Tanzania Journal of Engineering and Technology 2022, **41(1)**:19-26
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Websites: https://www.ajol.info/index.php/tjet/about; https://tjet.udsm.ac.tz

ISSN 1821-536X (**print**); ISSN 2619-8789 (**electronic**)
https://doi.org/10.52339/tjet.vi.769

Special Issue – First International Conference on Digital Transformation, 16 – 17, September 2021, Dar es Salaam, TANZANIA

An IoT Based Worker Safety Helmet Using Cloud Computing Technology

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ABSTRACT

Miner safety and security is a major challenge around the world due to the exposure to toxic gases that are frequently released in underground mines. Miners' health is adversely affected primarily by toxic gases, which endanger the workers' lives. Furthermore, human sensory abilities do not detect these dangerous gases. As a result, this paper proposes a safety monitoring system that includes a temperature sensor, humidity sensor, and gas sensors to detect harmful gases and alert miners to those harmful gases using the smart helmet they wear. These gases are transmitted to the control station via the cloud using Internet of Things devices. The station monitors parameters like temperature, humidity, and toxic gases like methane and carbon monoxide to detect any abnormalities and alert the miner via a buzzer on the helmet. The data is processed by the Thing Speak cloud, which enables users to communicate via internet-connected devices and displays a field graph of the transmitted data.

ARTICLE INFO

First presented: 16-17 September, 2021

Revised: 20 April, 2022

Accepted: May 24, 2022

Published: 15 July, 2022

Keywords: *safety, mining, helmet, toxic gases, temperature sensor*

INTRODUCTION

Safety is the most important part of any type of industry. This is because safety and security among others, are the basic aspects of any mining industry. Thus in order to avert any sorts of unwanted conditions, every mining industry must adhere to some basic precautions. But unfortunately, most mining companies do not strictly adhere to the rures of safety and security for their workers, which leads to accidents and hazards during working hours. Nonetheless, it is possible to adopt through the system of information technology, the IoT technology to ensure the safety and security of the mining workers. (Qiuping et al., 2011).

The purpose of this paper is to design a smart helmet for miners that can help to reduce possible accidents which could occur during the work process and also enhance a protection system that will avert accidents whenever the working place is contaminated with toxic gases. The helmet collects and conveys information from the underground mines to the ground team and base station team for monitoring all the activity happening underground while working. In order to achieve our objective we have chosen the Internet of things (IoT) technology to give the information through the means of web and thing speak software. Moreover, it is the latest technology to be implemented with smart devices. We are using Arduino ESP 8266 microcontroller as the heart of the project. For this, we will have a sensing mechanism to sense harmful gases to avoid and alert bad inhalation to the miners inside mining areas.

REVIEW OF RELATED WORKS

Under this section reviews of other works which are closely related to this research will be conducted, and the weaknesses and strengths of the reviewed works will also be pointed out.

The researchers, de Kock et al. (1997) formulated an automation facility for improving the coal mining industry in South Africa considering Productivity, health, and safetyissues. They made an investigation on the coal interface detection (CID); by employing the techniques of vibration analysis and natural gamma radiation, as well as considering infrared, power line carrier, and radio and optical fiber communication channels for data transmission in the coal mines. The development of this technology was an important step on security and safety issues in the mining industry. However it needed to be further improved in order to be inclusive of all aspects of safety and security in underground mines. This is because it has limitations which require people to carry out activities that could best be done through the use of more advanced technology. No wonder therefore, could such a system be confronted with bottlenecks in the course of its operation because of the limitations of human beings to discern security and safety risk aspects which cannot be detected by their own senses.

Qiang et al. (2009 proposed an intelligent helmet for coal miners based on the ZigBee wireless communication system. Their main objective was to detect the humidity level, methane concentration, and temperature of the mining area. The sensed data was to be sent or transmitted to the ground station through ZigBee technique. Its operation was based on the fact that a person who monitors the mining process on the ground station alerts the miner through voice communication about any risk events that occurred. The problem of its operation is the fact that it is impractical to alert miners via voice communication bearing in mind that they work in a noisy and rough environment. Moreover, due to its communication limitation it means that an extra person has to be designated in the monitoring room in order to monitor and alert the miners.

Gaidhane et al. (2016) proposed the use of safety helmets for miners based on the ZigBee wireless technology. They aimed at monitoring gas concentration, humidity and temperature of the underground mining surrounding. The sensed data was transmitted by wireless through the ZigBee communication system to the Control Centre. Whenever the sensed data was abnormal an alert was sent through the ZigBee facility by lighting up different LEDs and blowing up an alarm. The problem of this system was that although it enabled its users to only view the real-time data it lacked a data logging mechanism. Moreover, it had no facility for identifying which particular miner was experiencing difficulties.

Feng et al. (2010) proposed a Coal Mine Monitoring System Based on the RS485 Bus technology. This RS485 bus structure supports multipoint and a two-way communication facility. This type of monitoring system can be developed by using common 8-bit microcontrollers. It has the advantages of a simple circuit structure and low costs. However, due to the adoption of a master-slave structure network, it is difficult to guarantee the reliability of the network structure. Furthermore, data transmission distance through this technology is limited with poor real-time performance. Hazarika et al. (2016) presented a utilization of safety helmets for coal mine workers. The helmet was equipped with a methane and carbon monoxide gas sensor, which transmitted the data to the control room through a wireless module called Zigbee, which was connected to a helmet. Whenever carbon-monoxide or methane gas concentrations were beyond critical levels a micro controller in the control room would trigger an alarm and thus keep the plant and its workers safe by preventing an upcoming accident. The problem of this system was that it could not detect persons who fell down nor detect whether the miners were wearing the helmets or not.

Maity et al. (2012) devised a wireless surveillance and safety system for mine workers based on the Zigbee technology. The system addressed a cost-effective, flexible solution for underground mine workers' safety. A module of MEMS-based sensors was used for underground environmental monitoring and an automating progression of measuring data through digital wireless communication technique was proposed with high accuracy, smooth control, and reliability. A micro-controller was used for collecting data and making decisions, based on which mine worker was informed through alarm as well as voice systems. The voice system with both a microphone and speaker transformed into a digital signal and effectively communicated by wireless with a ground control center computer. However, the ZigBee, based on IEEE 802.15.4 which is fitted with hardware between the mine worker and the ground control center is used for short distances. Therefore, Zigbee as a short distance wireless communication network cannot be used effectively by authorities who are at long distances.

Lihui et al. (2008) invented a system where temperature, humidity, and methane values of the coal mine were collected by sensor nodes and the information was collected by an ARM controller for processing. For communication purposes the Zigbee technology was utilized. Thus if any aspects went wrong, an SMS was sent in order to alert and maintain the safety of the workers. None the less, it is not clear whether the alerts were sent to the ground station or directly to the workers. However, if the SMS was to be sent directly to the workers it would not be practical due to the harsh conditions of underground mining.

Chen et al. (2020) developed a coal mine safety monitoring system for sensing temperature, humidity, and the amount of carbon-dioxide present so that the data could be checked. If any uncertain conditions were observed, the message was sent with the help of GSM to the forensic and fire departments It is, however, not clear why the message has to be sent to the forest and fire department because the presentation does not indicate the relationship existing between that department and the coal mine. Under normal circumstances it is expected that such information would be dealt by the underground station and the base station in the mine so that proper interventions could be taken.

METHODS AND MATERIALS

The proposed developed system is divided into two parts; the first is the underground or mine station and the second is the ground or base station, see Figure 1.

Underground Station

The sensor value extraction is done by the underground station. As shown in Table 1 the underground station has sensors connected to the micro-controller. The proposed system comprises three sensors namely temperature, humidity, and gas sensors that sense the underground coal mine conditions. The Controller at the underground station transforms analog sensor values into digital data. The Wi-Fi transmitter to the Wi-Fi receiver of the base station further transmits this data.

Base Station

The base station plays a major role in monitoring the underground conditions, Wi-Fi receiver of the base station receives the signals from the Wi-Fi transmitter from an underground station, which is further fed to the controller. ESP8266 sends data to cloud computing with ThingSpeak and data can be displayed and controlled anywhere over IoT through a phone or a laptop.

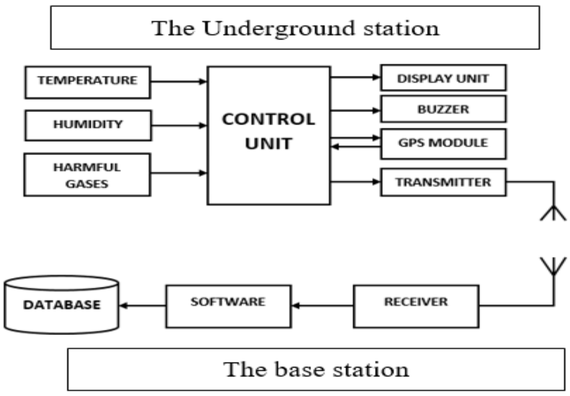

Figure 1: The proposed system.

Table 1: The base station (source: Kumar, 2021).

Parameter	Value	Units
Rated voltage	5	V DC
Operating voltage range	3 – 7	V DC
Rated current	30	mA
Resonant frequency	2300 ± 300	Hz
Sound pressure level	≥ 85	dB
Operating temperature	-20 – 70	°C

Arduino Uno

It is a microcontroller board based on ATmega328P. It has 14digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz quartz crystal, a USB connection, a power jack, and an ICSP header, and a reset button. It contains everything needed to support the microcontroller, refer to Figure 2.

LCD

Liquid Crystal Display is used to display the different parameters of the system. A 16X2 alphanumeric LCD that has a 250 kHz clock frequency is used (citation). The meaning for16X2 indicates that the number of columns is 16 and the number of rows is 2. The meaning for 20X4 indicates that the number of columns is 20 and the number of rows is 4. The LCD is interfaced with the mega 328p micro-controller to display all the details.

Figure 2: Arduino Uno (source: Kim, 2020).

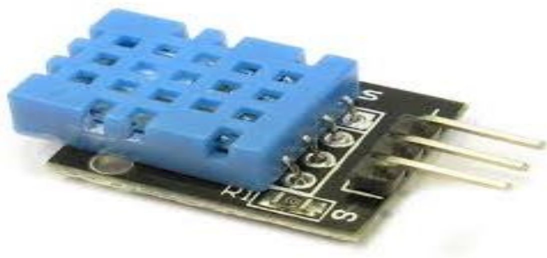

Figure 3: Temperature and humidity sensor. (source: Eldemerdash, 2020).

Alarm

This alarm will be used to inform or alert the miner when the environmental parameter exceedsthe preset values (refer to Table 1).

Temperature and humidity sensor

The system requires a sensor capable of measuring environmental temperature and humidity in the mining areas. The temperature sensor (shown in Figure 3) was able to measure the environment temperature and humidity so that when the temperature is abnormal (above 32 °C) and humidity (30 to 80%) above, it may send the signals to the microcontroller to display the unit and alert that the temperature or humidity is abnormal.

The system requires a gas sensor to measure the harmful gases like carbon monoxide (CO), carbon dioxide (CO_2), methane (CH_4), and ammonia (NH_3) in the mining environment.

When the gas measure is abnormal (above 10%) it sends the signals to the microcontroller to display the unit and alert the miner that there is a harmful gas around that area according to the data collected. The preferred gas sensor is MQ7 (Dinesh et al., 2021).

Monitoring section

The monitoring section is developed in Proteus software as shown by Figure 4.

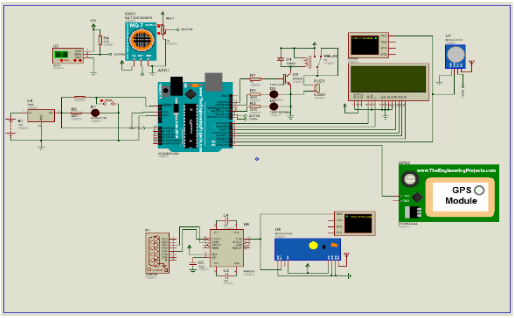

Figure 4: The simulation setup.

For monitoring purposes, the ThingSpeak application is used. ThingSpeak technology is an open-source IoT application and API to store and retrieve data from things using the HTTP protocol over the Internet or via a Local Area Network. ThingSpeak technology enables the creation of sensor logging applications, location-tracking applications, and a social network of things as well as indicating status updates. ThingSpeak is a cross-platform application written in Ruby language.

Proposed system flowchart

In Figure 5 flowchart, the sensors read the environmental parameters such as temperature and humidity and display them on the display unit. The sensed parameters are then compared with the predefined value set shown in Table 1. If there is any abnormal event the alarm is triggered and notifies the base station and the miners.

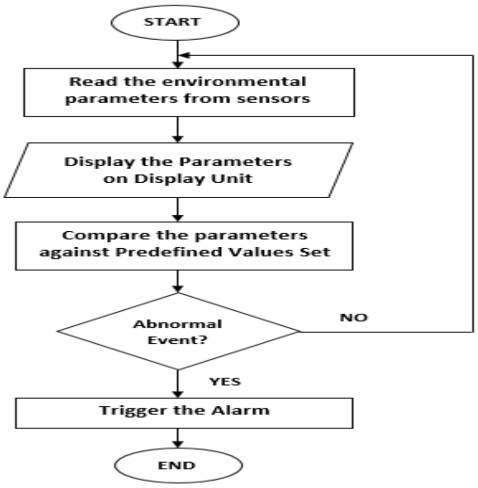

Figure 5: Flowchart of the detection process.

PERFORMANCE EVALUATION

The proposed system is evaluated using simulation and experiment evaluation. Figure 4 shows the simulation setup of the proposed solution. Moreover, Figures 6, 7 and 8 show the temperature and humidity setup and output. The monitoring screen for the base station is shown in Figure 9. Nevertheless, the prototype of the proposed solution was developed using available resources.

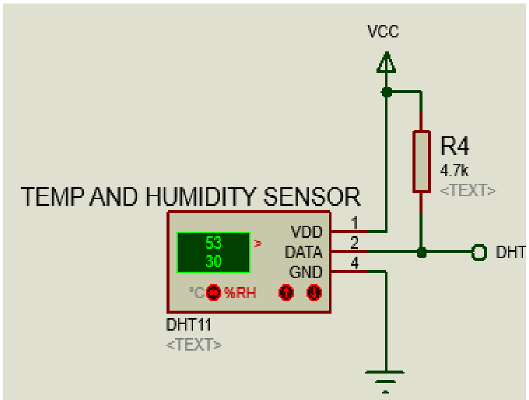

Figure 6: Temperature and humidity sensor simulation setup.

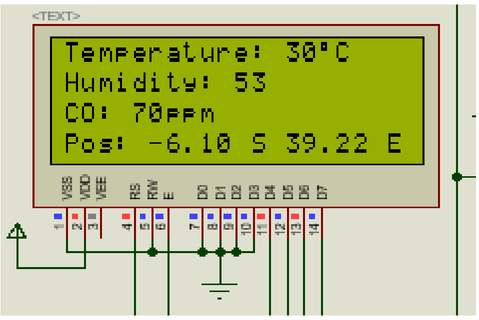

Figure 7: Temperature and humidity output during the simulation.

RESULT AND DISCUSSION

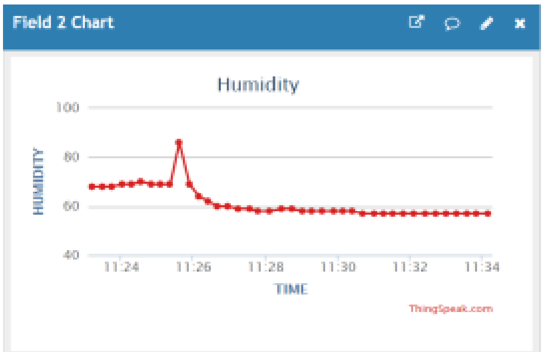

Figure 8: Temperature and humidity output.

Figure 9: Monitoring screen display for ThinSpeak.

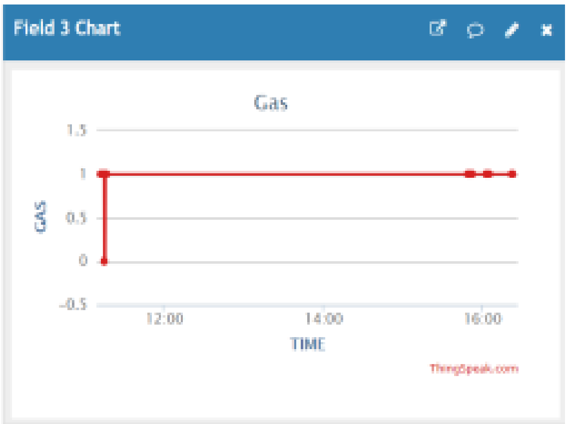

Figure 10: Monitoring screen on ThingSpeak displaying gas around a miner.

Figure 9 shows the monitoring screen on the ThingSpeak application results on the project which indicates the rise and fall of measured humidity, temperature, and carbon monoxide, so that the control station may be able to receive and see the real field graphs within 15 s after every extracted data is transmitted from the ground station.

A) This represents a Web page showing the temperature around a miner. The Figure 11, indicates the temperature around the miner working underground in a mine. The threshold value of the temperature is set at 50 degrees Celsius. In the following chart, the X-axis represents the time temperature in degrees Celsius and the Y-axis represents the temperature in degrees Celsius.

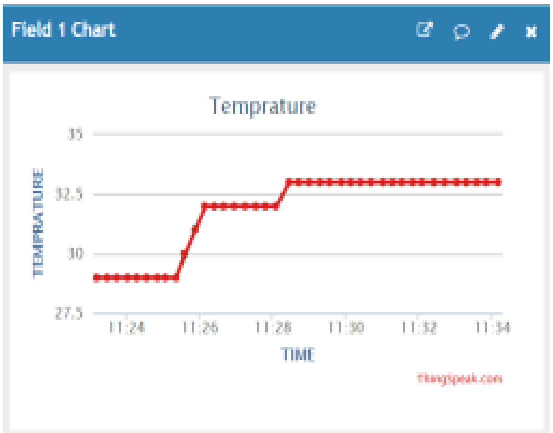

Figure 11: Web page displaying temperature around a miner.

B) This represents a Web page showing humidity around a miner. The Figure. 10

indicates the relative humidity around the miner working in an underground mine. The threshold value of the humidity is set at 90% RH. The X-axis represents the time and the Y-axis represents the related humidity in percentages.

C) This represents a Web page showing gas leakages around a miner. The gas sensor gives the digital output. According to Figure 11 when no gas is detected the output is 1. However, when gas is detected the output is 0. Thus under normal conditions the output of the sensor must be 1. In the following chart, the X-axis represents the time and the Y-axis represents the gas value.

CONCLUSION AND RECOMMENDATIONS

The purpose of this work was to develop a mining smart helmet, which can detect different types of hazardous events such as humidity conditions of mines, the temperature, and the existence of combustible gases. The heart of the system is the control unit that controls and monitors all these events using IoT. This system displays the parameters on the base station PC and alerts the miner. Thus from the base station, higher authorities can monitor substances, which can make informed decisions, which include issuing rescue operations for the miners. The findings indicate that the proposed technology solves the problems of communication by displaying the real-time data from the miners to the base station and ensures the safety of the workers. It is our cherished desire to see that the IoT technology is popularized. However, while this may be a good step forward we are committed to paying more attention towards the improvement of this technology in the future.

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