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Smart Helmet for Mining Workers with Real Time Monitoring and Hazard Detection

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Abstract- Hazardous industrial and mining environments pose significant risks to worker safety due to exposure to toxic gases, extreme environmental conditions, and physical stress. This paper presents the design and implementation of an Internet of Things (IoT)-based Smart Mining Helmet aimed at enhancing occupational safety through continuous monitoring and intelligent alert mechanisms. The proposed system integrates multiple sensors, including a gas sensor for detecting harmful gases, a temperature and humidity sensor for environmental monitoring, a vibration sensor for detecting abnormal motion, and a pulse sensor for monitoring the physiological condition of the worker. The system utilizes Wi-Fi connectivity and the Message Queuing Telemetry Transport (MQTT) protocol to transmit real-time sensor data to a cloud-based dashboard, enabling remote supervision. A GPS module is incorporated to provide location tracking, facilitating rapid response during emergency situations. The system performs threshold-based analysis of sensor data, and upon detecting unsafe conditions, it generates immediate alerts and notifications. Furthermore, the collected data can be logged and exported for further analysis, supporting predictive safety measures and decision-making. Experimental evaluation demonstrates that the proposed system reliably monitors environmental and physiological parameters and provides timely alerts under hazardous conditions. The solution is cost-effective, scalable, and suitable for deployment in real-world industrial applications.

Keywords: Smart Mining Helmet, Internet of Things (IoT), ESP32, MQTT Protocol, Gas Detection, Temperature and Humidity Monitoring, Pulse Sensor, Worker Safety, Real-Time Monitoring, GPS Tracking, Industrial Safety System.

I.INTRODUCTION

Industrial safety is a critical concern in hazardous working environments such as factories, mines, and construction sites. Workers are often exposed to dangerous gases, extreme temperatures, and health risks that can lead to serious accidents. Traditional monitoring systems are not efficient enough to provide real-time alerts and preventive measures.

With the advancement of Internet of Things (IoT) technology, it is possible to continuously monitor environmental and health parameters of workers. This paper presents an IoT-based smart safety monitoring system using ESP32, which integrates multiple sensors such as gas sensor, temperature sensor, pulse sensor, and accelerometer to ensure worker safety. The system provides real-time data monitoring and alerts through a mobile application, enabling quick response during emergencies.

Objectives

The primary objective of this project is to enhance worker safety using IoT technology. The system aims to monitor environmental conditions like gas concentration, temperature, and humidity, along with human health parameters such as heart rate and movement. Another objective is to provide instant alerts in case of abnormal conditions to prevent

accidents. The project also focuses on developing a cost-effective and easy-to-implement safety solution for industries. P

II. PROBLEM STATEMENT

In many industrial and hazardous working environments, worker safety is a major concern due to exposure to toxic gases, extreme temperatures, and physically demanding conditions. Traditional safety systems mainly rely on manual supervision and periodic inspections, which are not sufficient for continuous monitoring. As a result, accidents such as gas leaks, health issues, and unexpected falls often go undetected until it is too late, leading to serious injuries or even loss of life.

There is a lack of real-time monitoring systems that can simultaneously track both environmental conditions and worker health parameters. Additionally, the absence of immediate alert mechanisms and location tracking makes emergency response slow and inefficient. Hence, there is a need for an automated, reliable, and real-time safety monitoring system using technologies like the ESP32 microcontroller and IoT to ensure early detection of hazards, quick alerts, and improved worker safety.

III. EXISTING SYSTEM

Traditional safety systems rely on manual supervision and periodic inspections. These methods have several drawbacks:

Disadvantages

- No real-time monitoring
- Delayed response to emergencies
- Lack of automation
- High risk of human error
- Limited data analysis

IV. PROPOSED SYSTEM

The proposed system uses IoT technology to continuously monitor environmental and health conditions. It integrates multiple sensors with an ESP32 microcontroller.

Advantages

- Real-time monitoring
- Instant alert system
- Wireless communication
- Low cost and efficient
- Scalable and easy to implement

V.SYSTEM METHODOLOGY

The proposed Smart Mining Helmet system is designed to monitor environmental and physiological parameters of workers in hazardous mining environments using Internet of Things (IoT) technology. The methodology involves system design, sensor integration, data acquisition, communication, and alert generation. The overall architecture consists of multiple sensors interfaced with a central processing unit, which transmits data to a remote monitoring system.

1. System Structure

The system is built around the ESP32 microcontroller, which acts as the core processing unit. Various sensors such as a gas sensor (MQ-7), temperature and humidity sensor (DHT11), vibration sensor (ADXL335), and pulse sensor are connected to the ESP32. A GPS module is also integrated to provide real-time location tracking. These components work together to continuously monitor the working conditions and the health status of the user.

2. Data Acquisition and Processing

Sensor data is collected periodically from all connected modules. The temperature and humidity sensor measures environmental conditions, while the gas sensor detects harmful gases such as carbon monoxide. The vibration sensor identifies sudden movements or impacts, and the pulse sensor monitors the heart rate of the worker. The GPS module provides latitude and longitude coordinates. The ESP32 processes the collected data and converts it into a suitable format for transmission. Each parameter is compared against predefined threshold values to determine whether the condition is safe or hazardous.

3. Communication and Data Transmission

The system uses Wi-Fi connectivity to transmit data to a cloud-based platform using the MQTT protocol. The ESP32 publishes sensor data to specific MQTT topics, allowing the monitoring system to receive real-time updates. This ensures continuous communication between the helmet and the monitoring station.

4. Alert and Notification System

An alert mechanism is implemented to ensure immediate response during unsafe conditions. When

any sensor value exceeds its threshold limit, the system generates an alert message and transmits it through the MQTT dashboard. Notifications are displayed on the monitoring interface, enabling supervisors to take quick action. This real-time alert system significantly reduces response time and enhances safety.

5. Data Logging and Monitoring

The transmitted data is stored in the cloud platform for future analysis. The stored data can be used to identify patterns, analyze trends, and improve safety measures. The monitoring dashboard provides a visual representation of sensor values using graphs and indicators, making it easy to interpret system status.

6. System Workflow

The overall workflow of the system begins with sensor initialization, followed by continuous data acquisition. The collected data is processed and transmitted via Wi-Fi using MQTT. The monitoring system receives the data, displays it on the dashboard, and generates alerts when necessary. This cycle continues in real time, ensuring continuous monitoring of the worker's safety

Hardware Components

- ESP32 Microcontroller
- MQ-7 Gas Sensor
- DHT11 Sensor
- Pulse Sensor
- Accelerometer (ADXL335)
- GPS Module
- Buzzer
- Power Supply

Software Requirements

- Embedded C (Arduino IDE)
- Mobile Application for monitoring
- MQTT Protocol for communication

VI.SYSTEM ARCHITECTURE

The system uses an ESP32 microcontroller connected to sensors like MQ-7, DHT11, pulse sensor, and accelerometer to collect real-time data. The collected data is processed and compared with predefined safety limits. If any abnormal condition is detected, a buzzer alert is triggered. The data is then transmitted via Wi-Fi to a mobile application for real-time monitoring and notifications.

The system architecture of the IoT-based Smart Worker Safety Monitoring System is designed for real-time monitoring and efficient data communication. The sensing module collects data from sensors such as MQ-7, DHT11, pulse sensor, and accelerometer. This data is processed by the ESP32 microcontroller, which acts as the central unit. The processed data is transmitted through Wi-Fi using the MQTT protocol to a mobile application. The system continuously checks the data against safety thresholds to detect abnormal conditions. When unsafe conditions are identified, the alert module activates a buzzer and sends notifications. Additionally, the GPS module provides real-time location tracking for emergency situations.

VII.MODULES OF THE SYSTEM

1. Sensing Module

The sensing module is responsible for collecting real-time data from both the environment and the worker. It uses multiple sensors such as the MQ-7 gas sensor to detect harmful gases like carbon monoxide, the DHT11 sensor to measure temperature and humidity, a pulse sensor to monitor the worker's heart rate, and an accelerometer (ADXL335) to detect movement or sudden falls. These sensors continuously capture data and send it to the processing unit, ensuring that any change in environmental or health conditions is immediately recorded.

2. Processing Module

The processing module acts as the brain of the system and is implemented using the ESP32 microcontroller.

It receives input data from all sensors and performs real-time analysis. The ESP32 compares the sensor values with predefined threshold limits to determine whether the conditions are safe or unsafe. It also manages the overall system operation, including controlling alerts and handling communication tasks.

3. Communication Module

This module enables wireless data transmission between the system and the user. The ESP32 uses its built-in Wi-Fi capability along with the MQTT protocol to send sensor data to a mobile application. This ensures fast, reliable, and real-time communication. The module allows remote monitoring, meaning users can check the worker's condition from anywhere without being physically present at the site.

4. Alert Module

The alert module plays a crucial role in ensuring safety by providing immediate warnings during dangerous situations. When the processed data exceeds safe limits (for example, high gas levels or abnormal heart rate), the system activates a buzzer to alert the worker nearby. At the same time, a notification is sent to the mobile application, informing supervisors or users about the emergency. This quick alert mechanism helps in taking immediate action and preventing accidents.

5. Location Tracking Module

The location tracking module uses a GPS system to determine the real-time position of the worker. In case of emergencies such as accidents or exposure to hazardous conditions, the GPS module sends location data along with the alert message. This helps rescue teams or supervisors quickly locate the worker and provide assistance without delay, especially in large industrial areas.

6. Data Monitoring and Logging Module

This module is responsible for displaying and storing the collected data. A mobile application is used to visualize real-time sensor readings such as gas levels, temperature, heart rate, and movement status. It also logs the data for future analysis, which can help in identifying patterns, improving safety measures, and maintaining records of worker conditions over time.

7. Power Management Module

The power management module ensures that all components of the system receive a stable and efficient power supply. It may include batteries or regulated power sources to support continuous operation. This module also focuses on optimizing power consumption so that the system can run for longer durations without frequent recharging, making it suitable for practical industrial use.

VIII. FLOW DIAGRAM

The workflow begins with sensors collecting real-time environmental and health data such as gas level, temperature, pulse rate, and motion. This data is processed by the ESP32 microcontroller, which checks for abnormal conditions based on threshold values. The processed information is then sent to a mobile application for real-time monitoring and alert notification.

The process starts when the system is powered on and the ESP32 microcontroller initializes all connected components such as the MQ-7 gas sensor, DHT11 sensor, pulse sensor, accelerometer, and GPS module. After initialization, the system continuously reads sensor data including gas levels, temperature, humidity, heart rate, and worker movement. This data is then processed by the ESP32, where it is analyzed and compared with predefined safety threshold values.

In the decision stage, the system checks whether the readings are normal or abnormal. If all parameters are within safe limits, the data is sent to the cloud via Wi-

Fi using the MQTT protocol and displayed on the mobile application for real-time monitoring. If any parameter exceeds the safety limit, the system identifies it as a dangerous condition. Immediately, the alert module is activated, which triggers a buzzer and sends alert notifications to the mobile application.

At the same time, the GPS module provides the worker's location, helping in quick emergency response. This entire process runs continuously in a loop, ensuring 24/7 monitoring, quick detection of hazards, and improved worker safety in industrial environments.

IX. CONCLUSION

The IoT-based Smart Worker Safety Monitoring System provides an effective and reliable solution for ensuring safety in hazardous working environments. By integrating multiple sensors with the ESP32 microcontroller, the system continuously monitors both environmental conditions and worker health parameters in real time. The use of Wi-Fi and MQTT communication enables seamless data transmission to a mobile application, allowing remote monitoring and quick decision-making.

The system is capable of detecting abnormal conditions such as gas leakage, high temperature, irregular heart rate, and sudden movements, and immediately triggers alerts to prevent accidents. Additionally, the inclusion of GPS tracking enhances emergency response by providing the exact location of the worker. Overall, the proposed system improves workplace safety, reduces risks, and demonstrates the practical application of IoT technology. It is cost-effective, scalable, and suitable for real-world industrial applications, with potential for further enhancement using advanced technologies like AI and cloud analytics.

The developed IoT-based Smart Worker Safety Monitoring System successfully monitors environmental conditions and worker health in real time using the ESP32 microcontroller and multiple sensors. It effectively detects hazardous situations and provides immediate alerts along with location tracking for quick emergency response. Overall, the system improves worker safety, reduces risks, and proves to be a reliable and cost-effective solution for industrial applications.

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