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A Research Paper on "MQTT Based Monitoring System For Coal Mines Using Raspberry Pi"

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Abstract: Now in Modern days because of global warming and climate changes various challenges were faced in coal mines.In response to the urgent need for mitigating environmental challenges and enhancing operational efficiency in coal mines, the integration of advanced technologies becomes imperative.This project proposes an innovative approach by implementing a Smart Coal Mine System using IoT principles and MQTT protocol, centered around a Raspberry Pi controller.The system is designed to intelligently monitor and manage critical parameters within the underground mine environment, including temperature, humidity, gas levels and visibility in mines.By employing low-power and cost-effective Raspberry Pi, coupled with state-of-the-art sensors, the project aims to provide real-time data on the mine's climate conditions.In the event of an anomaly, such as a sudden increase in temperature, humidity, gas levels, and less visibility the system triggers a response mechanism. As a proactive measure, if there is any sudden increase in any of those sensor values along with the data log it is sent to the server's mail of the subscriber.

Index Terms **- Internet of Things (IOT), Message Queuing Telemetry Transport(MQTT),Sensors,Light Detecting Resistor(LDR).**

I.INTRODUCTION

In addressing the evolving challenges within the coal mining industry, we propose a forward-thinking alternative to the conventional wired monitoring systems. Recognizing the limitations posed by blind areas and the impracticality of laying expensive and time-consuming cables, our solution revolves around a state-of-the-art Coal Mine Safety Monitoring System built on the Internet of Things (IoT) paradigm.This innovative system aims to significantly enhance the safety and productivity of coal mines by leveraging IoT devices, prominently featuring the Raspberry Pi as a versatile and cost-effective controller.This protocol guarantees the efficient transmission of crucial data without any loss, offering a robust foundation for real-time monitoring.By strategically deploying IoT devices throughout the coal mine, we enable the continuous collection of essential parameters such as temperature, gas levels, LDR values and humidity.The MQTT protocol plays a pivotal role in creating a cohesive network where devices communicate seamlessly, providing a reliable and responsive system. The collected data can be analyzed centrally, offering insights that contribute to informed decision-making and improved safety protocols. Furthermore, the visualization of this data enhances the ability to monitor and control coal mine operations effectively, ultimately minimizing the risk of accidents and improving overall safety standards.In conclusion, our IoT-based Coal Mine Safety Monitoring System represents a paradigm shift from traditional wired setups, offering a scalable, cost-efficient, and technologically advanced solution. By embracing modern connectivity solutions and leveraging the power of MQTT, we aim to revolutionize coal mine safety, reduce accidents, and elevate the overall efficiency of coal mining operations.

II. AIM & OBJECTIVES

The primary goal of our system is to create a secure and conducive environment for mine workers, emphasizing real-time monitoring and proactive hazard detection in coal mines. The key objectives include:

1.Real-Time Sensor Data Monitoring
2.Hazard Detection and Miner Safety
3.Enhanced Coal Production and Control
4.Cloud-Based Logging for Continuous Improvement

The aim of the project is to monitor, control coal mines and to collect information of the mines using different sensors by interfacing it to Raspberry Pi to send that information to the users using MQTT protocol and store day-to-day log data in cloud i.e. Thingspeak.

III. WORKING PRINCIPLE

In the coal mining setting, sensors strategically positioned throughout different locations collect data on diverse environmental parameters, including gas concentrations and temperature levels, to proactively detect potential hazards. These sensors, which may encompass gas detectors and temperature sensors, interface with a Raspberry Pi. Subsequently, the Raspberry Pi transmits this data to designated subscribers, such as monitors or mobile phones, employing the MQTT protocol for efficient communication.

The system conducts a thorough analysis of the transmitted data, aiding in the identification of abnormal conditions or potential safety risks, such as elevated gas concentrations, increased temperatures, or low oxygen levels. Upon detection of any abnormal conditions, the system promptly generates alerts or warnings, manifesting as visual indicators or sound alarms. This immediate response mechanism is critical for ensuring swift reactions to emerging risks.Simultaneously, subscribers upload the crucial data to the web using the Raspberry Pi's in-built Wi-Fi module, facilitating remote monitoring and access by authorized personnel. The real-time data is displayed on monitors, with any alterations triggering corresponding changes in the display. Additionally, alerts in the form of audible alarms, such as buzzers, further enhance situational awareness.This dynamic project continuously evolves, leveraging advancements in technology to improve its effectiveness and accuracy. These integrated systems play a pivotal role in mitigating risks and elevating safety standards for miners operating in challenging underground environments.

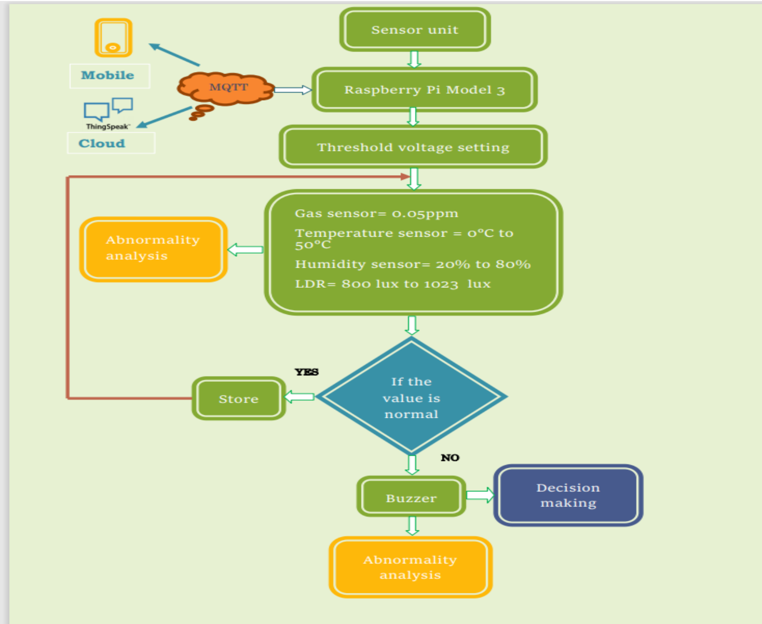


Fig.1 Flowchart for the operational system

IV. Proposed System

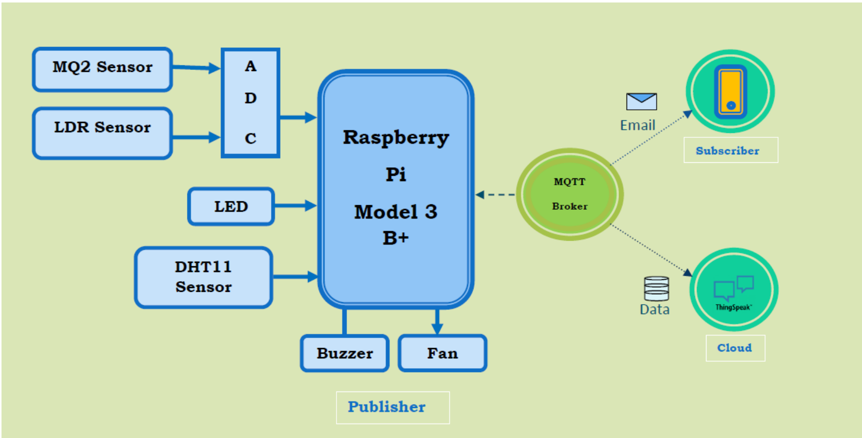


Fig.2 Block Diagram of MQTT based monitoring system for coal mine using raspberry pi

The sensors are interfaced with the Raspberry Pi using ADS 1115 analog-to-digital converter . All sensors we are using in this system are to sense the different environment conditions of the coal mines. The sensor threshold values are set so that if there are any changes in the environment of the mines it detects and gives an alert.

Case 1 :

"When the sensor readings surpass predefined threshold values, the data will be transmitted to the Raspberry Pi for immediate action. In response to this data trigger, a buzzer alert system will be activated, promptly notifying the workers within the mines. This serves as a proactive safety measure to alert personnel in real-time when critical thresholds are breached, ensuring a swift and effective response to potential hazards."

Case 2:

"When the sensor readings are within normal range or below the predefined threshold value, the data will be securely stored in the cloud. This stored data can be accessed by the user at any time for monitoring and review, providing a comprehensive overview of the ongoing activities and environmental conditions within the mines. This cloud-based storage approach ensures convenient and flexible access to historical data, facilitating thorough analysis and decision-making."

V. METHODOLOGY

The Raspberry Pi functions as the central controller unit, managing the interaction between hardware components and software coded in Python IDE based Thonny. Connected to the Raspberry Pi are the MQ2 gas sensor, DHT11 sensor, and LDR sensor. Upon system startup, the Raspberry Pi initiates the code, verifies connected hardware, and each component begins its respective functions.The MQ2 gas sensor detects hazardous gas content in the mining atmosphere, while the LDR sensor assesses darkness levels in the mining area. In the event of sensor values exceeding predefined thresholds, an emergency message is sent via the Wi-Fi module to the main authority. Simultaneously, an alarm buzzer activates, alerting mining workers to move to a safe zone and preventing potential dangers.

All sensed data is transmitted to the main unit and directly uploaded to the cloud, specifically Thingspeak. The continuous monitoring of the mining environment provides real-time data updates to the cloud.The system is equipped with email alerting functionality. When sensor data surpasses threshold values, an immediate email alert is sent to the main authority, providing details on the exceeded values and prompting swift action. The incorporation of email alerts enhances communication and ensures that authorities receive critical information in a timely manner.Thanks to the continuous upload of data to Thingspeak, the main authority can analyze the cause of any accidents by examining variations in the data. This analysis facilitates the identification of the reasons for accidents, enabling the implementation of precautionary measures to prevent similar incidents and minimize losses. The system, with its comprehensive safety features, contributes to enhanced worker safety and accident prevention in challenging underground mining environments.

The various hardware components we are using to built these system are as follows:

1.MQ2 Sensor	6.LED
2.LDR Sensor	7.Piezo Buzzer
3.DHT11 Sensor	8.5V DC Fan
4.ADS1115	9.Jumper wire
5.Raspberry Pi 3B+ Model	10.Breadboards

The software,protocols and cloud platform we are using to work on these system are as follows:

1.Thonny (Python IDE based language)
2.Thingspeak (Cloud Platform)
3.Message Query Telemetry Transport (MQTT protocol)
4.Raspbian OS (Raspberry Pi software)

Main Components Information:

1.MQ2 sensor: The MQ2 sensor is a gas sensor that is widely used for detecting various types of gasses, including methane, propane, butane, alcohol, carbon monoxide, and smoke. It operates on the principle of gas conductivity, where the electrical conductivity of the sensor changes in the presence of different gasses.

Fig 3.1 MQ2 sensor

2.LDR sensor: The Light Dependent Resistor (LDR), also known as a photoresistor, is a type of sensor that exhibits a change in resistance based on the intensity of light falling on its surface. LDRs are commonly used in various applications to measure and respond to ambient light levels.

Fig.3.2 LDR sensor

3.DHT 11 sensor: The DHT11 sensor is a low-cost digital temperature and humidity sensor widely used in various applications, including environmental monitoring, weather stations, and home automation systems.The DHT11 is a basic, ultra low-cost digital temperature and humidity sensor. It uses a capacitive humidity sensor and a thermistor to measure the surrounding air, and spits out a digital signal on the data pin (no analog input pins needed).

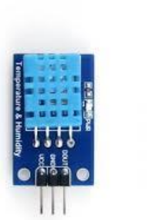


Fig.3.3 DHT11 sensor

4.ADS1115 (ADC converter): The ADS1115 is a precision analog-to-digital converter (ADC) with 16-bit resolution, commonly used for converting analog signals into digital data.The ADS1015 and ADS1115 are great analog to digital converters that are easy to use with the Raspberry Pi using its I2C communication bus.

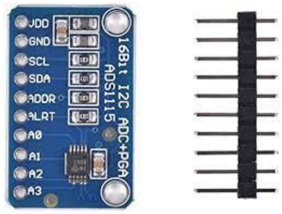


Fig 3.4 ADS1115

5.Raspberry Pi 3B+ Model: The Raspberry Pi 3B+ is a single-board computer developed by the Raspberry Pi Foundation.The Raspberry Pi 3 Model B+ is the latest product in the Raspberry Pi 3 range, boasting a 64-bit quad core processor running at 1.4GHz, dual-band 2.4GHz and 5GHz wireless LAN, Bluetooth 4.2/BLE, faster Ethernet, and PoE capability via a separate PoE HAT.The dual-band wireless LAN.

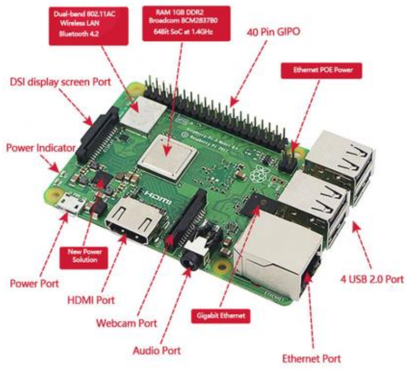


Fig 3.5 Raspberry Pi 3b+ model

6.LED:LEDs, or Light Emitting Diodes, are semiconductor devices that emit light when an electric current passes through them. LEDs are typically constructed from semiconductor materials such as gallium arsenide (GaAs), gallium phosphide (GaP), gallium arsenide phosphide (GaAsP), or gallium nitride (GaN). They consist of a semiconductor chip placed in a reflective housing, with two leads (an anode and a cathode) for connection to an electrical circuit.

Fig 3.6 LED

7.Piezo Buzzer:A piezo buzzer is an electronic component that produces sound by vibrating a piezoelectric element.Piezo buzzers are typically small and lightweight, making them suitable for applications where space is limited.Piezo buzzers can produce sound across a wide frequency range, typically from a few hundred hertz to several kilohertz, depending on the specific model.

Fig 3.7 Piezo Buzzer

8.DC Fan 5V:5V DC fans require a 5-volt power supply for operation. This voltage is typically supplied by batteries, USB ports, or DC power adapters.5V DC fans come in various sizes and form factors to suit different applications. Common sizes include 40mm, 60mm, 80mm, and 120mm fans, with corresponding airflow and noise levels.

Fig 3.8 DC Fan 5V

<u>Softwares, Protocols & Cloud Platform Information:</u>

1.Thonny (Python IDE based language): Thonny is a free Python Integrated Development Environment (IDE) that was especially designed with the beginner Pythonista in mind. Specifically, it has a built-in debugger that can help when you run into nasty bugs, and it offers the ability to do step through expression evaluation, among other really awesome features.

Fig 4.1 Thonny (Python IDE)

2.Thingspeak (Cloud Platform): ThingSpeak is an Internet of Things (IoT) platform that allows users to collect, store, analyze, visualize, and act on data from various IoT devices. It is particularly popular for its simplicity and versatility in building IoT applications.ThingSpeak provides cloud-based storage for IoT data. Users can send data from their devices to ThingSpeak and retrieve it later for analysis or visualization.

Fig 4.2 Thingspeak

3.Message Query Telemetry Transport (MQTT protocol):MQTT, which stands for Message Queuing Telemetry Transport, is a lightweight and efficient messaging protocol designed for low-bandwidth, high-latency, or unreliable networks. It is widely used in the Internet of Things (IoT) and other scenarios where a reliable and efficient communication protocol is essential.MQTT relies on a broker, which is a server that manages the communication between publishers and subscribers. The broker receives messages from publishers and forwards them to all connected subscribers with an interest in those messages.

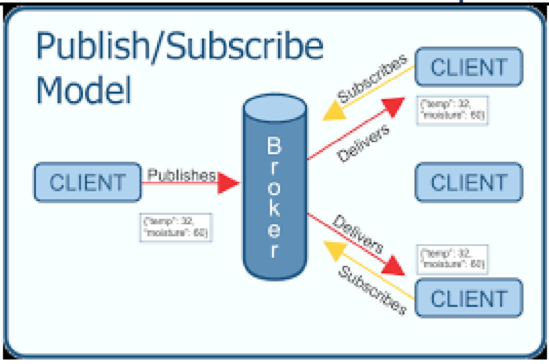


Fig 4.3 MQTT protocol

4.Raspbian OS (Raspberry Pi software): Raspberry Pi OS is based on the Debian operating system, a popular Linux distribution known for stability and a wide range of software packages.Raspberry Pi OS includes a configuration tool that simplifies various setup options, such as expanding the file system, changing the default password, configuring Wi-Fi, and enabling/disabling hardware interfaces.

Fig 4.4 Raspbian OS window

VI. FUTURE SCOPE

The MQTT-based coal mine monitoring and alerting system using Raspberry Pi provides a solid foundation for further enhancements and future expansions. Here are some potential future scopes and enhancements for the system:

1. Data Logging and Visualization:
   - Implement a data logging feature to store sensor readings over time.
   - Develop a web-based or desktop application to visualize historical sensor data using graphs and charts.
2. Remote Monitoring and Control:
   - Enable remote monitoring and control of the system via a web interface or mobile app.
   - Allow users to receive real-time notifications and alerts on their smartphones.
3. Machine Learning and Predictive Analytics:
   - Implement predictive maintenance strategies to minimize downtime and maximize safety.
   - Integrate machine learning algorithms to analyze sensor data patterns and predict potential hazards or equipment failures..
4. Environmental Monitoring:
   - Extend the system to monitor environmental factors beyond the coal mine, such as weather conditions or nearby pollution level.
   - Collaborate with environmental agencies to contribute to broader environmental monitoring efforts.

VII. RESULTS

The below figure shows the sample image of MQTT client windows, reporting the sensor values for every time interval. Time interval can be configurable.

Email Notifications to the subscriber end:

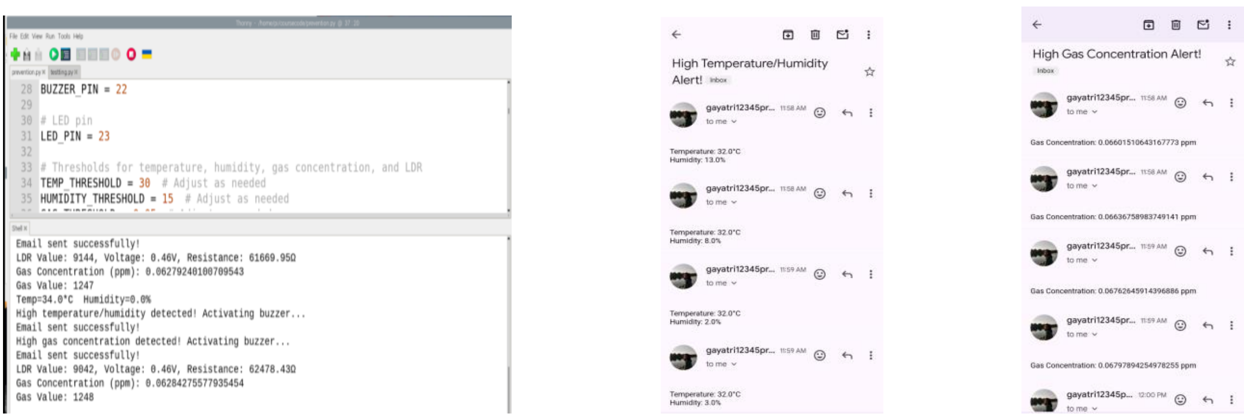
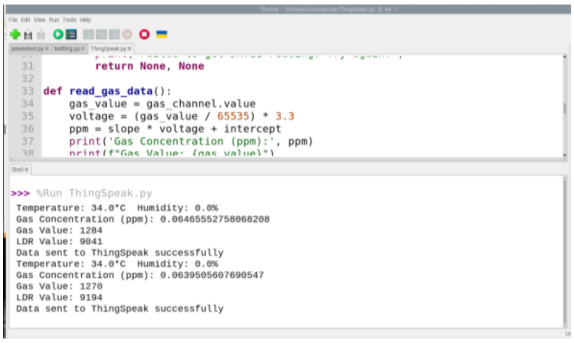
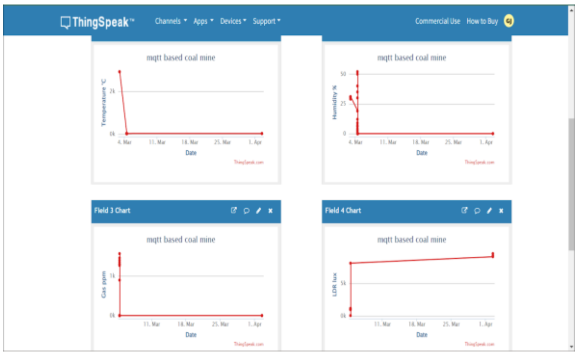


Fig 5.1 Email notification

Thingspeak Data View:





VII. CONCLUSION

The proposed real-time monitoring system for underground mines offers a comprehensive solution aimed at enhancing safety for miners. It provides continuous monitoring of various parameters such as toxic gasses and critical indicators within the mine, ensuring that potential dangers are detected early. Threshold alarms are triggered when sensor values exceed predefined levels, alerting miners in the area and allowing them to take necessary precautions or evacuate promptly.

VIII. ACKNOWLEDGEMENT

We would like to extend our heartfelt gratitude to the Head of the Electronics & Telecommunication Engineering Department for providing us with the opportunity to work on the proposed system. We appreciate the support and encouragement that allowed us to embark on this project.Our sincere thanks go to our guide for the invaluable guidance and constructive suggestions throughout the development of this work. Without their expertise and constant support, this project would not have been possible.We express our deep appreciation for the encouragement, timely assistance, and unwavering guidance provided by our beloved guide, which played a pivotal role in the successful completion of this proposed work within the stipulated time frame. Their commitment to our project has been instrumental in our academic and professional growth.Once again, we are grateful for the opportunity and guidance that have significantly contributed to the success of this endeavor.

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