JSS MAHAVIDYAPEETHA

JSS Science and Technology University

"Guardian Gear: Advancing Safety with Smart mining Helmet"

A technical project report submitted in partial fulfillment of the award of the degree of

BACHELOR OF ENGINEERING

IN

ELECTRONICS AND COMMUNICATION ENGINEERING

BY

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2023-2024

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CERTIFICATE

This is to certify that the work entitled "Guardian Gear: Advancing Safety with Smart mining Helmet" is a Bonafide work carried out by Pratham M, Sudeep G, Prabhuswamy, Sanath Kumar KS in partial fulfillment of the award of the degree of Bachelor of Engineering in Electronics and Communication Engineering for the award of Bachelor of Engineering by JSS Science and Technology University, Mysuru, during the year 2023-2024. The project report has been approved as it satisfies the academic requirements in respect to project work prescribed for the Bachelor of Engineering degree in Electronics and Communication Engineering.

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DECLARATION

We do hereby declare that the project titled "Guardian Gear: Advancing Safety with Smart mining Helmet" is carried out by the project group, under the guidance of Prof. Eshwari A Madappa, Assistant Professor, Department of Electronics and Communication Engineering, JSS Science and Technology University, Mysuru, in partial fulfillment of requirement for the award of Bachelor of Engineering by JSS Science and Technology University, Mysore, during the year 2023-2024.
We also declare that we have not submitted this dissertation to any other university for the award of any degree or diploma course.

Date:
Place: Mysore

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ACKNOWLEDGEMENT

The satisfaction and euphoria that accomplices the successful completion of any task would be incomplete without the mention of people who made it possible. We take the opportunity to express our sincere thanks to following persons without whom this project would not have been possible and whose firm believe in our capabilities and moral boosting to bring out full potential towards the forefront has played a major role in each and every step of our endeavor to success.

First and Foremost we ought to pay due regards to our institution JSS Science and Technology University, Mysuru, which provided us a great platform providing us an opportunity for carrying out this project work.

We are very much thankful to **Dr. C. Nataraju**, Principal, JSS Science and Technology University, Mysuru.

We are extremely greatfull to **Dr. U. B. Mahadevaswamy**, Professor and Head of the Department of Electronics and Communication Engineering, JSS Science and Technology University, Mysuru.

We take this opportunity to express our gratitude and sincere thanks to our project guide **Prof. Eshwari A Madappa**, Assistant Professor, Department of Electronics and Communication Engineering, JSS Science and Technology University, Mysuru, sustained encouragement, timely valuable guidance, immense help and co-operation throughout the tenure of the project.

We intended to express our sincere gratitude to all staff members and non teaching staff of Electronics and Communication Engineering, JSS Science and Technology University, Mysuru, for their help and support.

ABSTRACT

This report describes a new kind of smart helmet for miners that uses long-range LoRa WAN connection. The helmet provides a complete safety solution with its integrated GPS sensor for tracking location in real time, temperature and humidity sensors for environmental monitoring, impact sensor for collision detection, and smoke sensor for early hazard identification. Reliable data transmission is ensured via LoRa WAN, even from sites far below the surface. Thanks to greater situational awareness, quicker emergency reaction times, and real-time monitoring, this data—which includes location, environmental conditions, and potential hazards—allows for safer mining operations. This smart helmet has the potential to drastically lower workplace accidents and improve worker safety by enabling data-driven safety management. It also makes the working environment for miners safer.

Keywords: LoRa WAN, real time monitoring, temperature sensor, humidity sensors.

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Chapter 1

Introduction

The mining sector is vital to the modern world because it supplies materials needed for electronics, building, and renewable energy technology. However, safety issues are a part of mining operations by nature. Exposure to noxious gasses, dust, falling debris, and low visibility underground pose ongoing risks to miners. Difficulties with communication make these hazards even worse. Safety has long been a top priority in the mining industry, especially for subsurface mining. Mining accidents happen at every stage of the process of extracting metals or minerals. Every year, mining accidents claim thousands of lives, especially in the dangerous and labor-intensive coal and rock mining processes. One of the main causes of these tragedies is the collapse of mining slopes. The majority of mining slope collapses are not always fatal. The separated miners will benefit from immediate attention. However, in dimly lit subterranean mines, it is difficult to detect when a specific manual labourer is in distress. For this reason, we would like a system to monitor each miner's well-being.

The safety helmet is a uniform that all miners wear. Conventional safety protocols, although crucial, frequently depend on reactionary methods. Innovative technical solutions are required to address these developing issues and establish a safer work environment. In order to provide dependable connectivity, LoRaWAN (Long Range Wide Area Network) technology is used in this report's design and development of a smart helmet for miners. This helmet is a complete safety monitoring system with a variety of cutting-edge sensors, not simply another piece of protective gear. These sensors collect vital information about the surrounding environment and the safety of the miner, serving as the helmet's eyes and ears. Real-time data collection and transmission, which permits proactive safety actions and enhanced situational awareness, is the fundamental functionality. The helmet guarantees efficient communication even in deep subterranean regions where traditional technologies could struggle by seamlessly connecting with the LoRaWAN network. Two main benefits of the LoRaWAN network are its long-range communication capability and low battery consumption. This keeps the battery usage of the helmet low enough to allow for extended operation hours while enabling data transmission over large distances inside the mine. After being gathered, the sensor data is sent to a central server for analysis and processing. This information serves as the basis for several safety applications, enabling staff to give miner welfare top priority and make well-informed decisions. The technical specifications of the smart helmet system are covered in detail in this study, including the system architecture, LoRaWAN communication protocol, and sensor selection. It delves deeper into how this technology might be used to improve efficiency and safety in the mining sector. This smart helmet has the potential to completely transform mine safety procedures with its extensive monitoring capabilities, which would ultimately result in a marked decrease in industrial accidents and fatalities. The specific sensor functions, communication protocols, and expected effects of this smart helmet system on the mining industry will all be covered in detail in the parts that follow Mining's Human Cost and Innovation's Necessity.

Mining is one of the world's most dangerous industries, despite its vital role in providing resources. Numerous miners suffer injuries or pass away every year as a result of falling debris accidents, breathing in dangerous dust particles, or being exposed to toxic substances like carbon monoxide and methane. These hazards are further exacerbated by the darkness and poor vision found in mine shafts. Even though they are vital, traditional safety procedures frequently involve taking action after an incident has already happened. The human cost of mining demands a paradigm change in favor of preventative safety measures. This report presents a novel idea: a smart helmet that uses LoRaWAN technology to enable dependable communication for miners. This helmet becomes a complete safety monitoring system, surpassing the capabilities of traditional head protection. The Miner's Eyes and Ears: Sensor Integration

A variety of cutting-edge sensors built into the smart helmet serve as the miner's eyes and hearing. In real time, these sensors collect vital information on the surrounding environment and the health of the miners. Gas detectors, which are a type of environmental sensor, may detect harmful gases such as carbon monoxide or methane and warn surface workers and miners of any hazards. By continuously monitoring the air quality, dust monitors can keep miners from breathing in dangerous particulates. Furthermore, by ensuring ideal working conditions within the mine and reducing the risk of heat stress, temperature and humidity sensors can help. Data in Real Time for Preventive Safety Measures

The smart helmet's primary role is the real-time data collection and transmission capability. The helmet guarantees dependable connection even in deep underground regions where conventional Wi-Fi or cellular signals could be spotty or nonexistent, thanks to its seamless integration with the LoRaWAN network. The long-range communication characteristics of the LoRaWAN network enable data transmission over extended distances inside the mine. Moreover, the low power consumption of LoRaWAN guarantees effective battery usage for prolonged operation periods, reducing the frequency of recharge. After being gathered, the sensor data is sent to a central server for analysis and processing. This information serves as the basis for several preventative safety measures. When dangerous gas concentrations are found, real-time notifications may be set out, causing evacuation protocols to be initiated. In a similar vein, alarms may sound if a miner's heart rate rises above a predetermined level, maybe signifying exhaustion. Furthermore, by analyzing past data, trends and possible safety concerns can be found, enabling the implementation of preventative steps before incidents happen

1.1 Preamble

The modern world depends on the mining industry to provide the raw minerals required by many other industries, such as electronics, building, and renewable energy technology. But mining activities come with inherent safety risks. Regular exposure to toxic gases, dust, falling objects, and poor sight puts miners' health and safety at serious risk. Communication problems can make dangerous circumstances worse, which adds to the dangers. Though necessary, traditional safety procedures frequently depend more on reactive than on proactive measures. To address these changing issues and make mining a safer place to work, creative technical solutions are required. In order to improve miner safety and offer dependable connectivity, this paper investigates the design and development of a smart helmet using LoRa WAN (Long Range Wide Area Network) technology. This helmet is more than just protective headgear; it's a complete safety monitoring system with a wide range of cutting-edge sensors.

These sensors serve as the eyes and ears of the helmet, continuously collecting vital information about the surrounding conditions and the health of the miner. Proactive safety measures and enhanced situational awareness are made possible by this real-time data collection and transmission. Because of its seamless integration with the LoRa WAN, the helmet maintains excellent connectivity even in deep subterranean locations where older technologies may fail. With the long-range communication capabilities and low power consumption of the LoRa WAN network, the helmet can run for longer periods of time while transmitting data across great distances within the mine. A central server receives the gathered sensor data, which is then processed and analysed to create a variety of safety applications. The wellbeing of the miners is given priority, and data-centric decision-making is encouraged. This report explores the technical details of the smart helmet system, covering the sensor selection, LoRa WAN communication protocol, and system architecture. It also looks at how this technology might improve efficiency and safety in the mining industry. The smart helmet has the potential to drastically reduce industrial accidents and fatalities by revolutionising mine safety processes with its extensive monitoring capabilities. The parts that follow will go into great detail about the many sensor capabilities, communication protocols, and anticipated effects of this smart helmet system on the mining sector.

1.2 Motivation

The backbone of our modern world relies on the tireless work of miners, who extract the vital resources that fuel our technology and infrastructure. Yet, these heroes face constant danger in harsh environments. Our groundbreaking smart helmet, equipped with cutting-edge tech never before seen in mining, prioritizes miner safety like never before. It's a leap forward in hazard detection and communication, offering miners and rescue teams real-time insights to keep them safe and productive. All forms of mining offer the basic materials that make up our planet. Miners put their lives in danger to obtain these resources, which range from the metals in our cellphones to the building materials for our houses. By putting their health first, this cutting-edge helmet guarantees that they can work securely and productively. Although worker safety is given first priority in current mining operations, there is always space for improvement. Miners are still at risk from hazardous environments, falling items, and toxic gas, even with all the safety precautions in place. Conventional monitoring systems could have drawbacks. Furthermore, there is hardly any care for the safety of miners.

1.3 Problem Statement

Even though miners are essential to society, they face constant risks such hazardous situations, objects falling, and poisonous gases, which calls for more safety measures. Even though the safety of mine workers is of utmost importance, the current safety laws and monitoring programmes might not be adequate to meet all of the needs of miners. In order to close these gaps, our cutting-edge smart helmet for mining revolutionises safety procedures by providing real-time communication and hazard identification, greatly enhancing miner protection. By putting miner safety first and maximising productivity, our goal is to reduce risks, provide safe working conditions, and promote a more secure and sustainable mining industry.

1.4 Objectives

The main objectives of the project are:

1. **Toxic Gas Level Detection:** Real-time alerts to hazardous levels of toxic gases to prevent health issues and fatalities.

2. **Temperature and Humidity Monitoring: :** Implementation of sensors to monitor temperature and humidity levels for worker well-being.

3. **Fall and Collision Detection:** Advanced systems to identify and alert workers and supervisors in accidents.

4. **Real-time Communication Enablement** Integration of robust communication functionalities like two-way radios or wireless systems for seamless coordination and safety.

1.5 Existing Work

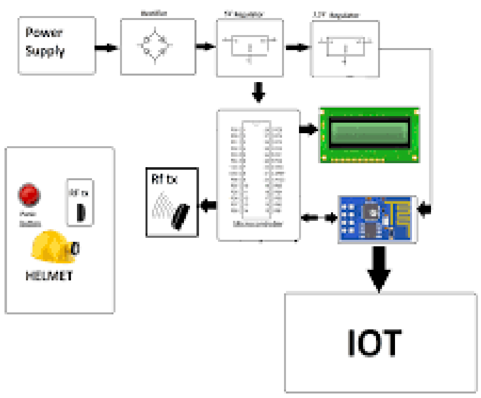

Figure 1.1: Existing Model

1. Although there isn't a great helmet among the many mines, some research has been done on the idea of using Bluetooth technologies, which have a number of drawbacks in terms of power supply and property. The current technique makes sure that a mining helmet shields the worker's head from various injuries. Paying attention to the status turns into a problematic aspect of the existing setup. Because the helmet is just too serious and difficult to work with, miners often feel pressured to take it off their heads. In the event that it is removed, miners may be exposed to hazardous situations. There isn't a smart helmet on the market

yet that can monitor its surroundings and develop substitutes to maintain worker safety. For the sole reason that hazardous gas could escape, the miners are not supplied with element supplies.The pictorial representation of the existing model is as shown in Figure 1.1 Existing model. The biggest difficulty mining organisations encounter is creating an environment free of barriers to communication.

1.6 Proposed Model

1. The main objective of the proposed work is to improve miner safety in hazardous conditions through the thorough design and implementation of an Internet of Things-based smart helmet-tracking system designed especially for coal miners. This project takes a multifaceted approach. It begins with the thoughtful selection and integration of hardware, including a GPS module, impact detection, temperature, humidity, and smoke sensors, all of which are flawlessly interfaced with an Arduino Uno microcontroller. The microcontroller's functionality will be driven by the creation of firmware in Embedded C, which will coordinate operations including sensor data collecting, threshold-based alert triggering, and LoRa-based wireless data transmission.

   A corresponding infrastructure will be built on the server side, consisting of a microcontroller and LoRa receiver module, which will be used to receive, process, and analyse data from the miners' helmets in order to identify and respond to potentially dangerous situations. Simultaneously, a Csharp desktop programme will provide an intuitive user interface for managing and monitoring sensor data in real time, guaranteeing timely reactions to possible safety hazards. Before these components are deployed in coal mines for practical assessment, their integration will be thoroughly evaluated to ensure smooth communication and dependable operation. To maintain system performance and comply with changing safety regulations, ongoing maintenance and upgrades will be carried out, optimising the system's ability to protect coal miners' health and safety. Figure 1.2: Block Diagram for the Transmitting end and Figure 1.3: Block Diagram for receiving end represents the corresponding block diagram for the transmitter and receiver end. The block diagram gives a idea about how the information will be collected and will be received at the receiver end through LoRa Transceiver.

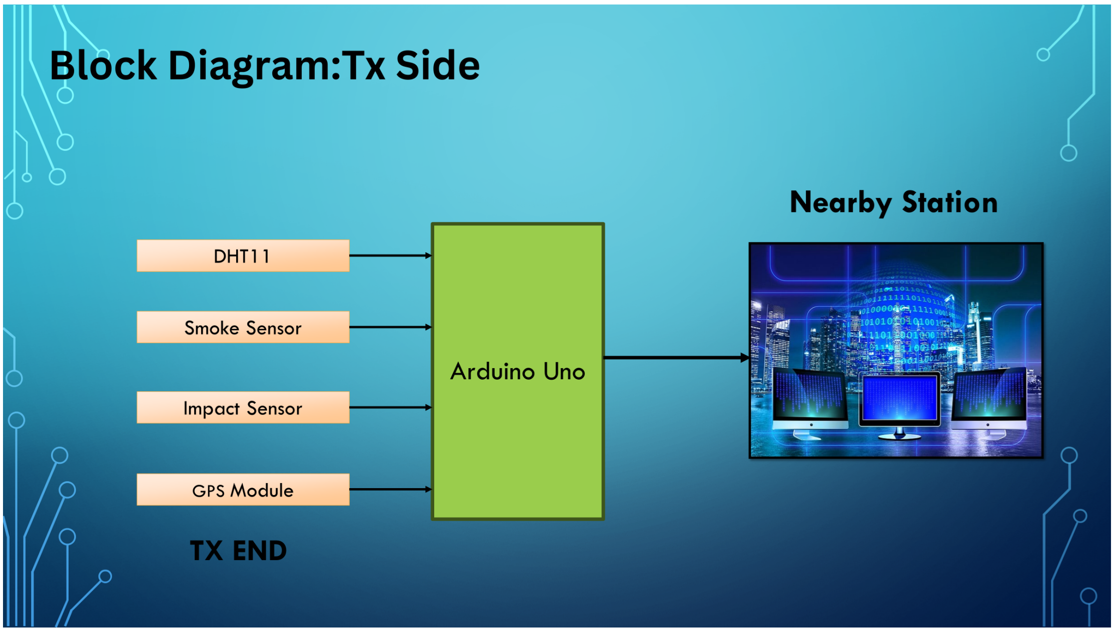

Figure 1.2: Block diagram for the transmitting end

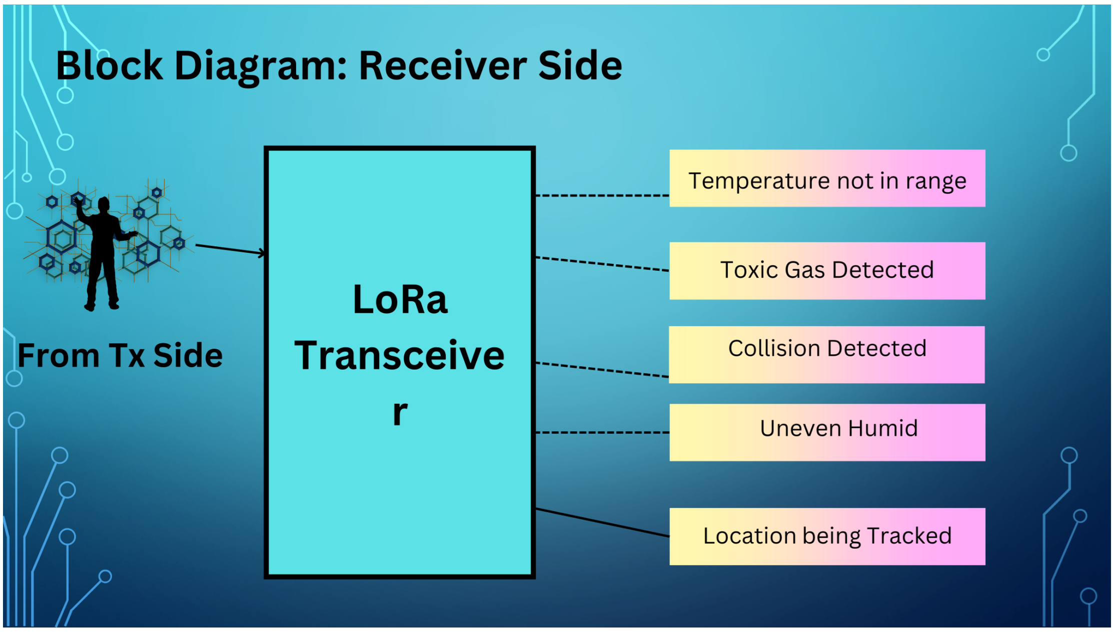

Figure 1.3: Block diagram for receiving end

A simple representation of how the flow of the proposed model is as shown in Figure 1.4: Flow chart for the Proposed model.It gives a idea about how the model will work from starting at the tx end to receiver end which is the base station.

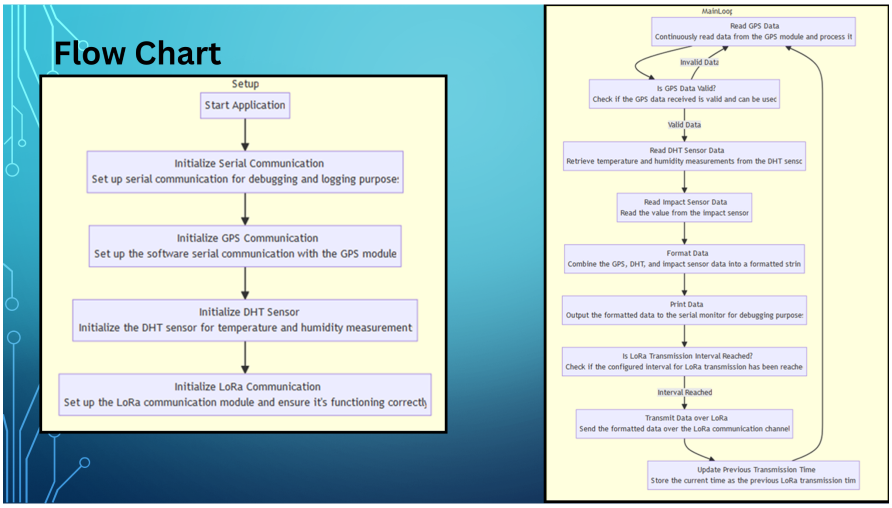

Figure 1.4: Flow chart for the Proposed model

1.7 Data Flow Diagram

A data flow diagram (DFD) models the process characteristics of an information system by providing a graphical depiction of the "flow" of data through the system. A DFD is frequently used as a first step to quickly sketch down the system's general layout; further information can be added later.[2] Data processing (structured design) visualisation is another application for DFDs.The Figure 1.5: Data Flow Level 0 and Figure 1.6: Data Flow Level 1 gives a picture of the initial stage to data flow at the receiver side. A DFD illustrates the types of data that will be entered into the system, the data that will be output, the data flow within the system, and the data storage locations. Unlike a flowchart, which also displays this information, it does not provide information on the timing of the process or whether it will run in parallel or sequential order.

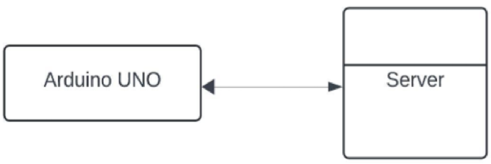

Figure 1.5: Data Flow Level 0

The level 0 gives a idea about the initial setup of the arduino uno connecting with the server and further proceeding to the next level with the integration of different sensors and modules with the designing of the end user's GUI model.

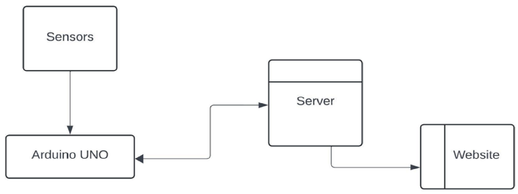

Figure 1.6: Data Flow Level 1

1.8 System Requirements

The system specifications and functional and non-functional requirements are covered in this section. The chapter opens with the system's functional and non-functional requirements. Next, the system specification is presented, which includes a synopsis of the system's hardware and software specifications.

1. Functional Requirements

   The IoT-based smart helmet-tracking system for coal miners has a number of functional criteria that cover different features and capabilities to guarantee miner safety and effective system operation. The following are the essential functioning needs:

   1. Sensor Integration: To monitor ambient conditions, the helmet is equipped with temperature, humidity, fire, vibration, and smoke sensors.

   2. Real-time data processing: When predetermined thresholds are surpassed, the Arduino Uno microcontroller is used to process sensor data and trigger warnings.

   3.Wireless Communication: Using LoRa technology to allow sensor data and GPS coordinates to be wirelessly transmitted to a central server.

   4.User Interface Development: Using Csharp to create a desktop application that manages server-side warnings and displays real-time sensor data.

   5. Safety Protocol Integration: Including features that, in an emergency, might use voice commands to direct miners to safer areas.

   6. System Testing: Extensive testing is necessary to guarantee the system's dependability and efficiency in actual mining settings.

1. Non Functional Requirements

   Rather than focusing on the particular capabilities a system offers, non-functional requirements list the attributes and features that characterise how the system functions. Non-functional requirements are critical to ensuring the performance, security, usability, and dependability of the IoT-based smart helmet-tracking system for coal miners. The following are some of the project's non-functional requirements:

   1. Reliability: Making sure the system performs accurately and consistently in a range of usage situations and environmental circumstances.

   2. Scalability: Creating a system that can grow in the future to handle new sensors or more powerful data processing tools.

   3. Usability: Designing an easy-to-use interface with clear feedback mechanisms and intuitive controls for both the hardware components and the desktop programme.

   4. Performance: Improving the system to reduce processing and transmission delay while guaranteeing prompt notifications and responses to hazardous conditions.

   5. Security: Putting safeguards in place to guard private information sent between the microcontroller, server, and sensors in order to prevent tampering or unwanted access.

   6. Durability: Choosing hardware materials and parts that are strong enough to endure the severe conditions commonly found in mining operations.

   7. Compliance: Making sure the system complies with legal requirements and industry best practices, as well as pertinent industry norms and laws controlling safety equipment and data privacy.

1.9 Organisation of the report

The report has five chapters that can be explained as follows in order to make it easier for readers to grasp the realised work:

1. Chapter 1 describes the main elements, such as the problem statement and an introduction to the proposed task. Based on the resources that are available, the chapter also describes the project's goals.

2. Chapter 2 outlines the literature review that was done to familiarise oneself with

the situation at hand and the project's scope. The usefulness of the current practises is revealed in this chapter.

3. Chapter 3 includes the software requirements for the system that will work best to ensure the project's smooth operation are detailed and discusses the Architecture outline that are being used in the process of upbringing the accuracy and efficiency of the project.

4. Chapter 4 outlines the implementation strategy that has been chosen to realise the goals based on the modules stated in the previous chapter, as well as the results that have been seen.

5. Chapter 5 focuses on discussions of the project's benefits, constraints, and potential future scope. The requested work is eventually completed.

Chapter 2

Literature Survey

To contribute to this field of advancement, it gets to be exceptionally vital to get it and assess the already existing strategies. Subsequently, the literature survey has been carried out for the project work where a few authors and their methods have been analyzed. At last, authoritative comparison is pulled out between as of now existing strategies and the proposed procedure on a few common grounds.

2.1 Previous Research

[1]. A study by Behr, Kumar, and Hancke from the University of Pretoria has developed a Smart Helmet for the mining industry, addressing hazards like air quality, helmet removal, and collisions. The helmet uses a static chamber method for monitoring air quality, an off-the-shelf IR sensor for helmet removal detection, an accelerometer for impact testing, and exceeds standard wireless transmission capabilities. Despite challenges in sensor integration, the Smart Helmet shows potential in improving miner safety, underscoring the importance of technological advancements in mitigating risks.

[2]. Shabina S. from K. Ramakrishnan College of Engineering has developed a Smart Helmet that uses RF and Wireless Sensor Network (WSN) technologies to enhance safety in underground mines. The system combines RF communication for real-time data transmission and worker localization, with WSN for monitoring environmental parameters like temperature, pressure, and gas levels. The system consists of three modules: the helmet, localizer, and control room, and triggers alarm sounds and displays warnings on LCD screens when deviations from safe parameters are detected. The system represents a significant advancement in mine safety technology, aiming to prevent disasters by providing real-time sensing, localization, and warning capabilities. This innovative solution aims to improve the security and well-being of mine workers worldwide, mitigating risks in underground mining environments.

[3]. Rathod et al. have developed a Smart Helmet system for the mining industry, using IoT technology to improve safety measures and mitigate risks faced by coal miners. The system uses ZigBee technology for communication and integrates sensors to detect hazardous gases, abnormal temperature, and humidity levels. It aims to enhance miners' life expectancy by providing timely alerts about potential dangers. The system focuses on three main risks: air quality, helmet removal, and collisions. Gas sensors detect toxic gases, while an IR sensor detects helmet removal. The system uses oximeters, gas sensors, atmospheric pressure sensors, and temperature and humidity sensors for comprehensive hazard detection. The system is expected to revolutionize mining safety protocols and redefine safety standards in the industry.

[4]. Suriyakrishnaan et al. have developed a Smart Safety Helmet system for coal mining applications, aiming to reduce risks faced by mine workers in underground environments. The system integrates various sensors, including gas sensors for methane and carbon monoxide detection, collision sensors, and temperature and humidity sensors, linked to an ATmega328 microcontroller. The system uses RF technology to transmit real-time data to the miner's helmet, providing immediate alerts in case of hazardous conditions. The helmet features a microcontroller, buzzer, and LCD to convey alerts. The system ensures proactive monitoring of environmental conditions, allowing miners to take precautionary measures promptly. The system's efficacy is demonstrated through simulations of gas detection, collision detection, and temperature monitoring scenarios. believe the system is a viable solution to enhance safety protocols in the coal mining industry. Further enhancements, such as IoT integration and additional sensor functionalities, could contribute to improved worker safety across various underground work environments.

[5]. Charde et al. have developed a Smart and Secured Helmet system to improve safety in coal mining. The system uses ZigBee technology for wireless communication, enabling real-time monitoring of harmful gases and temperature and humidity levels. The helmet detects dangerous events like helmet removal and collisions, triggering alerts via a buzzer. The system integrates sensors like MQ5 and MQ2 gas sensors, humidity sensors, temperature sensors, and heartbeat sensors, along with a microcontroller for data processing. The system also includes a control station for monitoring miners' conditions. The system is designed for future applications in railway and road safety.

[6]. Bushra Tabassum (2018), Dr. Baswaraj Gadgay, Veeresh Pujari (2018) a sensible Helmet for Air Quality and dangerous Event Detection for the Mining :An intelligent headgear has been created that can identify dangerous occurrences in the mining sector. When developing the helmet, the four primary categories of hazards—air quality, fire, helmet removal, and mercury sensors—were taken into account. The first is the amount of dangerous gases, like CO, SO2, NO2, and particulate matter, concentrated in the air. A miner taking off their mining helmet was categorised as the second hazardous event. After an attempt at developing an IR sensor was fruitless, the miner was able to correctly detect when the helmet was on their head using an off-the-shelf IR sensor. A small, easy-to-use tool for fire safety, the fire sensor is the third potentially dangerous event.

[7]. C.J. Beher, G. Hancke, Anuj, Kumar, (2018) A smart helmet for the mining industry that monitors air quality and detects harmful events An intelligent headgear has been created that can identify dangerous occurrences in the mining sector. The three primary categories of hazards—air quality, helmet removal, and collision (miners are struck by an object)—have all been taken into account in the creation of the helmet. After an attempt at developing an IR sensor was fruitless, the miner was able to correctly detect when the helmet was on their head using an off-the-shelf IR sensor. When miners are struck in the head by an object with a force greater than 1000 on the HIC, it is classified as the third hazardous event.

[8]. Paulchamy, Dr. B. (2019) An Intelligent Miners Helmet with Zigbee-Based Destructive Event Detection and Air Quality A smart helmet has been created to help the miners who operate in the mining sector. In the mining sector, bad things often happen that might cause serious injuries or even death. The most widely used helmet for miners is the LED variety due to its low power consumption and small weight. Apart from lighting, it does not, however, increase the safety of miners. Sensor data is gathered and sent via Zigbee wireless sensor networks. The central control unit receives facts from the cost-effective zigbee-based system.

[9]. Karthik NS, NA, and Raghavendra Rao B Divya L. Poojitha (2019) A Smart Helmet for Detecting Hazardous Events and Air Quality An alerting unit has been used to notify the critical amounts of hazardous gases, such as CO, SO2, and NO2, in the mining industry. An inexpensive infrared distance sensor was used to successfully complete the helmet removal test. The infrared sensor, which was created from the ground up, functioned.

[10]. B. Chandrakala, N. Balaji (2020) The Smart Helmet is an intelligent device designed for the mining industry that detects hazardous events. Here, a clever framework that can identify and evaluate hazardous events and air quality (toxic gases) in the underground mining sector is being put forth. It provides an additional method for analysing hazardous situations that arise during mining, such as those involving methane, propane, butane, benzene, carbon monoxide, and other deadly gases. A detailed description of a framework to evaluate the centralization of hazardous gases is provided for this suggested framework. The proposed framework, which is created using a Raspberry Pi, will display the position of the cap on the individual as well as any external contributions to the protective cap. Appropriate sensors will be used and connected to the Raspberry Pi via wifi in order to quantify these occurrences.

[11]. Dineshkumar Ponnusamy (2021) G Pradeepkumar, S Sanjay Rahul, N Sudharsanaa, S Suvetha A LoRaWAN-enabled Smart Helmet for the Mining Sector In mining regions where employee health is a major concern, air quality becomes a crucial consideration. The number of fatalities caused by the mixture of several hazardous gases beneath the mining area keeps rising daily. The total volatile organic compounds (TVOCs) and carbon dioxide play a major part in the workers' health systems. Numerous health problems, including weariness, nausea, emesis, epitasis, and dyspnea, are brought on by the instabilities in these TVOC levels. Excessive concentrations of these harmful substances in the atmosphere can lead to a variety of issues, including headaches and acute respiratory distress.

2.2 Summary of Literature Survey

Several innovative smart helmet systems have been developed to enhance miner safety, addressing key hazards such as air quality, helmet removal, and collisions. Researchers from the University of Pretoria, including Behr, Kumar, and Hancke, have designed a smart helmet that uses a static chamber method to monitor air quality, an off-the-shelf IR sensor for detecting helmet removal, and an accelerometer for impact testing. Despite challenges in sensor integration, this helmet exceeds standard wireless transmission capabilities and shows significant potential in improving miner safety.

Shabina S. from K. Ramakrishnan College of Engineering developed another smart helmet that utilizes RF and Wireless Sensor Network (WSN) technologies to enhance safety in underground mines. This system combines RF communication for real-time data transmission and worker localization with WSN for monitoring environmental parameters like temperature, pressure, and gas levels. The helmet, localizer, and control room modules work together to trigger alarms and display warnings when deviations from safe parameters are detected. Rathod et al. have created a smart helmet system that employs IoT and ZigBee technology to improve safety measures and mitigate risks faced by coal miners. Their helmet features gas sensors to detect toxic gases, an IR sensor for helmet removal detection, and atmospheric pressure sensors, providing timely alerts about potential dangers.

Suriyakrishnaan et al. developed a smart safety helmet system that integrates various sensors, including gas sensors for methane and carbon monoxide detection, collision sensors, and temperature and humidity sensors, all linked to an ATmega328 microcontroller. This system uses RF technology for real-time data transmission, ensuring proactive monitoring and immediate alerts. Lastly, Charde et al. have designed a smart and secured helmet system utilizing ZigBee technology for wireless communication. This helmet monitors harmful gases, temperature, and humidity levels, and detects helmet removal and collisions, triggering alerts via a buzzer. It integrates MQ5 and MQ2 gas sensors, humidity sensors, temperature sensors, and a heartbeat sensor, along with a microcontroller and a control station for comprehensive monitoring. These smart helmet systems represent significant advancements in mining safety technology, providing real-time hazard detection, communication, and warning capabilities, thereby aiming to improve the security and well-being of mine workers worldwide.

Chapter 3

Present Work Carried Out

In the below-mentioned sections, all the necessary details with respect to the project flow have been explained.

3.1 Hardware and Software Requirements

3.1.1 Hardware Requirements

1. **Arduino Uno:** Arduino UNO is a microcontroller; it is the central controller for our system in transmitter section and also receiver section. Arduino UNO is based on ATmega328. The Arduino UNO comprises of 14 Digital pins such as input output pins along with 6 analog inputs, a 16MHz Quartz crystal a Universal Serial Bus, a USB connection an, power jack and a button. Arduino UNO will be operated on an external supply from six to twenty volts. If we use RF module for this board is seven to twelve volts. The Arduino UNO is supplied with thirty male input output headers, during a dip thirty like configuration which might be programmed.Figure 3.1: Arduino Uno gives the pictorial represntation of arduino uno. The feauters are as follows
   - Microcontroller: ATmega328P
   - Operating voltage: 5V
   - Input voltage: 7-12V
   - Flash memory: 32KB
   - SRAM: 2KB
   - EEPROM: 1KB

Arduino uno is the widely used microcontroller for majority application due to its ease of use and less complexity. We can modify it to our requirement by dumping the designed code to the arduino through its ide.

Figure 3.1: Arduino Uno

2. **DHT11 Sensor:** DHT11 sensor is a digital temperature, humidity sensor widely used in various IoT projects. Figure 3.2: DHT11 shows the external view of the dht11 sensor.

   a. Sensor elements: The DHT11 sensor contains a combination of temperature and humidity sensors that output a calibrated digital signal. It uses a thermistor to measure temperature and a capacitive humidity sensor to measure relative humidity.

   b. Measuring range: The DHT11 sensor can measure temperature from 0°C to 50°C (32°F to 122°F) with an accuracy of ±2°C (±0.36°F). It can measure relative humidity from 20% to 90% RH with an accuracy of ±5% RH.

   c. Digital Output: The sensor provides digital output for measuring temperature and humidity. It communicates via a one-wire digital interface, making it easy to interface with a microcontroller.

   d. Low cost: One of the key features of the DHT11 sensor is its low cost, making it accessible to hobbyists and enthusiasts working on IoT projects on a tight budget.

   e. Operating Voltage: The DHT11 sensor typically operates at 3.3 volts or 5 volts, making it compatible with a wide range of microcontrollers and development boards.

   f. Sampling rate: The sensor needs some time between successive readings to stabilize its internal sensing elements. The recommended sampling rate is every 2 seconds for temperature and every 2 seconds for humidity.

g. Pin description: The DHT11 sensor is typically housed in a small plastic box with three pins for the interface: VCC (power), GND (ground), and DATA (digital output).

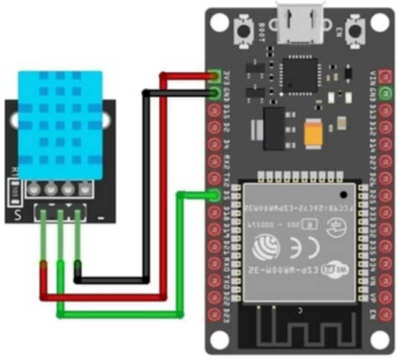

Figure 3.2: DHT11

3. **Antenna:**This module is essentially an ESP8266 Wi-Fi module with a built-in antenna. The ESP8266 is a widely used Wi-Fi module for IoT projects due to its low cost, low power consumption, and ease of use. It can connect to Wi-Fi networks and communicate with other devices over the internet. Figure 3.3: Antenna MT76813DBI shows the antenna picture. The antenna bundled with the MT76813DBI ESP8266 module represents a versatile and reliable solution for enabling wireless communication across a diverse array of applications. Whether facilitating data exchange in smart devices, industrial machinery, or specialized projects like smart helmets for mining, this antenna stands as a vital component driving connectivity and innovation in the realm of IoT and beyond.

Figure 3.3: Antenna

4. **Smoke Sensor:** AA cheap metal oxide semiconductor (MOS) gas sensor that is frequently used to detect smoke and other flammable gasses is the MQ-135. It can be used for a number of purposes, such as leak detection, air quality monitoring,

and fire alarms, and it has a high sensitivity to smoke. When the sensor comes into touch with smoke or flammable gasses, it changes conductivity, which is how it functions. An analog circuit can detect this change in conductivity, which can be utilized to detect the presence of gas or smoke.

Simple-to-use sensor for determining the airborne concentration of pollutants and other harmful gasses like benzone, alcohol, and smoking. The MQ-135 is perfect for robotics and microcontroller projects, gas leak detection, and gas alarm applications. It monitors gas concentration between 10 and 1000 ppm.

A tiny heating element and an electronic chemical sensor are used in the MQ series of sensors. They can be used indoors and are sensitive to a variety of gasses.

The sensor is highly sensitive and responds quickly, but it must heat up for a few minutes before it can produce correct measurements. The sensor's measured readings are output as an analog value that a microcontroller can simply evaluate.

This sensor is prepared to be connected to an Arduino board or other microcontroller.

Figure 3.4: Smoke Sensor

5. Impact Sensor: The phrase "impact sensor" describes a type of sensor that can be used to determine whether an impact has happened, such as a collision with a pedestrian, another car, a pole, etc. Additional information about the impact's severity or similar details may be provided by the sensor. The phrase "impact sensor" describes a type of sensor that can be used to determine whether an impact has happened, such as a collision with a pedestrian, another car, a pole, etc. Additional information about the impact's severity or similar details may be provided by the sensor. Lastly, mercury tilt switches, which rely on a mercury pool completing a circuit when tilted, are incredibly cheap but less sensitive. Your unique needs will determine which option is ideal, taking into account things like sensitivity, force range, response time, and cost.

Figure 3.5: Impact Sensor

6. **GPS Module:**The days of using paper maps and educated guesses to navigate are long gone. The ability to pinpoint our location on Earth has been revolutionized by GPS sensors, or global positioning system sensors. These amazing gadgets rely on a network of satellites in orbit that send out signals continuously.

   A GPS sensor can determine its distance from each satellite by receiving these signals, measuring the trip time, and computing the difference. The sensor uses this data along with an ingenious mathematical technique known as trilateration to pinpoint its exact location, frequently to within a few meters, with startling accuracy!

   The GPS module, a tiny electrical circuit, is the brains behind a GPS sensor. This module contains the processor that does the intricate computations as well as the receiver chip that picks up the weak satellite signals. The antenna works in tandem with the module and is essential to picking up these sporadic transmissions. The total performance of the sensor is affected by the different antenna designs and sizes that provide differing degrees of reception strength.

   The uses for GPS sensors are numerous and constantly growing. They provide us with straightforward navigation to our destinations and constitute the foundation of contemporary navigation systems found in our automobiles, smartphones, and wearables. GPS sensors are used in location-based services such as ride-hailing apps, location sharing, and even photo geotagging, in addition to navigation. Companies use their strength to track assets, keeping an eye on the whereabouts of machinery, cars, and other priceless possessions in real time. Utilizing GPS technology, farmers can map fields precisely and operate automated tractors, all of which maximize resource efficiency in precision agriculture. While scientists utilize GPS data for a variety of research pursuits, from tracking animal migration patterns to monitoring environmental changes, even emergency response teams rely on GPS to find individuals in crisis. The physical outlook for the gps module is as shown in Figure 3.6: GPS Module.

The advantages of GPS sensors are obvious: their great accuracy, worldwide coverage, and real- time updates make them indispensable instruments for a wide range of professional and domestic applications. It's crucial to recognize its drawbacks, though, including as its reliance on clear skies for signal reception and some privacy issues. Notwithstanding these drawbacks, GPS sensors continue to be a potent technological advancement that transform how we track, navigate, and engage with our surroundings.

Figure 3.6: GPS Module

7. **LoRa Transceiver:**Lora transceivers have revolutionized wireless communication. These specialized gadgets, in contrast to conventional methods, are excellent at sending and receiving data over remarkable distances with minimal power usage. LoRa is a special modulation method that allows for this magic.

The idea of spread spectrum is essential to LoRa's success. Consider a motorway with several lanes. Due to its lane-sharing arrangement, traditional wireless communication is susceptible to traffic congestion brought on by competing signals. However, by strategically dispersing the data over a larger range of channels, LoRa considerably lowers the likelihood of interference. This enables LoRa to operate with less transmission power and improves reliability in congested wireless situations. LoRa is ideal for devices that run on batteries since it uses less energy at lower power levels.

The advantages have practical uses. The foundation of Low-Power Wide-Area Networks (LPWAN) utilized in the Internet of Things (IoT) is made up of LoRa transceivers. Imagine a big farm with a network of sensors monitoring the soil conditions continuously. The range and power constraints of traditional wireless make it impractical. This is filled by LoRa transceivers, which allow for long-distance communication between these sensors and a central hub. This feature opens up a wide range of uses outside of smart agriculture. Connecting sensors for smart metering, environmental monitoring, and traffic management, LoRa is essential to smart city ambitions. LoRa is used by industrial operations across large areas for process control, asset tracking, and remote equipment monitoring.

LoRa even helps precision agriculture by enabling farmers to track livestock, keep an eye on soil conditions, and improve irrigation systems over large areas. Despite its remarkable low power consumption and long-range communication capabilities, LoRa has many drawbacks. As a necessary trade-off for the increased range and economical battery use, data transmission speeds are typically lower than those of some other wireless technologies. Furthermore, establishing a LoRa network might need more infrastructure than using widely accessible Wi-Fi or cellular networks. Figure 3.7: LoRa Transceive shows the physical look of the LoRa Transceiver.

LoRa transceivers are a potent technology that will have a big influence on wireless communication in the future, despite these drawbacks. Their resilience to obstacles such as interference and restricted power supplies renders them an invaluable resource for the rapidly developing realm of the Internet of Things and beyond.

Long-range (LoRa) technology's salient characteristics are:

a. Long Range: LoRa technology is perfect for applications where devices are dispersed over large geographic areas since it allows communication over several kilometres in open areas.

b. Low Power Consumption: Because LoRa devices are made to run on very little power, they are a good fit for battery-powered devices that must run for long stretches of time between charges or replacements.

c. Frequency Bands: LoRa can be deployed with flexibility and can comply with local laws in a variety of frequency bands, including the unlicensed ISM (Industrial, Scientific, and Medical) bands.

d. Open Standard: LoRa is an open standard technology that fosters creativity in the creation of LoRa-enabled products and permits device compatibility across various suppliers.

e. Security: End-to-end encryption and authentication are two security elements included in LoRa WAN, a protocol that is developed on top of LoRa technology and guarantees the confidentiality and integrity of data transferred.

f. Cost-Effectiveness: Compared to other wireless technologies, LoRa technology provides a long-range wireless communication solution that is less expensive in terms of infrastructure and operating costs.

Figure 3.7: LoRa Transceiver

3.1.2 Software Requirements

1. **Arduino Ide** Arduino IDE (Integrated Development Environment) is a free, open-source software that acts as your command center for the world of Arduino micro-controllers. Designed with beginners and hobbyists in mind, the IDE boasts a user-friendly interface with a clean layout and syntax highlighting for easy code reading and writing. Under the hood, Arduino uses a simplified version of C/C++, making it approachable for those with basic programming knowledge. But you don't have to start from scratch! The IDE comes pre-loaded with a treasure trove of code libraries, offering pre-written functions for common tasks and components, saving you tons of time and effort.

   Seamless hardware integration is another perk. With a simple USB connection, the IDE bridges the gap between your computer and various Arduino boards. Once you've crafted your program (called a sketch), uploading it to the board takes just a few clicks. But the interaction doesn't stop there. A built-in serial monitor window allows real-time communication, letting you see data flowing between your computer and the Arduino board. This is fantastic for debugging and visualizing sensor readings.

   The fun doesn't stop with the base functionalities. The board manager acts like a virtual toolbox, allowing you to effortlessly install support for different Arduino board types. Similarly, the library manager grants access to a vast and ever-growing collection of additional code libraries. Need to control an LCD screen? Interact with a temperature sensor? Chances are there's a library out there waiting to be explored. This rich ecosystem of tools and functionalities makes Arduino IDE the perfect platform for a multitude of applications.

   From prototyping electronics projects and learning to code to creating interactive devices that respond to the world around them, Arduino empowers you to bring your creative ideas to life. It's no wonder Arduino has become a favorite among hobbyists, educators, and even professionals for a wide range of applications.

2. **LoRa Communication Protocol:** The LoRa protocol is a physical layer protocol that establishes the radio signal properties needed for low-power, long-range communication. However, we require software libraries that manage the higher-level

communication features in order to employ LoRa for application use. Typically, these libraries run on top of a LoRaWAN stack, which offers the infrastructure needed for LoRa network message exchange. Combining Application Code Integration

Libraries for LoRaWAN include functions that let your application code communicate with the LoRa network. These features can be utilized for:
a) Join the Network: This is the first step in registering and connecting a device to a LoRaWAN network.
b)Send and Receive Data: Libraries offer tools for handling encryption, formatting messages, and sending and receiving data packets via the LoRaWAN network.
c)Handle Device State: Libraries may provide tools to handle possible communication problems, control power modes, and verify connection status.

3. **Programming Language: Embedded C**The C Standards Committee created Embedded C, a set of language extensions for the C programming language, to address issues of commonality between C extensions for various embedded devices. The C Standards Committee created Embedded C, a collection of language extensions for the C programming language, in order to solve issues with commonality between C extensions for various embedded systems.
Traditionally, in order to implement exotic options like several different memory banks, fixed-point arithmetic, and fundamental I/O operations, embedded C programming requires nonstandard additions to the C language.Within a larger mechanical or electrical system, an embedded system is a computer system that serves a specific purpose and frequently faces real-time computing limitations. It is integrated into a full device, frequently with mechanical and hardware components. A large number of modern gadgets are managed by embedded systems. The majority of microprocessors are produced as parts of embedded systems.
When compared to their broader counterparts, typical embedded computers have low power consumption, compact size, tough operating ranges, and inexpensive unit costs. This results in limited process resources, making them far more difficult to programme and work with. Microcontrollers, or CPUs with inbuilt memory or peripheral interfaces, are the main component of most modern embedded systems.
Since an embedded system is committed to a single purpose, design engineers can maximise its performance and dependability while lowering the product's size and

cost. Because of economies of scale, some embedded systems are manufactured in large quantities.

Portable electronics like MP3 players and digital watches fall under the category of embedded systems, as do big, fixed installations like industrial controllers and traffic lights, as well as very complicated systems like avionics, MRIs, and hybrid cars.

4. **C Sharp**Microsoft's Anders Hejlsberg created the Csharp programming language in 2000, and in 2002 and 2003, Ecma (ECMA-334) and ISO/IEC (ISO/IEC 23270 and 20619) both recognised it as an international standard. Microsoft released Csharp along with the closed-source.NET Framework and Visual Studio. Microsoft didn't have any open-source products at the time. A free and open-source project named Mono was launched four years later, in 2004, offering a cross-platform compiler and runtime environment for the Csharp programming language. Ten years later, Microsoft introduced the free, open-source, cross-platform Visual Studio Code code editor, Roslyn compiler, and unified.NET platform software framework, all of which supported CSharp. Although Mono joined Microsoft as well, it did not combine with dotNET.

   a.Probability:

   The programming language that most closely resembles the Common Language Infrastructure (CLI) underneath is Csharp, by design. The majority of its intrinsic types match the value types that the CLI framework has developed. Nevertheless, the language specification makes no mention of the compiler's code production requirements; that is, it makes no mention of the need for a Csharp compiler to target a Common Language Runtime, produce Common Intermediate Language (CIL), or produce any other particular format. Similar to conventional Csharp or Fortran compilers, certain Csharp compilers can also produce machine code.

   b.Typing:

   The keywords var and new[] indicate implicitly typed variable declarations and implicitly typed arrays that are followed by a collection initializer in Csharp.

   c.Namespace:

   With features and rules very similar to a package, a Csharp namespace offers the same degree of code separation as a Java package or a Cpp namespace. Namespaces may be imported by use the syntax "using".

   d.Memory access:

Only explicitly indicated unsafe blocks in C can use memory address pointers, and in order for programmes containing unsafe code to execute, the necessary permissions must be obtained. It is impossible to gain a reference to a "dead" object (one that has been garbage collected) or to a random block of memory. The majority of object access is accomplished using safe object references, which always either point to a "live" object or have the well-defined null value.
An instance of an unmanaged value type that does not contain any references to objects—such as class instances, arrays, or strings—that are subject to trash collections can be referenced by an unsafe pointer. Pointers can still be stored and changed by code that is not flagged as dangerous via the System.Managed memory is automatically garbage collected; it cannot be actively freed. By relieving the programmer of the duty of releasing memory that is often no longer needed, garbage collection solves the issue of memory leaks.
Although code that keeps references to objects for longer than necessary may still use more memory than is necessary, garbage collection can access the memory once the last reference to an object is destroyed.
e.Exception:
Programmers have access to a variety of common exceptions. System exceptions are frequently thrown by methods in standard libraries under certain conditions, and the scope of these exceptions is typically documented. For classes, custom exception classes can be built, enabling handling to be applied as necessary for certain situations. Csharp does not have checked exceptions (in contrast to Java). This choice was made consciously in light of the scalability and versionability concerns.

The following are some benefits of utilising Csharp Window Forms for GUI creation:

• Csharp Windows Forms is a graphical user interface (GUI) technology that lets programmers make desktop Windows apps. The.NET framework and the Csharp programming language are used to construct Windows Forms applications. Controls like buttons, text boxes, labels, and other user interface components are added to a form by dragging and dropping them there.

• Developers can create apps using a wide range of controls provided by the Windows Forms framework. The purpose of these controls is to give Windows users a dependable and recognisable UI. By changing a number of settings and managing events, developers can alter how these controls look and behave.

• Microsoft Visual Studio, an integrated development environment (IDE) that offers a visual designer for creating and organising the user interface elements, can be used to create a Windows Forms application in C. You can construct your user interface (UI) using the drag-and-drop visual designer, which also features an intuitive interface that makes it simple to set the characteristics of each control.

• Visual Studio comes with a code editor that lets developers create the C code that drives the logic of the programme in addition to a visual designer. Developers are capable of managing events and carrying out operations including business logic implementation, data manipulation, and validation.

• Windows Forms applications are flexible and may be used to develop a wide range of applications, including games and multimedia applications, as well as data entry, management, and reporting applications.

3.2 Methodology

Mine environments are harsh and necessitate creative ways to put worker safety first.The smart helmet for miners as a full safety system that can monitor ambient conditions, identify potential hazards, and provide real-time location data in answer to this pressing demand. In-depth information about the project's hardware components, development process, software development considerations, and possible future developments are covered in this document.

Hardware Symphony: The Crucial Parts.

Because of the synergistic link between its essential parts, the smart helmet for miners works as a coherent unit: The adaptable DHT11 sensor is essential for keeping an eye on the environment inside the helmet. Temperature and humidity are two essential elements that it measures. Miners may experience discomfort, dehydration, and even heatstroke as a result of extreme heat or humidity. Real-time monitoring and prompt intervention are made possible by the data from the DHT11 sensor in the event that readings above safe thresholds.

Impact Sensor: The safety of miners is seriously threatened by the unpredictability of the mining environment, which includes the possibility of rockfalls or collapses. As a watchful defender, the impact sensor senses unexpected hits or collisions. The sensor detects a substantial impact and sets off an alert system that notifies the base station and may cause the helmet to flash or sound an alarm. This instant alert system may be essential for starting a rescue operation in a timely manner. Smoke Sensor: Miners are extremely vulnerable to the negative health effects of gasses such as carbon monoxide. By identifying smoke or gas particles in the surrounding air, the smoke sensor serves as a silent sentinel. The sensor notifies the base station in the event that hazardous gas is detected, allowing mine workers to quickly respond. Potential deaths from hazardous gas leaks can be avoided with early discovery.

GPS Module: Especially in large-scale mining operations, precise location data is critical to guaranteeing miner safety. This vital role is carried out by the GPS module that is integrated within the helmet. It continuously obtains the coordinates of the miner's latitude and longitude, giving emergency personnel access to critical data. Rescue crews may find miners fast and effectively with the help of this data, possibly saving lives in dire circumstances.

LoRa Transceiver with MT76813DBI Antenna: The helmet and base station communicate with each other through the LoRa transceiver. Data transmission over long distances is made possible by this low-power, wide-area network (LPWAN) technology, which guarantees dependable connectivity even in deep mine shafts and isolated mining locations. With its special design for LoRa applications, the MT76813DBI antenna maximizes both signal transmission and reception, ensuring reliable and clear data transfer between the base station and the helmet.

Arduino Uno: This little device serves as the system's central nervous system. The DHT11, impact sensor, smoke sensor, and GPS module are the sensors whose data collection is handled by this microcontroller. After processing this data, it uses pre-programmed actions depending on criteria to start working. For example, the Arduino Uno will sound an alert on the helmet and notify the base station if the temperature reading from the DHT11 sensor goes above the safe limit. Furthermore, the Arduino Uno controls the LoRa transceiver's connectivity, guaranteeing that sensor data is sent to the intended recipient device without interruption. The Careful Path: Development Process A painstaking development approach is needed to turn the plan into a working model. This is a detailed explanation of the procedure:

Hardware Assembly: The electronic components must be carefully assembled as the initial stage. This entails utilizing jumper wires to solder connections between the Arduino Uno, LoRa transceiver, GPS module, impact sensor, smoke sensor, and DHT11 sensor. To ensure user comfort and prevent damage while in use, these parts must be safely and ergonomically fastened inside the helmet.

Sensor Calibration: Accuracy of the sensors is vital because they are all essential to the system's operation. Accurate reflection of the surrounding environment in data readings is ensured through sensor calibration. To discern between little bumps and large impacts, for example, calibrating the impact sensor may require modifying its sensitivity levels. Similar to this, in order to properly generate alerts, the DHT11 sensor may need to have the proper temperature and humidity thresholds set.

Programming the Arduino Uno: The Arduino Uno's programming is what keeps the system running. The many components' interactions and responses to various scenarios are determined by this code. The following is a summary of the main features the code will include:

Reading Sensor Data: The algorithm continuously retrieves information from the GPS module (location data), impact sensor (collision detection), smoke sensor (gas detection), and DHT11 sensor (temperature and humidity).

Threshold Comparison: The code assesses whether the impact, humidity, and temperature values from the sensors exceed pre-established thresholds. When a reading deviates from the safe range, the code triggers predetermined actions. Base Station Development

The helmet system serves as a route for two-way communication. Sensor data is transmitted by the helmet, and it is received and interpreted by a specified base station. A closer look into base station development is provided here:

Hardware considerations: A computer or specialized receiver unit can serve as the base station. Hardware that can pick up LoRa signals from helmets within the mine's working range is needed. To effectively receive signals, an antenna that is compatible with LoRa technology is required.

Software Engineering: The way the received data is presented and used is greatly dependent on the base station software. This program can be made to: Data

Visualization: In an easily navigable fashion, the software may show sensor data (temperature, humidity, impact detection, gas detection, and GPS location) from several miners. Dashboards, real-time graphs, or alert messages may be used in this.
Testing and Improvement: Extensive testing is a crucial step in guaranteeing the dependability and performance of the system. Here are some vital things to think about during testing:
Testing of Individual Components: To ensure accuracy and functionality, test the Arduino Uno and each sensor separately before integrating them. This guarantees accurate data processing and collecting.
System Integration Testing: The complete system, comprising the base station, sensors, Arduino Uno, LoRa transceiver, and helmet, needs to be extensively tested once the separate components have been tested. This entails modeling a variety of situations (such as high temperatures, impacts, and gas detection) and confirming whether the system reacts as planned, setting off alerts, and reliably transferring data.
Real-World Testing: It's critical to do controlled real-world testing in a secure mine setting. This makes it possible to evaluate the system's functionality in real-world settings and spot any possible problems that would not have been obvious in simulations.
Data-Driven Decision Making: Mine management may find great use in the sensor data that has been gathered. Mine managers can decide on ventilation plans, support structure reinforcement, and possible evacuation procedures by looking at patterns in temperature, humidity, and impact events in particular regions.
Integration with Current Mine Management Systems: It is possible to integrate the data gathered by the smart helmet system with the current mine management systems. This makes it possible to see mine operations from a more comprehensive perspective and to monitor environmental factors, miner safety, production statistics, and equipment status in real time.

Thus with the help of all the above mentioned components and their working , when there is uneven temperature or humid and it raises above the given value it will immediately report it to the base station. And if there is any collision or the sudden rock breakdown the impact sensor will get activated and will notify the base station. All the communication thing will happen through LoRaW transceiver along with MT76813DBI Antenna in order to establish connection from miners to base station. A smoke sensor has been installed to monitor the raise in toxic gas levels. To track the miner the GPS has been deployed which will give the initial location of the miner and keeps a track of him. The Pseudo code is as shown in Figure 3.8: Pseudo code of the microcontroller where data values are compared to the threshold value and Figure 3.9: Pseudo code of server side where data is received.

Furthermore, a Csharp-programmed desktop application is employed, offering a user-friendly interface that enables miners and the supervisor to track real-time sensor data and alarms. To guarantee dependable communication between the helmets and servers—all the way down to the desktop applications—the components must be completely linked. Following successful testing, the system is put into use in several coal mines, where safety compliance is ensured by maintaining proper inspection, calibration, and software update procedures.

Figure 3.8: Pseudo code of the microcontroller where data values are compared to the threshold value.

The pseudo code gives the idea of the overview of the main functional code. Pseudo code for the transmitting and reception end is shown in the respective figures. The

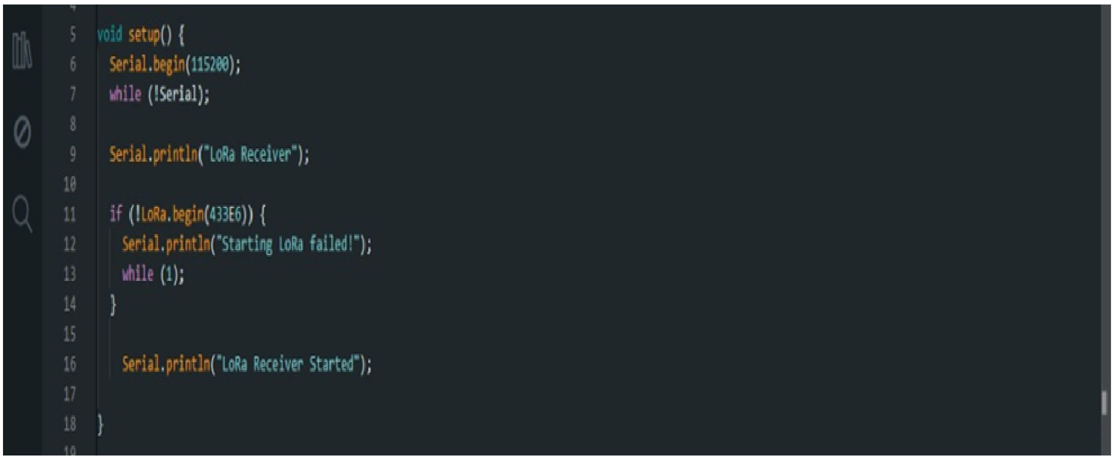

Figure 3.9: Pseudo code of server side where data is received.

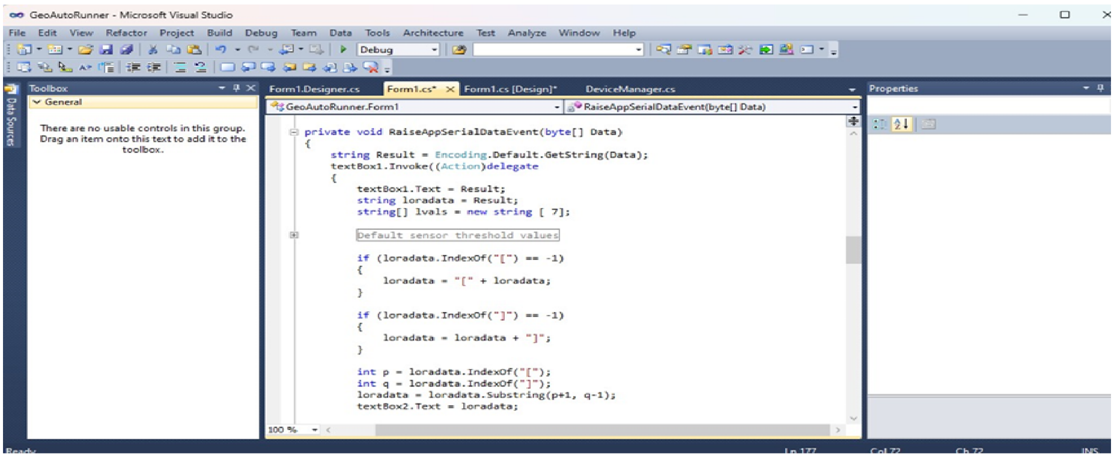

Figure 3.10: Pseudo code of the GUI where data is continuously monitored

GUI part is developed with the help of Csharp which is user friendly and easy to code. Figure 3.10: Pseudo code of the GUI where data is continuously monitored gives the idea of the Pseudo code for GUI part.

Chapter 4

Results and Discussions

4.1 Hardware Part Results

4.1.1 Model Creation:

In order to ensure that the smart helmet model effectively improves miner safety through the integration of cutting-edge technology for real-time hazard identification and communication, a number of crucial actions must be taken. The hardware assembly first entails mounting a number of sensors and parts within the helmet, such as temperature and humidity sensors, GPS modules, accelerometers for impact testing, gas sensors (MQ5, MQ2), and an infrared sensor for detecting helmet removal. A central microcontroller, like an Arduino Uno or an ATmega328, is connected to these sensors and is responsible for processing the data that is gathered. The helmet's communication system combines ZigBee and RF technology to deliver dependable real-time data transfer even in the demanding underground mining environment. Long-range communication with low power consumption is made possible by the LoRa transceiver and the MT76813DBI antenna, allowing for continuous monitoring without the need for frequent battery replacements.

[11]The microcontroller is programmed as part of the software development process to continuously gather sensor data, compare it to predetermined safety criteria, and, if needed, sound an alert. The firmware of the system makes sure that information from the helmet is sent to a control station so that dashboards or LCD screens can display it in real time. When dangerous conditions are recognised, such as the presence of harmful gases or unusually high or low humidity or temperature, alerts are programmed to sound alarms or show warnings. The hardware model of the smart helmet is shown in Figure 4.1: overview of the helmet. Ultimately, a comprehensive testing programme is

implemented to confirm that the system operates as intended in both lab-based settings and actual mining situations. This include setting the sensors' calibration, creating dangerous situations, and making sure the helmet consistently sounds alarms and sends data as intended. In order to improve the system and make sure miners are well-protected, a thorough testing procedure is necessary.

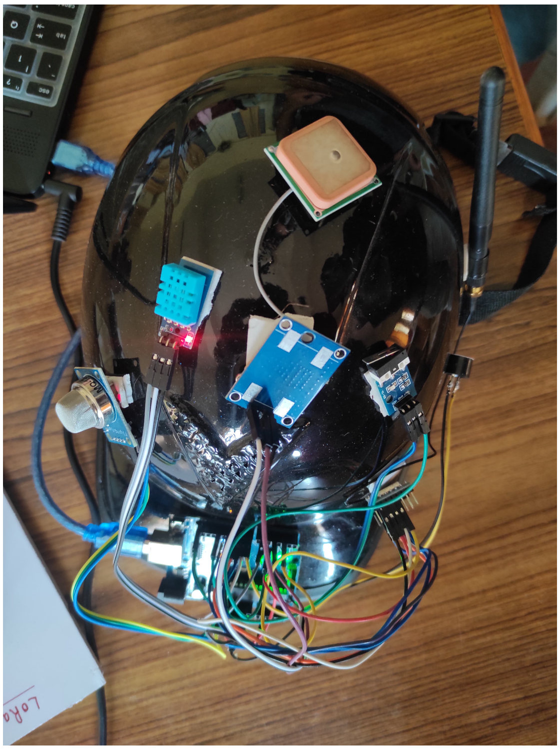

Figure 4.1: overview of the helmet

4.2 Software Part Results

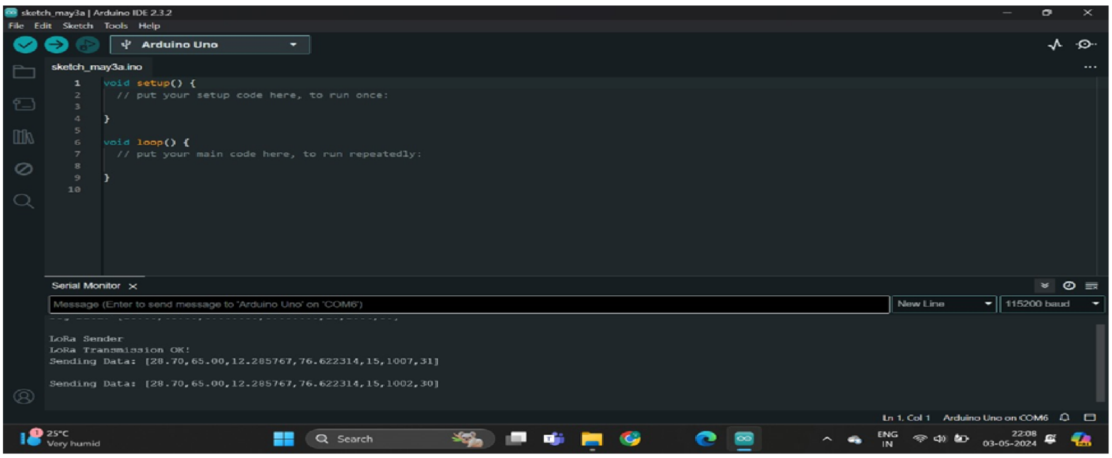

Figure 4.2: Data sent from the helmet side microcontroller

The Figure 4.2: Data sent from the helmet side microcontroller and Figure 4.3: Data received at the server side microcontroller represent the code designned for the transmitting and receiving end. It also shows the output of the packet sent and received which contains the info of the values of the temperature, humidty, Smoke value, Impact value and the location of the miners. Along with this the Figure 4.4: overview of the model provides the overall setup of the tx and rx end with the physical model.

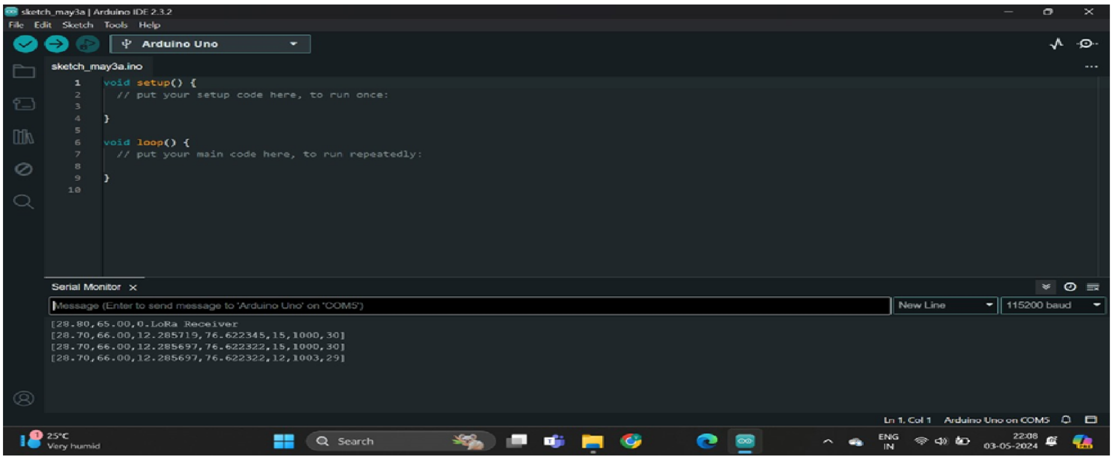

Figure 4.3: Data received at the server side microcontroller.

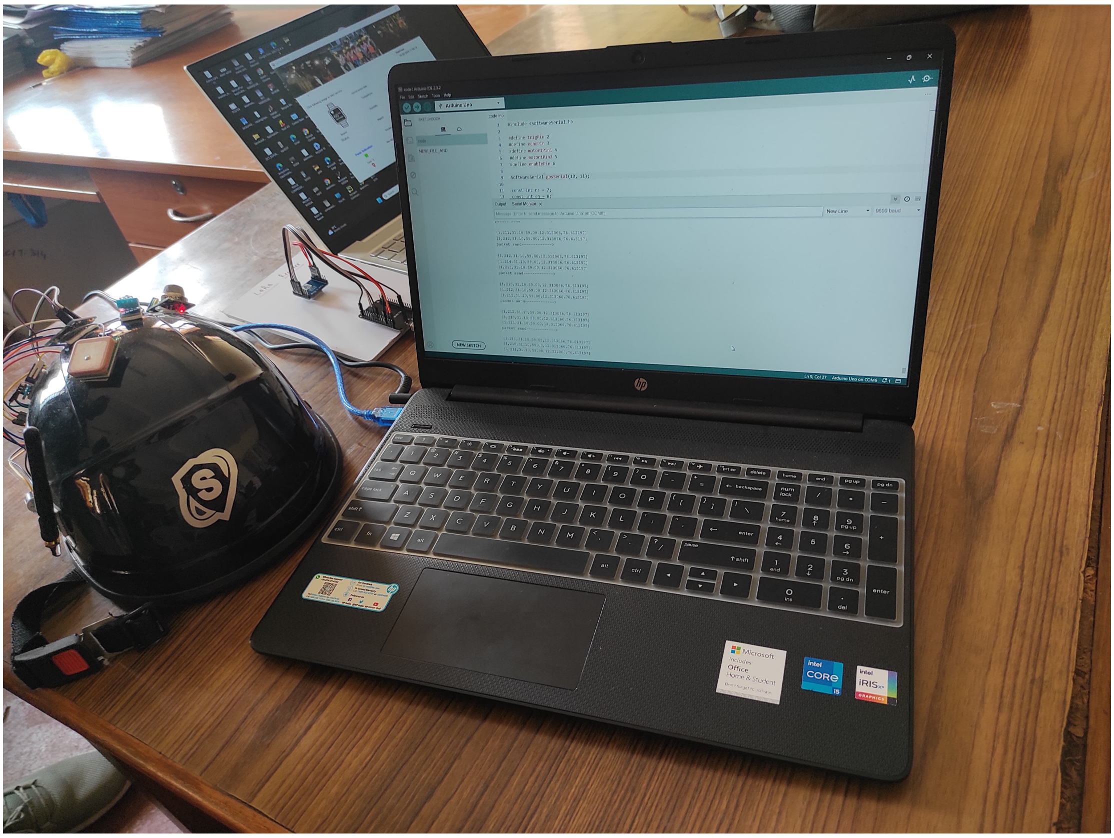

Figure 4.4: overview of the model

1. The following shows the output from the transmitter end where TX sending the required specialised values. The Figure 4.5: output from the TX side and Figure 4.6: Testings at client side and Figure 4.7: Testings at receiver side represent the testing tables and the output from the tx side.

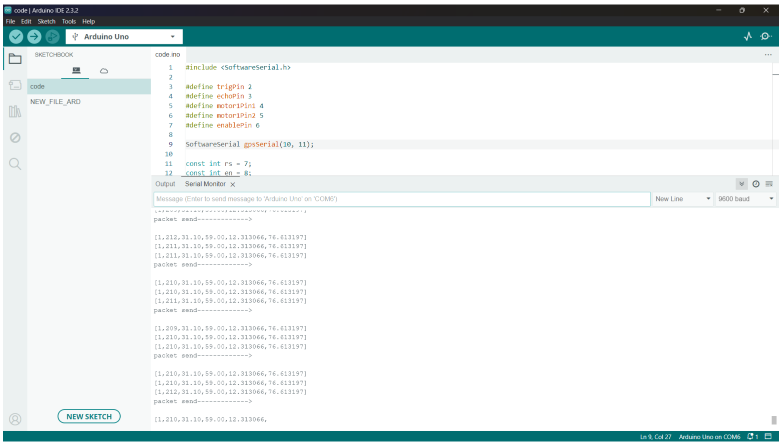

Figure 4.5: output from the TX side

	Input	Expected Output	Test 1	Test 2	Test 3
1	Temperature and Humidity Sensor	38° C	Fail	Pass	Pass
2	Smoke Sensor	100 ppm	Fail	Fail	Pass
4	GPS	-	Fail	Fail	Pass

Figure 4.6: Testings at client side

	Input	Expected Output	Test 1	Test 2	Test 3
1	Temperature and Humidity Sensor	38° C	Fail	Pass	Pass
2	Smoke Sensor	100 ppm	Fail	Fail	Pass
3	GPS (°N °E)	-	Fail	Fail	Pass

Figure 4.7: Testings at receiver side

2. After successfully sending TX data which will be able to do after the GPS module is setup properly. Above shown is the Output at the receiver side. The Figure 4.8: Front end Display at the base station and Figure 4.9: Front end Setup represent the final front end setup which includes the LoRa receiver and the GUI part.

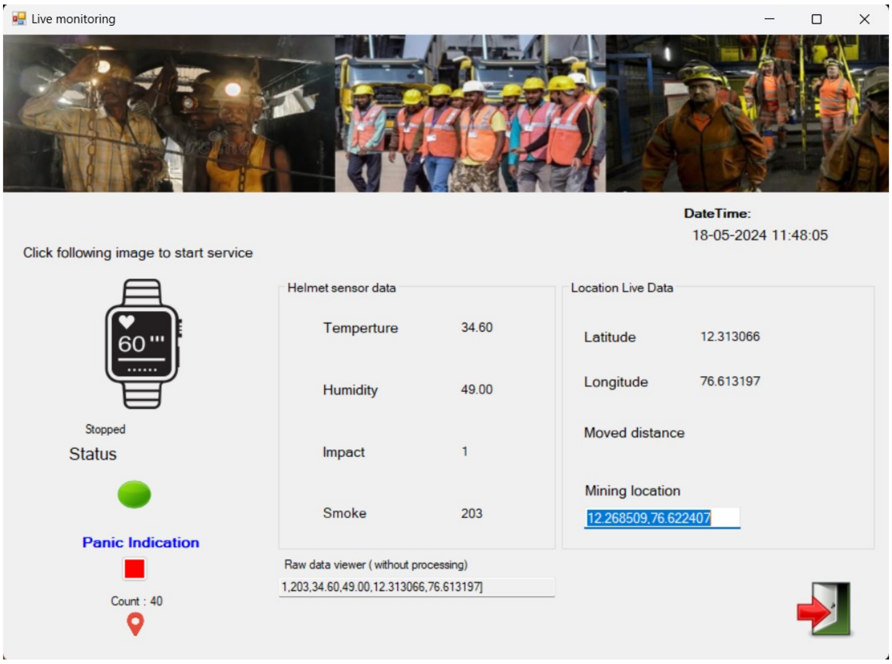

Figure 4.8: Front end Display at the base station

Figure 4.9: Front end Setup

Chapter 5

Conclusion

5.1 Conclusion

A notable development in mining safety technology is the creation and application of smart helmet systems. These creative ideas handle important mining environment dangers like air quality, helmet removal, and collisions by combining cutting-edge sensors and LoRaWAN communication technologies. Even in the harsh circumstances of subterranean mines, these smart helmets rely on dependable real-time monitoring and data transfer thanks to a mix of IoT technologies and LoRaWAN.

These helmets greatly improve the safety and well-being of miners by combining GPS modules, accelerometers, temperature and humidity monitors, gas sensors and full hazard identification with instantaneous notifications. Microcontrollers like the Arduino Uno and ATmega328 are integrated to provide effective data processing and timely reactions to dangerous situations. With the help of the MT76813DBI antenna and LoRa transceivers, long-range communication may be achieved with low power consumption, allowing for continuous monitoring and fewer battery changes. These systems have undergone extensive testing and calibration, which has shown their efficacy in actual mining situations and highlighted their potential to completely change mine safety procedures. In addition to providing instantaneous hazard detection and alert capabilities, the smart helmets also provide proactive monitoring, allowing miners to swiftly take preventative action. This all-encompassing approach to safety emphasises how crucial technological developments are to reducing dangers and safeguarding miners' lives. [9]In summary, this report's presentation of smart helmet systems for mining offers a strong way to raise industry safety standards. These helmets provide a safer working environment for miners by utilising cutting-edge technology, which lowers the number of accidents and fatalities. The ongoing advancement and incorporation of more sensor features and Internet of Things capabilities have the potential to further enhance worker safety in a variety of subterranean work settings. In the end, these ideas hope to improve productivity while putting worker safety first, making the mining industry safer and more sustainable.

5.1.1 Application

a) The system keeps an eye on temperature, humidity, and gas concentrations (such carbon monoxide) on a constant basis. When potentially dangerous situations are identified, it instantly notifies miners so they may take the necessary safety measures.
b)The technology allows miners to use the panic/emergency button on their helmets to send out distress signals in the event of an emergency, such as a gas leak, a cave-in, or injuries.[10] Rapid reaction and rescue activities are made easier by this programme.
c)The technology keeps track of miners' exact whereabouts in real time within the mining operation. This data is crucial for tracking miners' movements and guaranteeing their safety, particularly in intricate subterranean settings.
d)The gathered information, encompassing gas concentrations, atmospheric circumstances, and emergency notifications, is recorded and examined. Investigations into incidents, safety audits, and enhancing safety procedures can all benefit from this data.
e)By utilising Internet of Things (IoT) technology, the system creates a network that is connected and allows for data sharing and remote monitoring. From the surface, our programme enables centralised monitoring of numerous miners and locations.
f)The system's cutting-edge technology adds an extra degree of safety while integrating flawlessly with current safety standards and procedures. It is an additional layer of protection for standard safety gear like helmets and PPE.
g)Because of its scalable design, the system can accommodate the addition of new sensors or functions as mining technology advances. It can change to accommodate unique safety requirements and obstacles in different mining environments

5.2 Advantages and Limitations

5.2.1 Advantages

Real-time environmental monitoring continuously measures temperature, humidity, and air quality to improve worker safety by warning miners about possible risks including heatstroke, respiratory problems, or dangerous gas leaks.

1. Impact Detection: This technology detects head injuries caused by crashes or falling items, resulting in instant notifications and allowing rescue personnel to respond more quickly.

2. Improved Contextual AwarenessGPS Monitoring: locates miners underground, making rescue operations easier and enhancing worker safety in general. This is especially important in case of emergencies or mine collapses

3. Enhanced Productivity and Efficiency:
   • Better Work Conditions: Maintains ideal humidity and temperature levels, which lessen heat exhaustion and worker weariness and increase concentration and output.
   • Data-Driven Decision Making: Offers insightful information about the state of the mine, enabling efficient resource allocation and workflow planning.

4. Decreased Downtime:[Preventing equipment failures and reducing unscheduled downtime can be achieved by proactive maintenance alerts that utilize sensor data.

5. Better Instruction: The information gathered from the helmet can be utilized to pinpoint areas where safety protocols and educational initiatives need to be strengthened.

6. Regulation Compliance: Assures adherence to changing safety requirements and shows a dedication to the welfare of employees.

7. A favorable public perception: Using cutting edge technology to invest in worker safety has a beneficial impact on a mining company's reputation and sense of social responsibility.

   All things considered, the mining smart helmet offers a ground-breaking method for managing mine operations and worker safety. With its ability to provide real-time monitoring, enhanced communication, and insightful data, this technology has the potential to drastically improve the mining sector

5.2.2 Limitations

1. Arrangement and Upkeep Complexity: It can be difficult to integrate different sensors and communication technologies into a single helmet system, and installation and maintenance may call for specialised skills. It takes careful assembly and regular calibration to make sure that every part—including accelerometers, GPS modules, temperature and humidity monitors, gas sensors, and LoRaWAN communication systems—works as a unit. This intricacy may raise expenses and cause maintenance-related downtime, which could reduce mining operations' overall effectiveness.

2. Initial Cost and Implementation: A sizable upfront investment is required for the creation and distribution of smart helmets. The expenses incurred in the investigation, creation, and acquisition of sophisticated sensors, microcontrollers, and communication modules might be substantial. The cost is further increased by the infrastructure needed for LoRaWAN networks and central server systems for data processing and analysis. These upfront expenditures might be too much for smaller mining firms or operations in underdeveloped nations, which would prevent the technology from being widely adopted even though it has the potential to improve miner safety.

5.3 Future Scope

With so much room for growth and development, the mining smart helmet system presents a number of promising avenues for improving worker safety and productivity in the mining sector.

1. Enhanced Sensor Integration: More sensors may be added to the smart helmet in later versions for even more thorough monitoring. To further enhance safety precautions, consider incorporating biometric sensors to track the oxygen and heart rates of miners or integrating sophisticated gas sensors that can identify a broader variety of hazardous materials.

2. Enhanced Communication Systems: The real-time data transmission capabilities of the smart helmets may be further improved by upcoming advancements in communication technology, such as the creation of 5G networks. This would make communication possible even in the most remote and deep places, more quickly and reliably.

3. Energy Efficiency and Sustainable Power Sources: Using low-power components and better battery technology, for example, will help make smart helmets more energy-efficient in the future. The helmets' operational life might be further increased by including sustainable power sources, like as solar panels or energy collecting from miner motions, which would require less frequent recharging.

4. Integration with Current Mining Infrastructure: To establish a comprehensive environment for safety and operational monitoring, the smart helmet system can be further connected with current mine management systems. This will facilitate smooth data exchange and all-encompassing safety management, enhancing operational effectiveness and decision-making.

5. Scalability and Customisation: As technology advances, scalable and adaptable solutions can be created to meet the needs of various mining operations, ranging from massive industrial mines to more intimate artisanal ventures. This would enable a wider spectrum of mining operations to utilise cutting-edge safety technology.

In conclusion, there is a great deal of room for growth in the field of smart helmet technology in the mining industry. These innovations have the potential to greatly enhance miner safety, operational effectiveness, and sustainability. Smart helmets can be essential in making the mining industry safer and more productive by consistently developing and incorporating new technology.

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