INTEGRATED APP & WEB-BASED SAFETY AND PRODUCTIVITY MONITORING SYSTEM FOR COAL MINES USING CUSTOM SOFTWARE

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Abstract

This article presents a safety monitoring system and productivity management for coal mines using the Internet of Things (IoT). The proposed system comprises of an underground section and a ground section. ESP32 Module is responsible for monitoring underground conditions through various sensors, such as an Heart Rate sensor, pulse sensor, and a temperature and humidity sensor,MPU6050 Sensor. Then this collected data is sent by ESP32 to the ground section via a wireless connection. ESP32 is responsible for sending alert messages through Message based on the readings of these sensors.

The ground section, which can be a mobile device or PC, monitors the information from the underground section via a web page made using HTML, CSS, and JavaScript in real-time, with its server being ESP32. The hardware and software for the system is designed and developed in view of the conditions in coal mines. The system enables miners to trigger four predefined emergency messages—Emergency Alert, Health Help Request, I'm Safe, and Message to Family—using dedicated buttons. Additionally, a low-temperature warning is automatically generated when the sensed temperature drops below a predefined limit, enhancing overall safety and responsiveness. By seamlessly integrating wireless technology with an advanced alerting system, the proposed solution emerges as a smart and efficient tool to enhance safety in coal mines.

Keywords— coal mine safety, ESP32, monitoring system, IoT, sensors.

I. INTRODUCTION

Mining, the extraction of coal or minerals from underground, presents risks to workers. The challenging underground conditions expose them to potential injuries and fatalities, often resulting from human error and difficult ambient conditions. Monitoring these conditions without risking lives is a significant challenge, necessitating ongoing safety improvements. Achieving a balance between productivity and worker safety is a crucial concern in the mining sector [1]. Mine accidents result from the combined impact of hazardous factors, encompassing fire, gas leakage, radiation, high-temperature sources, and environmental elements like combustible materials. Survey data reveals mining as the most perilous occupation in India, with one fatality occurring every third day. These risks are attributed to diverse extraction methods for various minerals, escalating with mine depth. In the coal industry, safety concerns are particularly pronounced, especially with the unsupported mining method lacking artificial supports. Underground coal mining entails greater risks due to ventilation issues and the potential for collapse compared to surface mining. The majority of accidents occur in subterranean mines [2]. Existing monitoring systems in coal mines primarily rely on cable networks, which are prone to frequent damage during accidents such as explosions. These damages severely hinder rescue operations and the detection of critical events. Additionally, these systems often suffer from a notable limitation of accurately tracking the number of personnel present underground. [3]. In emergency situations, reliable wireless communication systems are crucial for survival.

Traditional wired communication systems may not always be dependable, particularly during accidents or disasters where infrastructure damage is common. Wireless radio systems provide a viable alternative, offering flexibility, mobility, and the ability to establish communication quickly in challenging environments. These systems enable emergency responders tocoordinate rescue efforts, aid those in need, and ensure effective communication when traditional methods may fail [4]. Creating safer mining technologies is essential, and smart devices powered by the Internet of Things (IoT) can make a big difference in solving this problem. IoT provides a framework for sensors and devices to communicate seamlessly within intelligent environments, facilitating easy sharing of information across different platforms. The recent uptake of various wireless technologies positions IoT as a groundbreaking technology, capitalizing on the vast opportunities offered by the Internet. Its recent implementation in smart cities has generated interest in creating sophisticated systems across various sectors such as offices, retail, agriculture, water management, transportation, healthcare, and energy [5], [6].

This paper presents an IoT based real-time safety monitoring system for coal mines. The motivation for carrying out this work is that traditional wired monitoring systems, which are currently used in coal mines for communication are susceptible to damage and can obstruct rescue efforts in emergencies. The proposed system consists of various sensors, such as a heart rate sensor, pulse sensor,MPU6050 sensor,DFPlayer Mini Module, and temperature and humidity sensor. These sensors collect data in real-time and send alerts to webpage and message if the predefined threshold for safe conditions is exceeded. Results demonstrate the system & proficiency in promptly detecting unsafe conditions, ensuring swift response through advanced wireless technology. Hence, this innovative solution proves to be a smart and efficient tool for significantly improving safety in coal mines, offering real-time monitoring and rapid alerting capabilities.

The remaining sections of the article are structured as follows: Section II delves into related works within this field.

Following that, Section III introduces the proposed system. Section IV elaborates on the system & functionality, while Section V encompasses the results and discussion. The conclusion is presented in Section VI, wrapping up the discussion.

II. RELATED WORK

The occurrence of explosions, flooding, gas poisoning, mine collapses, and choking becomes imminent when specific factors surpass a certain threshold. This system assesses these conditions and activates buzzers to notify employees and ground control during such emergencies. To ensure proper functioning, small sensors and radio frequency modules are utilized. Elevated levels of psychological and physical stress can lead to diminished performance and unsafe procedures, potentially resulting in fatalities (Lee et al., 2016) [7]. Gaidhane et al. [8] introduced a smart helmet system for underground coal miners utilizing Zigbee technology. This system offers real-time monitoring of workers during potential threats in the field. It describes how the smart helmet continuously monitors hazardous conditions in mines, including humidity, temperature, and airborne gas components like sulphur dioxide and methane. Molani et al. [9] examined how mining industry can be made adaptable to IoT systems. This article addresses the challenges in mining sector and provided suggestions for developing an effective model for different mining sectors. Jucá et al. [10] introduced a cost-effective approach for data acquisition systems in decentralized renewable energy plants. Their paper details an agricultural environment monitoring system utilising Wireless Sensor Network (WSN) technology. This system is designed to monitor various aspects of outdoor agricultural production, offering insights into environmental conditions crucial for optimal plant growth and resource management. Saranya et al. [11] proposed a system employing ARM controllers for monitoring purposes in coal mine. The system regulates ventilation for mine workers based on the prevailing climate conditions. Utilising low-power and cost-effective components such as ARM, DHT11 sensor, smoke detector, and gas sensor, along with Wi-Fi, the system controls the climate state in mine using a motor. This approach improves traditional coal mine monitoring systems, contributing to enhanced safety and accident reduction in coal mines reliant on wired networks for production monitoring. Arif Hussain et al. [12] introduced a ZigBee-based WSN for coal mine safety monitoring, utilizing iBeacon for miner identification. Comparative analysis shows that suggested system outperformed others. Deokar et al. [13] focused on enhancing coal mine productivity and reducing costs while emphasizing nworker safety. Their wireless sensor-based monitoring system effectively tracks underground staff dynamics, monitoring gas levels such as SO2, NO2, and CO. This system promptly delivers emergency alerts for falls and detects helmet removal using a limit switch. With early warnings and emergency switches on both ends, it facilitates rapid responses to prevent casualties, offering a thorough safety solution for underground mining operations. Maity et al. [14] developed a system for continuous monitoring to enhance the protection and safety of underground mine workers. This module relies on MEMS-based sensors and comprises two components: a hardware circuit affixed to the workers & bodies, typically integrated into their helmets, and a ground control center computer system. Communication is facilitated through Zigbee technology. Salankar et al. [15] proposed a system that utilises Zigbee technology to monitor coal mine parameters like carbon monoxide levels, temperature, and water level. The system aims to aid in decision-making for the protection of miners. It collects data from sensors and informs workers through various alarm tones and LED displays to alert them about potential hazards. Pranjal Hazarika [16] introduced a smart safety helmet for miners, equipped with MQ3 and MQ4 gas sensors to detect hazardous gases. Data is transmitted to the control center via the helmet & inbuilt X-Bee module, and when carbon monoxide or methane levels exceed certain criteria, a microcontroller there sets off sirens. Badrinath et al. [17] proposed a middleware for remote automation to automate control and monitor physical sensors. Suriyakrishnaan et al. [18] employ Arduino Uno, GP2Y1010, DHT11, MQ-5, MQ-7 sensors, and the ESP8277 WIFI module. These devices detect dust levels, humidity, temperature, methane, and carbon monoxide gas concentrations respectively. Shakunthala et al. [19] introduced an IoT safety system integrating gas sensors, a DHT11 sensor, and an accelerometer. Data from these sensors is routed to an Arduino ATmega2560 MCU for precise control. Vishnukumar et al. [20] introduced a helmet system integrated with sensors like heart rate, temperature, humidity, and gas sensors for coal mine workers & safety monitoring.

III. PROPOSED SYSTEM

The proposed methodology aims to enhance coal mine safety through continuous monitoring and real-time communication between underground and ground sections. It utilizes a Wi-Fi module to create a resilient safety system, enabling prompt responses to safety hazards. The system consists of two main sections: the underground and the ground.

A. Underground Section

The block diagram and circuit diagram for the underground section are illustrated in Fig. 1 and Fig. 2, respectively. A network of sensors is deployed to monitor crucial environmental conditions like temperature, humidity, and gas levels. These sensors gather data and transmit it to a E S P 32 microcontroller. Within the microcontroller, data undergoes processing against predefined thresholds. If any deviation from these thresholds occurs, an alarm system is triggered by the ESP32 microcontroller, m a n u a l l y alerting individuals within the coal mine. This integrated system ensures continuous monitoring and swift response to any potential hazards, prioritising the safety of workers underground. Furthermore, the system employs a Wi-Fi module to relay this vital information.

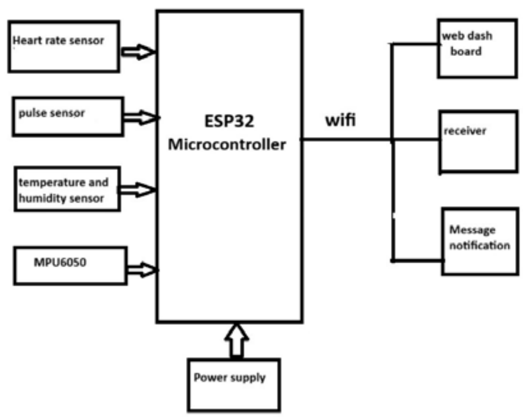

Fig. 1. Block diagram of underground section.

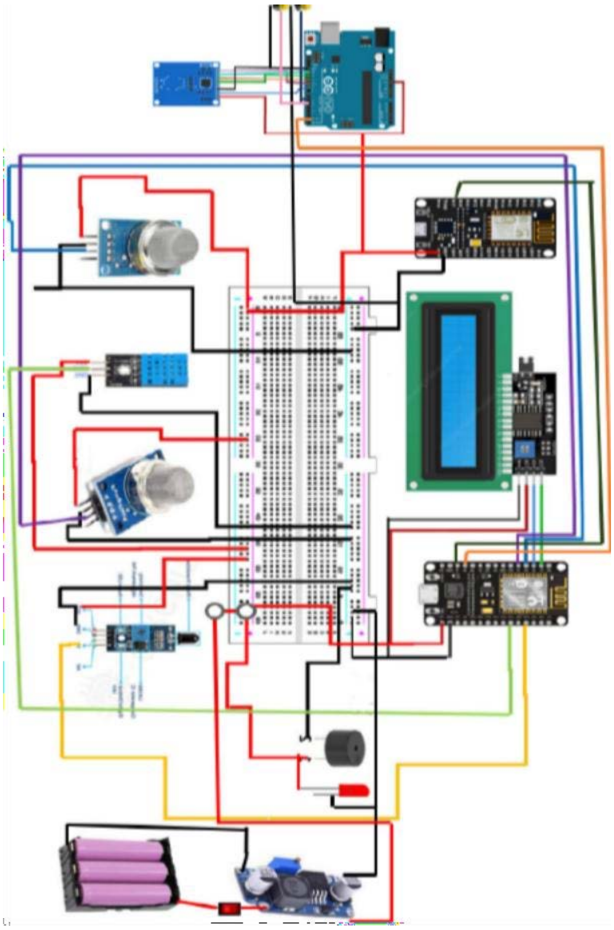

Fig. 2. Circuit diagram of proposed system.

ESP32 role involves sending alert messages to reciever , triggered by the readings received from the sensors. To enhance safety protocols further, each miner is equipped with an ID card. This not only facilitates personnel tracking but becomes especially vital in the unfortunate event of accidents, helping us ascertain the number of miners present on-site. The following sensors are used in underground section:

• HR Sensor
• Pulse Sensor
• MPU6050(Accelometer+gyroscope)
• DHT11 (Temperature & Humidity sensor)

B. Ground Section

The block diagram of the ground section of the proposed system is shown in Fig. 3.

A dedicated PC or mobile device serves as the central hub for capturing transmitted data from the underground sensors. This data is presented in a user-friendly format through an HTML, CSS, and JavaScript webpage, offering an accessible and comprehensive overview of the information. This platform enables the ground surveillance team to efficiently monitor and respond promptly to any abnormal conditions within the coal mine. To further augment responsiveness in emergency situations, the system incorporates a mechanism for relaying critical information to higher authorities via a designated Telegram group. This secondary channel ensures that, in the rare event that the surveillance team overlooks a potential hazard, other competent authorities are promptly informed and can take the necessary action.

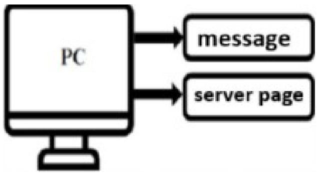

Fig. 3 Block diagram of ground section.

IV. WORKING OF PROPOSED SYSTEM

To achieve a thorough comprehension of the system & operation, the following sections are presented

A. Flow Chart

Flow chart comprises the work flow of suggested system is presented in Fig. 4. This flowchart illustrates a real-time monitoring system using wireless transmission for sensor data to a control room.. Wi-Fi is responsible for real-time transmission of data to the control room, with alerts sent to a message app of the admin. Further details will follow in the subsequent section.

B. Hardware Implementation

In the proposed system, we advocate for the incorporation of a Wi-Fi module to facilitate continuous monitoring and real-time communication between the underground and ground sections.

The system is equipped with sensors to detect the heart rate,pulse rate ,temperature and humidity sensors, and a fall detection sensor. sensor designed to identify adverse conditions. Data is collected by sensors and is transmitted to the ground section for surveillance through an accessible web page interface.

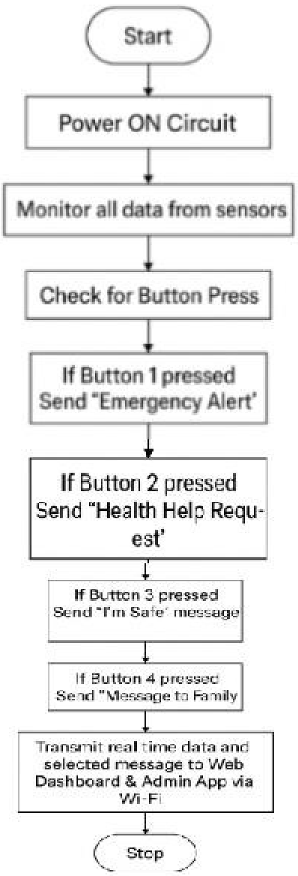

Fig. 4. Flow chart of proposed system.

In the event of an emergency, the alarm system is activated, prompting both the subterranean workforce and the ground team to implement precautionary measures promptly. This integrated approach aims to enhance overall safety measures within the coal mining environment.

1) Environment Sensing

The coal mine safety system integrates various sensors for monitoring. Notably, heart rate sensor ,for monitoring heart rate of worker, pulse sensor for monitoring pulse rate , DHT11 sensors monitor humidity and temperature, detecting adverse environmental changes. This multifaceted sensor setup aims to bolster overall safety protocols in the coal mine, ensuring early detection and rapid response to potential risks. All sensored data are processed by ESP32 and transmitted via wifi to web dashboard. Apart from automated testing the system incorporates four manual button Emergency alert, Health help request, I am safe, message to family there by ensuring efficient communication and rapid response during critical situations. It senses the mine worker body conditions ensuring he is safe to move into mining environment.

This integrated monitoring approach ensures continuous approach of miner's well being

TABLE I. THRESHOLD VALUES SET FOR VARIOUS PARAMETERS

S. No.	Parameter	Threshold Value set
1	Temperature(degrees Celsius)	45
2	Heart rate	60-100bpm
3	Blood pressure	120/80mmhg
4	Spo2 level	>95%
5	Fall detection	Acceleration>2g

2) Data Transmission

After gathering and processing sensor data, the ESP32 smoothly sends the refined information to the ground using its built-in Wi-Fi. This quick data transfer ensures that the ground promptly receives valuable insights, facilitating fast decision-making based on real-time environmental data. The ESP32 Wi-Fi capabilities make this process efficient, enhancing the coal mine monitoring and safety system. Here, the ESP32 operates in Access Point mode, generating a Wi-Fi network for seamless integration and improved operational responsiveness.

3) Monitoring System

Upon data arrival at your PC, a user-friendly web page facilitates seamless monitoring of underground conditions. This interface delivers real-time data, presenting a user-friendly platform for effective surveillance. The fundamental structure of the server-page is crafted using HTML, CSS, and JavaScript, ensuring a straightforward and visually pleasing experience for users. ESP32 acts as a server for this web page.

4) Alarming System

The alarm system transmits alert notifications and sensor data to the web-based admin dashboard and receiver through Wi-Fi for continuous monitoring. In case of an emergency or manual alert from the miner, an instant message is also sent to the admin's mobile application for immediate attention. The ESP32 microcontroller manages data communication and alert transmission. Miners can send predefined messages such as *Emergency Alert*, *Health Help Request*, *I'm Safe*, and

Message to Family using dedicated buttons, ensuring quick communication and improved safety within the mining environment.

5) People Present Inside Mine

As part of the safety management system, each miner’s presence is monitored through the integrated ESP32-based tracking module. The system records and updates the status of all miners inside the mine in real time through the web dashboard. Miners can log their entry and exit using assigned buttons or authenticated access interfaces, ensuring accurate headcount management.. The integration of real-time tracking not only improves operational visibility but also enhances worker safety by ensuring that the number of people present in the mine is continuously updated and accessible to higher officials.

V. RESULTS AND DISCUSSIONS

The outcomes obtained from the proposed ESP32-based system have been analysed and summarised in Table II and Table III. Table II shows the monitoring system results under normal conditions, comparing sensor readings with their respective threshold values. Table III presents the system’s response during emergency situations, highlighting the corresponding alert actions. Fig. 5(a) illustrates the real-time readings displayed on the web dashboard. The ESP32 microcontroller is programmed to update sensor data at regular five-second intervals, ensuring accurate and continuous monitoring.

Fig 5(a) During emergency conditions, the ESP32 system automatically transmits an SMS alert to the admin’s registered mobile number. The message includes apredefined alert text (e.g., “Help”) followed by the miner’sreal-time GPS coordinates (latitude and longitude). These coordinates enable immediate identification of the worker’s location for rapid rescue response and safety verification.

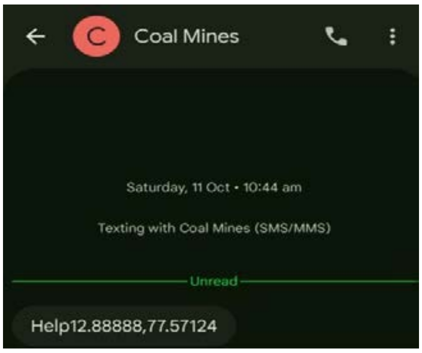

Fig. 5(a). Showing Alert on Message.

VI. CONCLUSIONS

This work presents an IoT-based real-time health and safety monitoring system for coal mine workers using the ESP32 microcontroller. The proposed system successfully integrates multiple sensors to measure vital health parameters such as heart rate, pulse, temperature, and humidity, along with motion detection using the MPU6050 sensor. Through the implementation of a real-time monitoring framework, it provides an accurate and immediate understanding of both human health and environmental conditions inside the mine. The inclusion of a buzzer and LED-based alarm mechanism ensures that workers receive quick alerts during emergencies. Additionally, the integration of a Wi-Fi module enables seamless wireless communication with the web dashboard, allowing real-time data access and alerts to the admin. This work demonstrates a reliable, cost-effective, and scalable approach to improving worker safety and operational efficiency in hazardous mining environments. Future enhancements may include the integration of GPS for precise location tracking and the use of machine learning algorithms for predictive safety analysis and early hazard detection.

KEY ACHIEVEMENTS:

1. Ultra-Low Cost: $30 total system cost—10-30× cheaper than commercial devices
2. Clinical Accuracy: HR ±2.4 BPM, SpO_2 ±1.0% meet home monitoring standards
3. Real-Time Communication:& lt;3-second latency from sensor to dashboard
4. High Reliability: 99.8% uptime, automatic reconnection
5. Open-Source: Complete transparency enables customization and research
6. Dual Interface: Web dashboard for visualization + serial terminal for data logging

The system addresses critical healthcare needs—continuous monitoring of elderly, post-operative patients, chronic disease management, and pandemic response— while remaining accessible to lowincome populations and resource-constrained facilities. User testing with elderly participants validated the design & usability, particularly the preference for physical buttons and local displays over smart phone-dependent solutions.

Impact Potential:

• Healthcare Equity: Provides affordable real-time health monitoring for developing regions.

• Cost Savings: Reduces costs by up to $2,970 per month.

• Research Support: Facilitates studies on IoT-based [healthcare and ML analytics.

• Emergency Response:Enhances safety through fall detection and emergency alerts

VII. FUTURE SCOPE

• Integration of additional sensors such as gas, air quality, and seismic sensors to provide a more comprehensive safety monitoring system.

• Implementation of GPS technology to track the real-time location of miners inside the mine during emergency situations.

• Application of machine learning algorithms for predictive analysis to detect possible health or environmental hazards in advance.

• Development of a cloud-based database for long-term storage and analysis of historical sensor data.

• Enhancement of the mobile application with analytics, notification logs, and voice alert features for better communication and decision-making.

• Expansion of the system to support multiple mine sites through centralized web dashboard management for large-scale monitoring. Implementation of blockchain technology for secure and tamper-proof data logging and access control.

• Development of a predictive maintenance module to monitor equipment health and reduce downtime.

• Introduction of solar or battery backup units to ensure uninterrupted operation during power failures.

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