temperature Data Out

To take temperature data from the DHT11 sensor and upload it to the Thinkspeak Sever. Temperature readings are monitored and saved in the figure below. Temperature readings in the surrounding area will be constant, so an external heat source (such as finger touching) is used to cause variation in the graph.

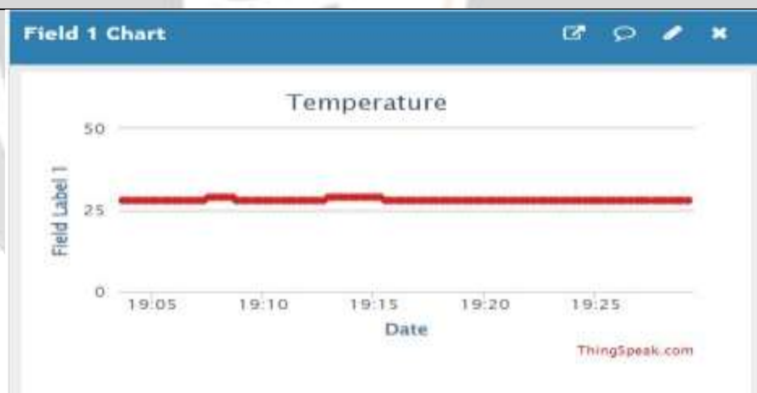

Fig : Surrounding Temperature data output in Thinkspeak Server

2) Surrounding Humidity Data

To take Humidity data from the DHT11 sensor and upload it to the Thinkspeak Sever. Humidity readings are monitored and saved in the figure below. Humidity readings in the surrounding area will be constant, so external dehumidifier is used(example Air Conditioner) to Reduce Humidity Value.

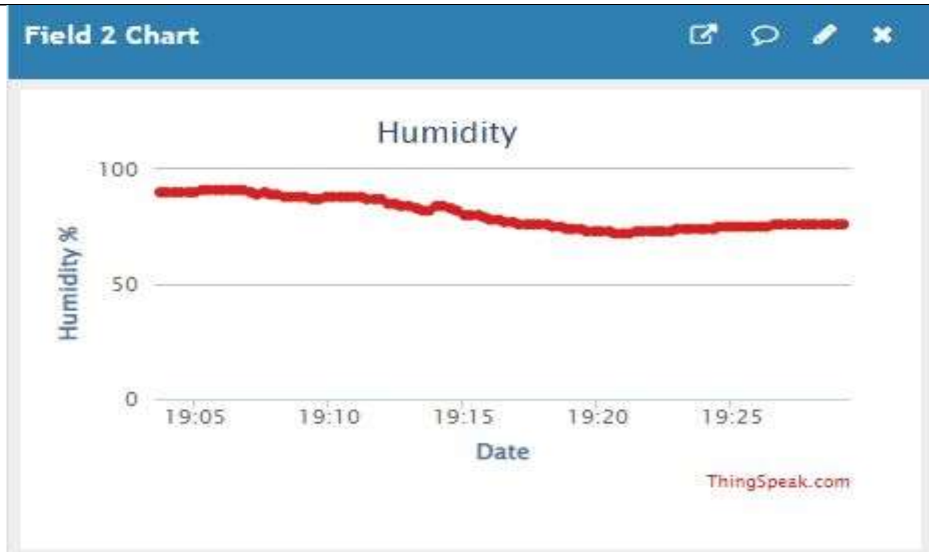

Fig: Surrounding Humidity Value in Thinkspeak Server website

3) Surrounding Dust Concentration In mg/m3

To take Dust Concentration data from the DHT11 sensor and upload it to the Thinkspeak Sever. Dust Concentration readings are monitored and saved in the figure below. Dust Concentration readings in the surrounding area will be constant, so external Dust or particle source such as smoke is used to change the reading or for variation in reading.

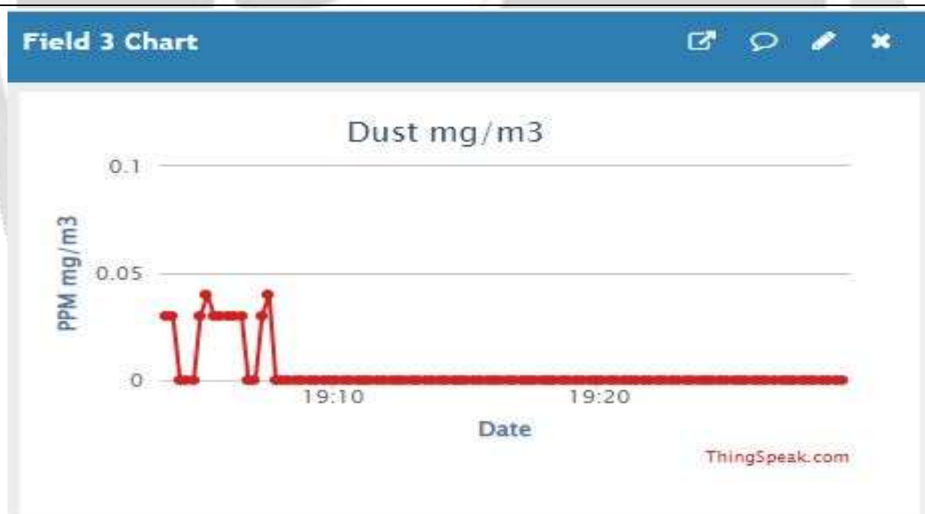

Fig: Surrounding Dust Concentration Value in Thinkspeak Server website

Fig : External Dust or smoke Source for variation in reading

5.2 Comparison Graphs In Between the Parameters

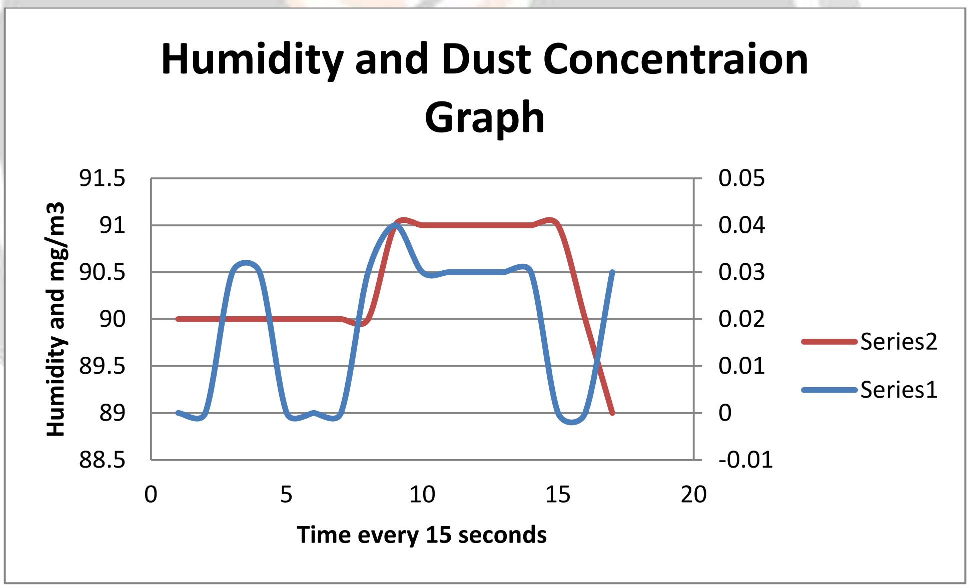

Fig : Humidity and Dust Concentration(mg/m3) Graph From The Readings

The advantage of reading log data is that it allows for subsequent remapping and comparative analysis of different parameters. As in the graph above, which compares humidity and dust concentration. It demonstrates that when humidity rises, dust concentration falls. Correct, since the water vapours in the air settle down the very small dust particles.

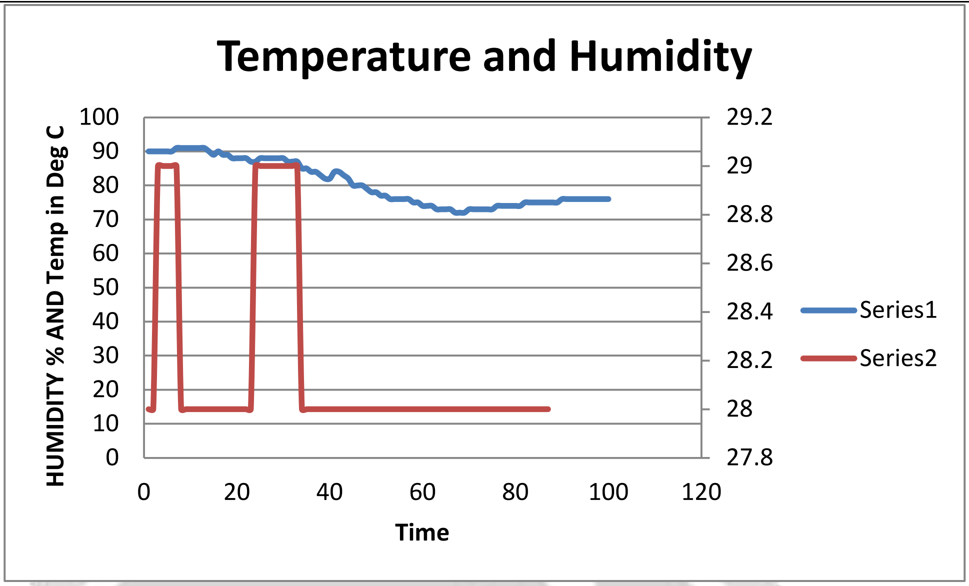

Fig : Comparision Grpah In between Temperature and Humidity

Similar to the comparison graph between dust concentration and humidity shown above, a comparison graph between additional parameters such as temperature and humidity may be created and analysed. When a result, as the temperature rises, the humidity falls and Vice versa.

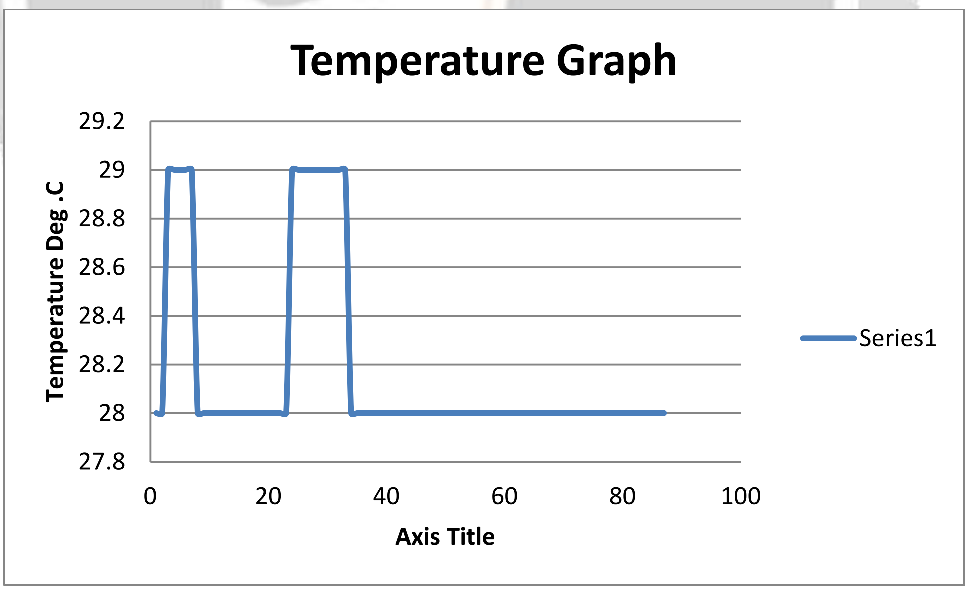

Fig : Single Temperature Variation Graph From log data

This is a single parameter graph from log data; when compared to the Thinkspeak graph, it is clear that the Thinkspeak graph provides a graphical record of all the data, testing data, and regular stable data.

However, only precise temporal data that was collected for the final reading is necessary for analysis; otherwise, no data is required for analysis.

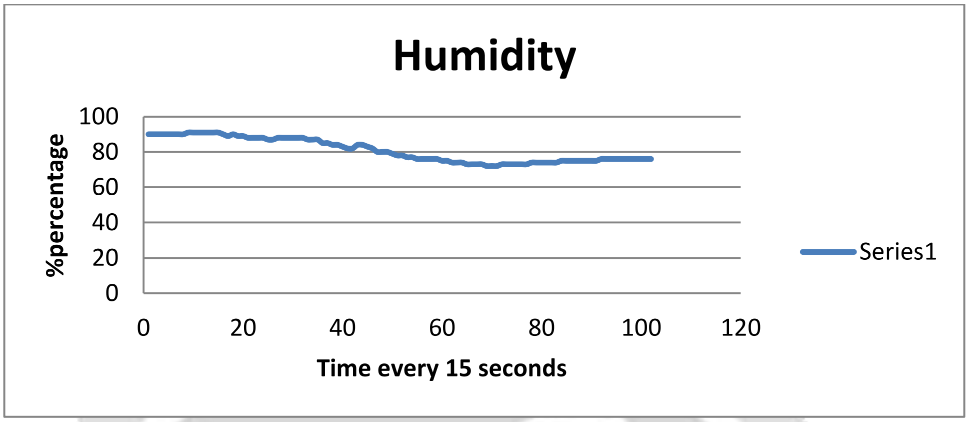

Fig: Humidity variation graph from log data

Log data humidity graph,log data graph is clear and reveals specifics like the humidity level at a certain moment or overall period. Most essential, just the necessary data may be transformed into a graph. It is not necessary to plot all of the readings graphs from today, tomorrow, and ten days later. Only a specific day or time graph may be taken and converted into graphical form from Excel format.

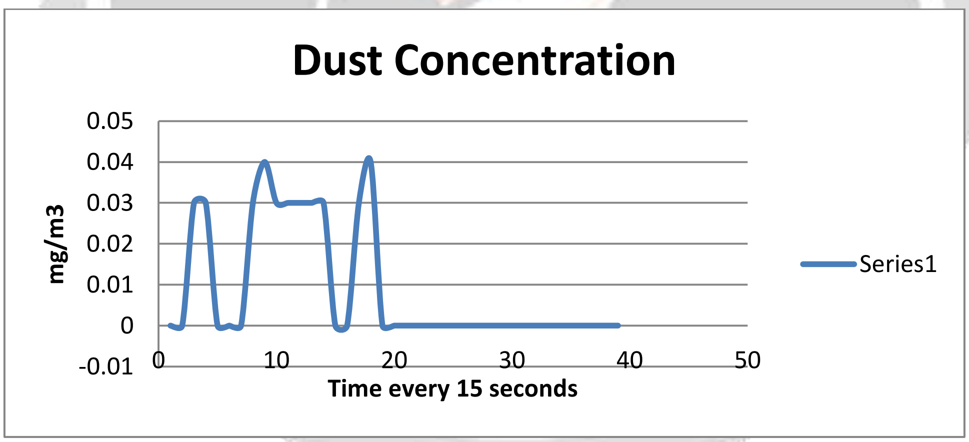

Fig : Dust Con centration Graph from log data

Dust concentration level is used to illustrate Particulate matter in the surrounding environment, and its unit is mg/m3 (milligrammes per cubic metre) or PM2.5. Using the Sensor GP2Y1010AU0F Fine dust particles as little as 1mg/m3 can be detected. Because the majority of the particulate matter content in the room is constant, smoke sources are utilized to alter the readings so that sensor operation and live data feeding may be shown on the Thinkspeak Cloud Server Website.

61. Conclusion

NodeMCU Controller is an outstanding, low-power module for IoT-based live data monitoring and logging with sensors. Due to the fact that many sensors provide 5v output but the NodeMCU can only accept 3.3v input, an auxiliary controller or hardware is required to receive sensor data and transmit it to the NodeMCU Controller. Because Thinkspeak Cloud Server is a Cloud Platform, real-time data updates necessitate a subscription (paying version). In this endeavour, for instance, a Trial version account is created that updates data every 15 seconds. Numerous IoT-based hardwares are prohibitively expensive and require extensive Embedded programming. This system employs low-cost IoT-based hardware and the C and C++ programming languages for Embedded Programming and Server Interfacing. The Arduino Ide open source software compiler is used for programming. The ESP8266.h header file includes the MQTT internet communication protocol for connectivity with the Thinkspeak server. Two programmes are utilised in this project: one for the ATmega328 Controller to communicate serially with the NodeMCU and another for the NodeMCU to publish data to the internet. Data can also be uploaded and analysed with other Cloud-based systems. The limitation of Thinkspeak is that it does not display comparison graphs or graphs for specific time periods separately.Although it offers advanced features, such as Matlab analysis for advanced analysis, it also has basic features.

6.2 FUTURE SCOPE

1) Multiple advanced and necessary sensors can be used in tandem with controlling devices to monitor and control the environment or subject.

2) It can be utilised for real-time health surveillance and administration in the medical field.

It has multiple applications in the medical field for monitoring patients' health and implementing the necessary measures to regulate their health.

In the event of a specialised environmental control system, number three.

Artificial intelligence (AI)-powered vehicles and systems.

4) This system provides actual data input to the cloud server, enabling the AI analysis-based cloud server to resolve complex issues, such as providing 24x7 traffic updates and instituting safety measures by analysing driver behaviour with AI technology.

5) Using the ESP32 Board controller with the camera option, the AI server can receive live views for analysis.

6) Using the MQTT Protocol, a server or website can be constructed for safe and secure data storage.

7) As the future is heavily reliant on the internet, this device may aid in monitoring and regulating a variety of variables using logical functional programming and a sophisticated cloud server to address complex issues.

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