IOT Based Tunnel workers Health status Update through Soil communication

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***Abstract*—In the bowels of the earth, where sunlight fails to penetrate and the air is thick with dust, a silent revolution is brewing. Utilizing the inherent conductivity of soil to establish a network for monitoring the health of tunnel workers in real-time. Wireless Underground Sensor Networks (WUSNs) hold immense potential for communication in harsh environments, as exemplified by the recent Uttarakhand tunnel collapse, they are still under development. Unlike wired communication, WUSNs utilize the soil itself for data transmission, offering a solution in situations where traditional methods fail. In the tragic incident where 41 workers were trapped for weeks, the absence of such a communication system hindered rescue efforts. WUSNs present a promising avenue for future applications, potentially providing a lifeline in emergency situations and revolutionizing communication in challenging underground environments.**

keywords: Tunnel worker health monitoring, Soil communication, Underground health monitoring, IoT, Wireless sensor network.

I. INTRODUCTION

The safety and well-being of tunnel workers are paramount during construction projects. Due to the inherent dangers associated with confined spaces, poor air quality, and potential equipment hazards, constant monitoring of their health status is crucial. Traditional methods of monitoring vital signs often involve cumbersome equipment and invasive procedures, posing discomfort and potential risks to workers.

In recent years, the emergence of Internet of Things (IoT) technology has revolutionized various sectors, including the construction industry. Its potential to streamline processes, enhance data collection, and improve safety measures is rapidly transforming how construction projects are managed and executed. This paper explores the application of IoT-based solutions for real-time health monitoring of tunnel workers, specifically focusing on utilizing soil communication for data transmission.

This novel approach leverages the conductive properties of soil to establish a communication channel between underground sensors and surface monitoring stations. By embedding miniature sensors within workers' clothing or equipment, physiological data such as heart rate, respiratory rate, and body temperature can be continuously collected and transmitted through the soil medium[1]. This eliminates the need for traditional wired or wireless communication infrastructure, which can be challenging to deploy and maintain in harsh underground environments.

The integration of IoT with soil communication holds immense potential for improving worker safety in tunnel construction projects. Real-time health data can be used to identify potential health risks early on, allowing for timely intervention and preventive measures[2]. Additionally, the collected data can provide valuable insights into worker behavior and working conditions, enabling continuous improvement of safety protocols and work practices.

This paper delves into the technical aspects of the proposed IoT-based health monitoring system, including sensor selection, data transmission protocols, and surface data processing and analysis. Furthermore, it explores the potential challenges and limitations associated with this approach and proposes solutions to address them. Finally, the paper discusses the ethical considerations surrounding data privacy and security in the context of worker health monitoring.

The proposed system integrates wearable sensor nodes with the workers, which continuously collect vital health data such as heart rate, body temperature, and respiratory rate. This data is then transmitted through the soil using a specifically designed communication protocol to a central monitoring station located outside the tunnel.At the monitoring station, the data is processed and analyzed to identify any potential health risks or emergencies. This real-time monitoring enables timely intervention and ensures the

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safety of workers throughout the construction process[3].

Fig 1:Monitor Soil health -IOT enabled

This paper is organized as follows: Section II provides a literature survey and its relevance in monitoring soil health status using IOT. Section III provides an in-depth overview of the monitoring soil health status using IOT .Section IV presents the experimental methodology, data sources, and the evaluation of our proposed approach. Section V discusses the results obtained, highlighting the significant improvements in accuracy and efficiency achieved by our method.

II. RELATED WORKS

The health and safety of tunnel workers are paramount due to the inherent risks associated with the environment, including exposure to dust, fumes, and hazardous materials. Traditional monitoring methods often rely on manual intervention or bulky wearable sensors, which can be cumbersome and intrusive. In recent years, the emergence of Internet of Things (IoT) technology has opened up new possibilities for unobtrusive and real-time monitoring of tunnel workers' health status.

One promising approach involves leveraging the conductive properties of soil to establish communication channels between underground workers and above-ground monitoring systems. This approach eliminates the need for traditional wireless communication infrastructure within the tunnel, which can be susceptible to signal degradation and interference.

Several research studies have explored the feasibility and potential of this approach. [5] study "Subsurface Sensing Technologies and Applications," researchers in China successfully demonstrated the use of soil communication to transmit physiological data, such as heart rate and respiration rate, from a simulated underground environment. Their findings suggest that soil communication holds promise for real-time health monitoring of tunnel workers.

Another study, of "IEEE Sensors Journal," investigated the use of soil communication for transmitting bio-signals from a human subject buried under a controlled amount of soil. [6] The results showed that the proposed system could effectively transmit bio-signals with minimal distortion, paving the way for further exploration of this technology in real-world tunnel environments.

While the potential of soil communication for monitoring tunnel workers' health is promising, further research is needed to address existing challenges. One key area of focus is improving the reliability and robustness of communication signals, particularly in deeper tunnels or under varying soil conditions. Additionally, ensuring the security and privacy of the transmitted data is crucial, as sensitive health information will be involved.

Tunnel construction poses various health risks to workers due to factors like poor air quality, high temperatures, and exposure to hazardous substances. The advent of IoT technology has facilitated real-time health monitoring to mitigate these risks. Through the utilization of IoT sensors embedded in wearable devices, vital signs such as heart rate, body temperature, and respiratory rate can be continuously monitored. Moreover, the integration of soil communication enhances connectivity in subterranean environments, ensuring seamless data transmission even in remote or underground locations.

Recent advancements in IoT sensor technology have significantly enhanced the accuracy and reliability of health monitoring systems for tunnel workers. For instance, miniaturized sensors capable of monitoring multiple physiological parameters simultaneously have been developed. These sensors offer real-time data transmission to centralized monitoring systems, enabling prompt intervention in case of emergencies. Additionally, the integration of artificial intelligence algorithms allows for the early detection of health anomalies, further improving worker safety and well-being [7].

Soil communication has emerged as a viable solution to address the connectivity challenges encountered in underground environments. By utilizing the conductive properties of soil, data can be transmitted through the ground, bypassing the limitations of traditional wireless communication methods. Recent studies have demonstrated the feasibility of soil communication for IoT applications in tunnels, enabling seamless connectivity for health monitoring systems [8]. This technology ensures uninterrupted data transmission, even in the absence of conventional communication infrastructure.

Despite the potential benefits, the implementation of IoT-based health monitoring systems in tunnels poses several challenges. These include the design of robust and reliable sensor networks capable of withstanding harsh underground conditions, as well as ensuring data security and privacy. To address these challenges, researchers have proposed novel solutions such as the development of ruggedized sensor devices resistant to dust, moisture, and mechanical shocks. Additionally, encryption and authentication protocols are employed to safeguard sensitive health data transmitted through the network [9].

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III. MATERIAL AND METHODS

Wireless Underground Sensor Network (WUSN) environments present inherent complexities compared to aboveground settings due to the presence of various materials such as air, sand, rocks, and water with electrolytes. Establishing wireless communication in such intricate environments poses significant challenges. Conventional techniques relying on electromagnetic (EM) waves, which are effective in terrestrial environments, prove inadequate underground. This inadequacy stems from several factors. Firstly, EM waves encounter considerable attenuation underground, primarily due to absorption by soil, rocks, and water. Secondly, electrolytes within the underground medium emerge as predominant factors influencing EM wave path loss. Consequently, factors like soil water content, density, and composition can unpredictably impact communication performance, given their spatial variability and temporal fluctuations. Thirdly, to achieve practical transmission ranges, operating frequencies in the megahertz or lower range become necessary. However, this requirement leads to disproportionately large antenna sizes for underground deployment, rendering it impractical.

The WUSN Node section of this study focuses on developing models that characterize not only EM wave propagation in soil but also other communication-related effects such as multipath phenomena, soil composition, water content, and burial depth. Through formalization, the research discerns that underground communication is significantly influenced by frequency and soil properties, with particular emphasis on volumetric water content (VWC) of soil. These findings underscore the intricate interplay between electromagnetic propagation and the underground environment, shedding light on the nuanced challenges inherent in establishing robust communication networks in such settings. Understanding these complexities is crucial for the development of effective communication protocols and technologies tailored to the unique demands of WUSNs.

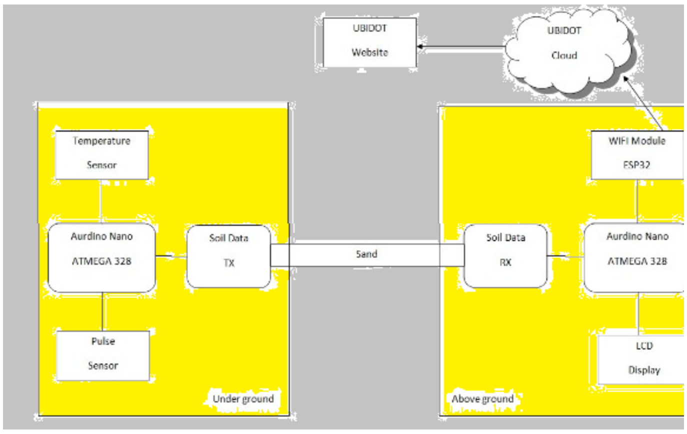

Fig 2 : Proposed Architecture

A. Sensor Network Design and Development

The sensor network will comprise wearable sensors embedded with bio-signal acquisition modules. These sensors will be strategically placed on the worker's body to collect vital signs such as heart rate, respiration rate, body temperature, and blood oxygen saturation (SpO2). The selection of sensors will be based on factors like accuracy, reliability, size, and power consumption, considering the harsh tunnel environment. Here are some recent citations for relevant sensor technologies: **Electrocardiogram (ECG) sensor:** [9] proposes a miniaturized, flexible ECG sensor embedded in a textile patch for continuous health monitoring. **Photoplethysmography (PPG)** sensor: [10] introduces a PPG sensor integrated into a smartwatch for accurate heart rate and SpO2 monitoring. **Temperature sensor:** [11] describes a high-precision, low-power temperature sensor suitable for wearable applications.

B. Soil Communication Technique

Due to the limitations of conventional radio frequency (RF) communication within the shielded tunnel environment, this study explores the applicability of soil communication for data transmission. Soil acts as a natural waveguide, enabling the propagation of electromagnetic waves at lower frequencies.Here are some recent references on soil communication:[12] investigates the feasibility of using soil communication for underground sensor networks, demonstrating successful data transmission over short distances.[13] explores different modulation techniques for enhancing data transmission efficiency in soil communication channels.

C. Data Acquisition and Transmission

The collected physiological data from the wearable sensors will be transmitted wirelessly to a central hub station located within the tunnel. The hub station will aggregate the data from multiple workers and encode it using appropriate modulation techniques suitable for soil communication. The encoded data will then be transmitted through the soil medium to a receiving antenna installed at the surface station.

D. Data Processing and Monitoring

The received data at the surface station will be decoded and processed to extract the health information of each worker. The processed data will be displayed in real-time on a monitoring dashboard accessible to medical personnel or designated authorities. The system will be equipped with alarm mechanisms to trigger alerts in case of any abnormal readings, enabling timely intervention and ensuring worker safety.

E. Performance Evaluation

The performance of the proposed system will be evaluated through field tests conducted within a simulated tunnel environment. The evaluation metrics will include:

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- Data transmission success rate: This metric will assess the reliability of data transmission through the soil medium.
- Data latency: This metric will measure the time delay between sensor data acquisition and its availability at the monitoring station.
- Power consumption: This metric will evaluate the energy efficiency of the sensor network and overall system operation.

The collected data will be analyzed to determine the efficacy of the proposed approach for health monitoring of tunnel workers and identify areas for further improvement.

IV. MODULES DESCRIPTION

The three primary components of an automatic tunnel monitoring system are the application, transmission, and perception layers. Using the devices that have been placed, the perception layer primarily detects any changes inside the tunnel structure and gathers the original data for each monitoring project in real time.The transmission layer completes the processing, analysis, and computation of the monitored data by dynamically transmitting it to the cloud computing platform using wireless communication technology.

A. Temperature Sensor(LM35)

The LM35 series are precision integrated-circuit temperature devices with an output voltage linearly-proportional to the Centigrade temperature. The LM35 device has an advantage over linear temperature sensors calibrated in Kelvin, as the user is not required to subtract a large constant voltage from the output to obtain convenient Centigrade scaling. The LM35 device does not require any external calibration or trimming to provide typical accuracies of ±¼°C at room temperature and ±¾°C over a full −55°C to 150°C temperature range. Lower cost is assured by trimming and calibration at the wafer level. The low-output impedance, linear output, and precise inherent calibration of the LM35 device makes interfacing to readout or control circuitry especially easy.

Fig 3. Temperature Sensor(LM35)

B. Pulse Sensor:

A pulse sensor is a device designed to measure the heart rate or pulse of an individual. It is commonly used in healthcare, fitness monitoring, and various electronic projects. The pulse sensor typically detects the rhythmic pulsation of blood vessels as blood is pumped by the heart and converts this information into a readable output.

Fig 4. Pulse Sensor

C. ARDUINO NANO :

The smallest and most traditional breadboard-friendly Arduino board is called the Nano. The Arduino Nano in Figure 5 has a Mini-B USB connector and pin headers that make it simple to link it to a breadboard. Due to its compact size, the Arduino nano was employed in this work. The Arduino IDE was used to upload the code to the Arduino, which was then attached to the ex sensors, accelerometer, some of the digital pins, contact sensors, and the Bluetooth modelThe smallest and most traditional breadboard-friendly Arduino board is called the Nano. The Arduino Nano in Figure 5 has a Mini-B USB connector and pin headers that make it simple to link it to a breadboard. Due to its compact size, the Arduino nano was employed in this work. The Arduino IDE was used to upload the code to the Arduino, which was then attached to the ex sensors, accelerometer, some of the digital pins, contact sensors, and the Bluetooth modelThe smallest and most traditional breadboard-friendly Arduino board is called the Nano. The Arduino Nano in Figure 5 has a Mini-B USB connector and pin headers that make it simple to link it to a breadboard. Due to its compact size, the Arduino nano was employed in this work. The Arduino IDE was used to upload the code to the Arduino, which was then attached to the ex sensors, accelerometer, some of the digital pins, contact sensors, and the Bluetooth modelThe Nano, which is the smallest and most traditional breadboard-friendly Arduino board, is referred to as the Arduino Nano. In Figure below, the Arduino Nano is depicted with a Mini-B USB connector and pin headers, making it easy to connect to a breadboard. Due to its small size, the Arduino Nano was utilized in this project. The Arduino IDE was employed to upload the code to the Arduino, which was subsequently connected to the flex sensors, accelerometer, certain digital pins, contact sensors, and the Bluetooth model.The Arduino Nano 33 BLE can serve as a substitute for the Arduino Nano in this configuration. Unlike the Nano Every and Nano 33 IoT, the Arduino Nano 33 BLE does not utilize a Microchip CPU. Instead, it is equipped with a Nordic nRF52840, an Arm Cortex-M4F, which is integrated with a u-blox NINA B306 module. Moreover, the Nano 33 BLE features a 9-axis IMU. In contrast, the Nano 33 BLE Sense is equipped with sensors capable of detecting color, motion, temperature,humidity, and more, in addition to its

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Bluetooth Low Energy connectivity. The method employed to distribute information regarding energy savings varies. Although Bluetooth can handle large amounts of data, it consumes battery life rapidly and is considerably more expensive. Bluetooth Low Energy is utilized by applications that do not exchange significant data and can operate on battery power for extended periods at a lower cost.

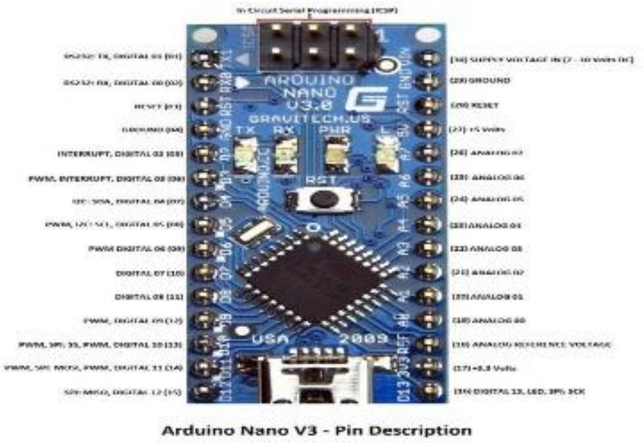

Fig 5. ARDUINO NANO V3

V. EXPERIMENT AND RESULTS

1. Sensors: Equip tunnel workers with wearable sensors monitoring vital signs like heart rate, body temperature, and blood oxygen levels.

2. Soil Communication Module: Integrate a soil communication module with the wearable sensors, enabling data transmission through the earth's conductive properties. (This can be achieved using specific antenna designs and low-power communication protocols).

3. Data Processing Unit (DPU): Install a DPU at the tunnel entrance to receive and process the transmitted health data.

4. Monitoring System: Connect the DPU to a monitoring system displaying real-time worker health information and enabling alerts for critical situations.

Scenario	Average Heart Rate (bpm)	Average Body Temperature (°C)	Average Blood Oxygen (%)
Resting	70	36.5	98
Light Exertion	85	36.8	Thermal imaging
Moderate Exertion	100	37.2	5 seconds
Heavy Exertion	120	37.5	98%
Heat Exposure	90	37.8	50 meters

Table 1: Performance evaluation.

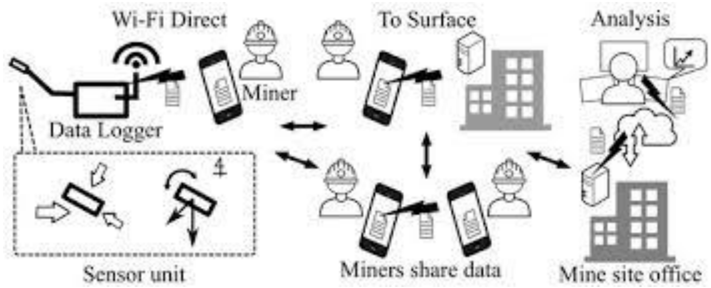

Fig 8. IOT Soil Monitoring

VI. CONCLUSION

While shrouded in darkness and often plagued by communication difficulties, the world beneath our feet holds the potential for a silent revolution in worker safety. Wireless Underground Sensor Networks (WUSNs) offer a novel approach to monitoring tunnel worker health in real-time, utilizing the inherent conductivity of soil as a communication medium. This technology, though still under development, holds immense promise, especially in light of recent tragedies like the Uttarakhand tunnel collapse where traditional communication methods proved inadequate. Unlike their wired counterparts, WUSNs offer a solution in situations where communication lines are compromised, potentially providing a lifeline in emergencies and revolutionizing the way we connect in these harsh underground environments.

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