Wireless Surveillance and Safety System for Mine Worker Using RF

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ABSTRACT:

Mine safety has been a paramount concern for decades, with the risks to human life and the potential for resource loss escalating in tandem with the advancement of mining operations. Despite significant technological progress in other industries, communication systems within underground mines often remain stubbornly reliant on outdated and inadequate technologies. This reliance on antiquated systems directly contributes to safety hazards and hinders effective emergency response, impacting both worker well-being and operational efficiency. This project addresses this critical gap by developing a cost-effective, flexible, and robust wireless communication solution specifically designed to enhance underground mine worker safety. Current communication practices in many underground mines still heavily depend on wired telephone systems. These systems present numerous limitations. Their fixed infrastructure makes them vulnerable to damage from rockfalls, explosions, and other mine-related incidents, potentially severing communication lines during critical emergencies.

The limited mobility afforded by wired systems also restricts communication to fixed locations, hindering real-time information exchange between mobile workers and the surface control center. This project introduces a novel approach to underground mine communication by implementing a wireless network solution that addresses the shortcomings of traditional wired systems. The proposed system utilizes [**Insert Specific Technology Here, e.g., mesh networking, Wi-Fi, RFID, or a combination**] to establish a robust and reliable communication network throughout the mine. This technology offers several key advantages in the challenging underground environment. Mesh networking, for instance, creates a self-healing and redundant network by allowing each node to act as a repeater, extending the network's range and

ensuring continued communication even if some nodes are damaged. Wi-Fi offers high bandwidth capabilities for data transmission, enabling real- time video streaming and other data- intensive applications. RFID technology can be integrated for personnel tracking and equipment management, enhancing safety and operational efficiency. A combination of these technologies can be strategically deployed to optimize performance based on specific mine conditions and operational needs.

The implementation of this wireless communication system will significantly enhance underground mine safety in several ways. Real-time communication between miners and the surface will facilitate rapid response to emergencies, enabling immediate dispatch of rescue teams and coordination of evacuation efforts. The system will also enable continuous monitoring of environmental conditions, such as gas levels, temperature, and air quality, allowing for early detection of hazardous situations and proactive implementation of safety measures. Furthermore, the improved communication infrastructure will facilitate better coordination of daily operations, leading to increased productivity and reduced downtime. This project represents a significant advancement in underground mine communication technology. By providing a cost-effective, flexible, and robust wireless solution, it addresses the critical need for improved safety and operational efficiency in the mining industry. The implementation of this system has the potential to significantly reduce the risk of accidents, save lives, and improve the overall working conditions for underground miners. The selection of the specific technology or combination of technologies will be based on a thorough analysis of the mine environment, operational requirements, and cost considerations, ensuring the optimal performance and effectiveness of the proposed communication system.

***Keywords* —coal mine, Helmet, rf Tracker, Sensors, Thing Speak, Wi-Fi.**

I. INTRODUCTION

This project, titled **"IoT-Based Mining Workers Tracking and Safety System with Application Interface,"** aims to enhance industrial safety through the development of a smart helmet for workers operating in hazardous environments. In the industrial sector, safety is of paramount importance. However, there are instances where workers deliberately remove their helmets to avoid detection by safety engineers or security cameras—thereby putting themselves at serious risk. The core objective of this project is to design a smart helmet prototype that ensures worker safety by integrating various sensors capable of monitoring environmental and physiological conditions. Many industrial accidents today are caused by factors such as poor visibility, inadequate lighting, and excessive noise. A smart helmet equipped with advanced sensors can help mitigate these risks by continuously collecting and transmitting critical safety data. This system employs Internet of Things (IoT) technology to enable real-time monitoring. Sensor data from the helmet is transmitted to the **Thing Speak IoT cloud platform**, which aggregates, visualizes, and analyzes live data streams. Thing Speak allows for immediate visualization of the data and can be configured to send alerts in case of emergency or abnormal conditions. This real-time feedback mechanism significantly improves situational awareness and helps in taking prompt preventive or corrective actions to safeguard workers in industrial and mining environments.

Worker safety remains a critical concern in the mining industry. Every year, thousands of miners lose their lives in accidents, and many more suffer serious injuries, particularly in coal mining and hard rock mining operations. The primary causes of these accidents include gas or dust explosions, toxic gas exposure, improper use of explosives, electrical burns, fires, structural collapses, rockfalls, flooding, and equipment-related incidents such as slips, trips, or malfunctioning machinery. One of the notable issues in coal mines is the lack of proper use of personal protective equipment (PPE), such as helmets and safety boots. Furthermore, there are often no adequate systems in place to verify whether workers are wearing their PPE correctly. Effective supervision and real-time monitoring of PPE usage are therefore vital for ensuring worker safety. Underground mining environments are especially hazardous due to poor lighting and limited oxygen, which can lead to workers falling unconscious from suffocation or injury, without supervisors being immediately aware of their condition—thus delaying timely medical assistance.

Among the most dangerous hazards in coal mines are harmful gases such as carbon monoxide, methane, and liquefied petroleum gas (LPG), which are highly toxic and explosive [1]. Ventilation systems play a crucial role in underground mines by ensuring the supply of fresh air, maintaining non-toxic and non-explosive atmospheres, and enabling overall operational efficiency. Historically, primitive methods such as the use of canaries were employed to detect toxic gases. Today, intelligent ventilation monitoring systems offer real-time data, allowing for dynamic adjustment of airflow based on environmental conditions, thereby significantly improving safety [2]. The proposed study focuses on an IoT-based smart helmet designed to enhance underground worker safety. The helmet is equipped with various sensors to monitor critical environmental parameters such as gas levels, temperature, and humidity. The device also includes a helmet removal sensor, collision sensor, and gas sensor, all connected to a microcontroller that collects data and sends alerts in real time. When any hazardous condition is detected, the system transmits alerts to an application interface installed at multiple monitoring points throughout the mining site. This enables immediate response and preventive actions, significantly reducing the risk to worker health and safety.

III. PROPOSED WORK

In this project, we have developed an advanced protective helmet integrated with multiple sensors to detect hazardous conditions and enhance the safety of mining workers. The smart helmet is designed to identify and respond to various risks in real time, ensuring continuous monitoring and quick emergency response. Firstly, **hazardous gases** such as methane, carbon monoxide, and other toxic fumes are detected using dedicated **gas sensors**. When dangerous gas levels are identified, a **solenoid valve** is automatically activated to release supplemental oxygen, providing immediate relief to the miner. Secondly, one common unsafe practice observed is the removal of helmets by miners while working. To address this, an **infrared (IR) sensor** has been incorporated to detect when the helmet is removed from the worker's head, triggering a safety alert. Thirdly, to detect physical impacts, a **force sensor** is used to identify instances where a miner is struck by an object with force exceeding a predefined threshold.

This helps in identifying accidents such as rock falls or collisions. In addition to these, **unpredictable environmental conditions** such as abnormal **temperature** and **pressure** are continuously monitored. The data is transmitted wirelessly to a **central control station** via a communication module for real-time tracking and analysis. To enhance situational awareness and worker visibility, a **GPS module** is integrated into the helmet, allowing for precise location tracking of each worker underground. For emergency situations, a **panic switch** is provided, which can be manually activated by the miner to immediately notify the control center of critical distress or danger. Finally, the helmet includes a **fire sensor** capable of detecting fire even from a considerable distance. This ensures early fire detection and allows timely evacuation or safety responses to prevent injury or loss of life. The proposed smart helmet provides a comprehensive safety solution for miners by integrating real-time sensing, communication, and emergency response features—all aimed at minimizing workplace accidents and improving rescue efficiency.

IV. IMPLEMENTATION

The primary objective of this project is to develop a **smart helmet system** specifically designed for miners, with the goal of preventing accidents and safeguarding lives in hazardous working environments. The system integrates various sensors and wireless communication technologies to detect and respond to dangerous conditions in real-time. The helmet is equipped with a **gas sensor** to detect the presence of toxic gases such as methane (CH_4), carbon monoxide (CO), and other harmful substances commonly found in mining environments. When gas levels exceed safety thresholds, the system immediately triggers an alert and activates a **solenoid valve** to supply oxygen, helping to prevent asphyxiation A **smart helmet** is an advanced safety device embedded with various sensors designed to monitor the physical and environmental conditions of a worker in hazardous industrial settings, such as mining. These sensors collect critical data—including gas concentration, temperature, pressure, and fire detection—which can then be transmitted over an **IoT network** for real-time analysis and response.

In this project, the **Thing Speak IoT Cloud Platform** is utilized to monitor the safety parameters of workers. Thing Speak is an IoT analytics platform that enables the aggregation, visualization, and analysis of live data streams in the cloud. Sensor data from the smart helmet is sent to thing Speak, where it can be instantly visualized and analyzed. The platform also supports the generation of automated alerts, allowing timely actions in response to hazardous conditions. This system functions as a **real-time monitoring solution**, offering continuous oversight of the mining environment. The primary objective of the project is to design and implement an efficient real-time IoT-based smart helmet that can detect and report critical underground hazards such as gas leaks, fire outbreaks, pressure anomalies, and temperature variations. With remote monitoring capabilities, supervisors can take proactive safety measures, thereby significantly reducing the risk to workers and improving response times during emergencies.

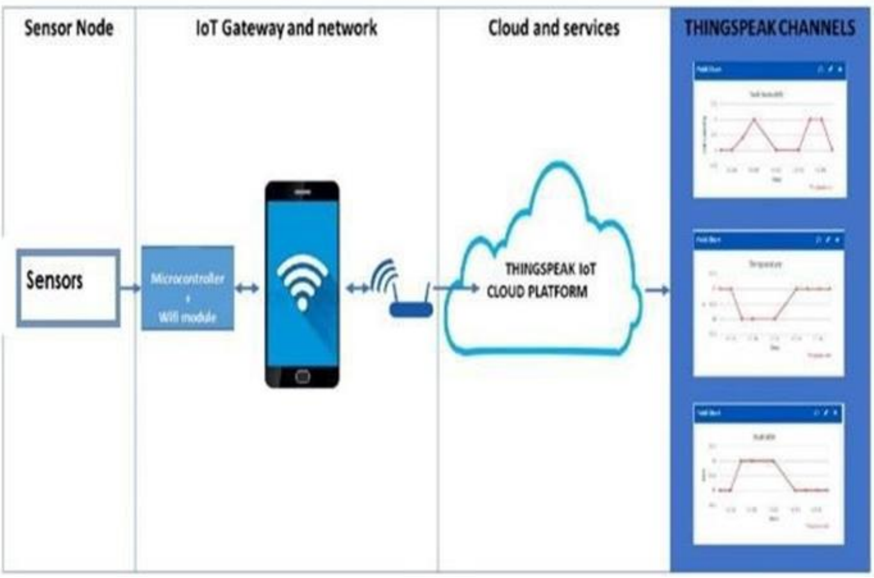

Fig.1: System Architecture

Key Components and Their Functions

1. **Temperature & Humidity Sensor (DHT11):**

The **DHT11** sensor is used to monitor the temperature and humidity levels within the mining environment. When either parameter exceeds predefined safe limits, the system activates a **buzzer** to alert the worker. Simultaneously, the sensor transmits the data to the **AWS IoT platform**, where it is displayed on the monitoring dashboard. This allows remote supervisors to be instantly aware of any abnormal environmental conditions and take necessary precautions.

2. **Gas Sensor (MQ-4):**

The smart helmet incorporates an **MQ-4 gas sensor**, which is primarily used to detect the presence of **methane gas** in the air. It operates within a concentration range of **300 ppm to 10,000 ppm**, making it highly effective in identifying gas leaks in mines or petroleum-based environments. Upon detecting hazardous gas levels, the system immediately triggers a **buzzer alert** and sends a **rescue message** to the IoT network to initiate timely safety protocols.

3. **Emergency Switch:**

A **manually operated emergency switch** is embedded in the helmet, allowing the worker to request immediate assistance. In situations where the worker experiences breathing difficulty, injury, or any other emergency, pressing this switch will instantly send an **alert message** to the central server. This enables monitoring personnel to respond quickly and provide necessary support without delay.

4. **Fire Sensor:**

The **fire sensor** installed in the helmet is designed to detect flames or elevated temperatures indicative of fire hazards, even from a considerable distance. This sensor is critical in assessing the **severity of fires**, especially after explosions or gas leaks. Early detection through this sensor enables prompt evacuation and activation of firefighting or rescue operations, thereby reducing the risk of casualties.

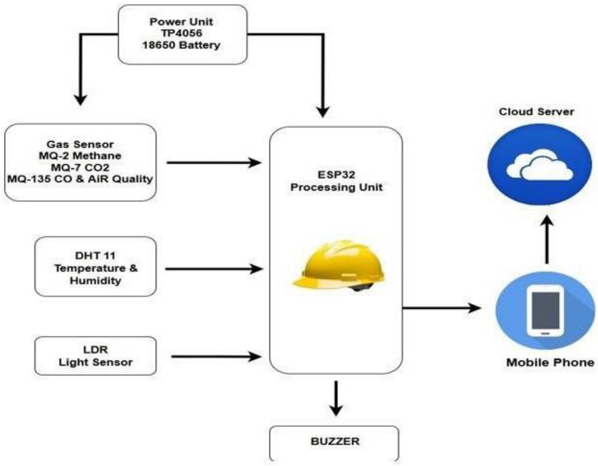

Fig.2.Hardware and Software Used

Software Design

The software design phase is structured in alignment with the operational flow of the system. It is divided into two main components: **sequence programming** and **interface programming**. Both components are essential and must work in coordination to fulfill the intended functionality of the smart helmet system.

- **Sequence programming** manages the logical flow and behavior of sensor readings, condition checks, and system responses (such as triggering alerts or sending data to the cloud).
- **Interface programming** is responsible for establishing communication between the helmet and the user-facing platform—such as the AWS IoT dashboard or any mobile/web application that displays real-time data and alerts.

To ensure reliable system performance, the software design undergoes multiple stages of **testing, calibration, and troubleshooting**. These steps are critical after integrating the hardware and software components, as any malfunction or unexpected behavior must be diagnosed and corrected.

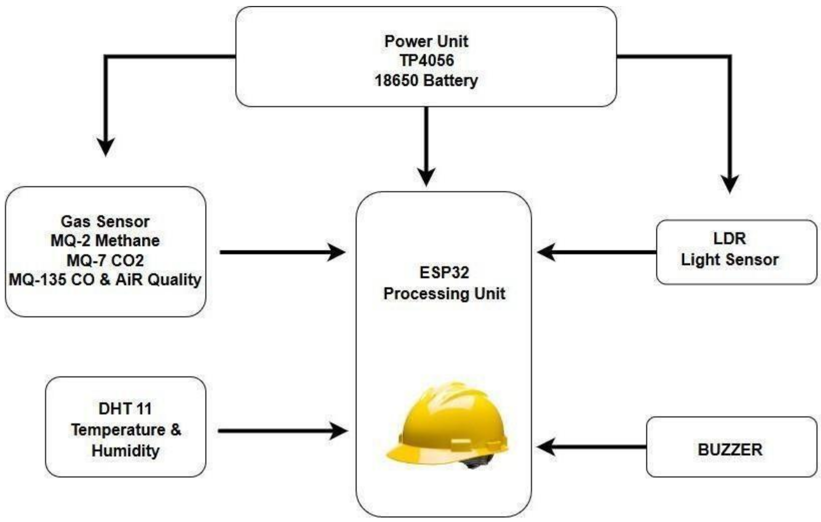

Fig.3.Flow of Hardware Section

It is important to note that even minor design flaws at this stage can lead to **time-consuming setbacks**, often requiring developers to revisit earlier development phases to identify and correct issues. Therefore, careful planning, thorough debugging, and rigorous testing are essential to ensure smooth and efficient operation of the smart helmet system.

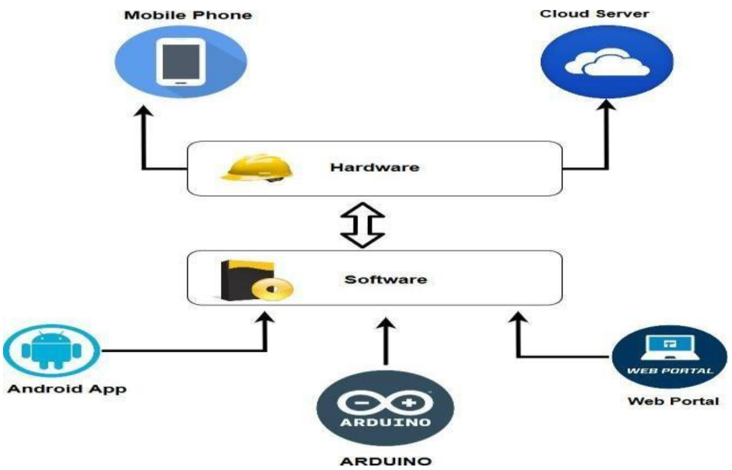

Fig.4.Flow of Software Section Smart Helmet Design

Hardware Components and Descriptions

1. ESP32 Microcontroller

The **ESP32** is a powerful microcontroller equipped with advanced features compared to its predecessor, the ESP8266. It includes:

- Dual-core processor
- Faster Wi-Fi connectivity
- Bluetooth Low Energy (BLE) support
- More GPIO pins with flexible pin assignments (UART, SPI, I2C, etc.)
- Built-in sensors: temperature sensor, hall effect sensor, and touch-sensitive pins

Thanks to **multiplexing**, a single GPIO pin can serve multiple functions depending on code configuration, enhancing design flexibility. The ESP32 remains cost-effective, making it ideal for IoT applications like this smart helmet.

2. MQ Series Gas Sensors

• MQ-2 Gas Sensor

Detects a variety of gases including **hydrogen, LPG, propane, methane**, and **combustible vapors**.

- Operates at 5V
- Sensitivity is adjustable via an onboard **potentiometer**
- Higher gas concentration = lower resistance = higher output voltage

- **MQ-4 Gas Sensor**

Specializes in **methane detection**, ideal for mining environments.

- Detects concentrations from **300 ppm to 10,000 ppm**

- Triggers alerts upon hazardous gas detection

- **MQ-7 Gas Sensor**

Primarily used for **carbon monoxide (CO) detection**.

- Built with **Tin Dioxide (SnO_2)** on an **Al_2O_3 ceramic tube**
- Operates in a cyclic heating pattern (high and low temperatures) to improve accuracy
- Has six pins: four for signal, two for heater supply

- **MQ-135 Air Quality Sensor**

Detects **toxic gases** like **ammonia, sulfur compounds, benzene vapor, nitrogen oxides, and smoke**.

- Ideal for indoor and industrial air quality monitoring
- Works well with simple drive and monitoring circuits

3. DHT11 Temperature & Humidity Sensor

The **DHT11** is a reliable digital sensor used to measure **temperature and relative humidity**.

- Combines a resistive humidity element and an NTC thermistor
- Interfaced with an 8-bit microcontroller for signal processing
- Offers:
  - Fast response time
  - Anti-interference capability
  - Cost-effectiveness
- When readings exceed thresholds, a **buzzer** is activated for alerting

4. Infrared (IR) Sensor

Used for **helmet removal detection**.

- Continuously transmits IR signals
- When the signal is **blocked**, it confirms the helmet is being worn
- If the signal is **uninterrupted**, it indicates helmet removal and triggers an alert

5. Piezoelectric Buzzer

The **Piezo buzzer** provides audio alerts in response to hazardous readings.

- Operates on **3–12V DC**
- Consists of a **Piezo disc and oscillator**
- Commonly used in digital alarm systems to produce beeping sounds during events such as:
  - Gas leak detection
  - Temperature threshold breach
  - Helmet removal
  - Emergency button press

6. Emergency Switch

A **manual push-button switch** integrated into the helmet.

- Activated by the worker in case of emergencies (e.g., difficulty breathing, injury)

• Sends an **immediate alert** to the control room via the IoT system

V TESTING & VALIDATION

Testing and validation are vital to confirming the functionality and reliability of the Wireless Surveillance and Safety System for Mine Workers Using RF. This phase ensures that the system components respond accurately under simulated hazardous mining conditions, including gas exposure, elevated temperature, and manual emergency activation.

The tests were conducted using the developed Arduino-based system, which integrates an MQ-2 gas sensor, DHT-11 temperature sensor, 433 MHz RF communication module, LCD, and buzzer. When hazardous conditions are simulated, the system updates the LCD in real time, activates a buzzer, and sends encoded emergency messages (e.g., 1, 2, or 3) via RF to the remote receiver.

The Serial Monitor at the control centre side displays:

Miner 1: High Temperature Detected Miner 1: Poisonous

Gas Detected Miner 1: Emergency......Emergency......

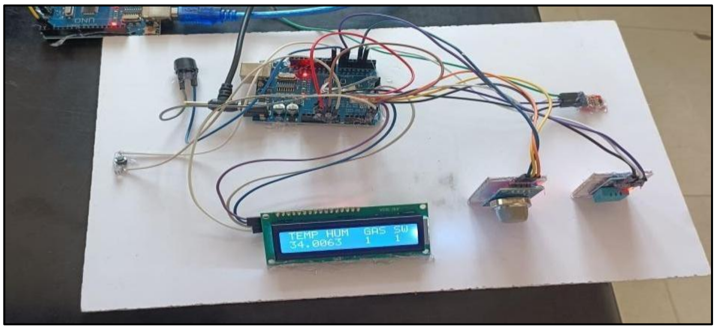

Fig 5: TESTING AND VALIDATION

This confirms the successful transmission and reception of alerts.

Validation also included checking power efficiency, ensuring the system operates effectively on limited power sources typical of underground settings. The test outcomes demonstrated that the sensors provide accurate data, the buzzer and LCD respond

CONCLUSION

This project, Wireless Surveillance and Safety System for Mine Workers Using RF, has been successfully developed to enhance worker safety in underground environments. By using MQ-2 gas and DHT-11 temperature sensors, the system continuously monitors air quality and temperature, providing real-time alerts when hazardous conditions are detected. If gas levels rise above a safe threshold or temperatures become too high, a buzzer sounds an alarm, an LCD displays warnings, and an RF module transmits alerts to supervisors. The HT12E encoder and HT12D decoder ensure that alerts are transmitted without interference, allowing supervisors to take immediate action and prevent accidents.

FUTURE SCOPE

Looking ahead, several improvements can make this system even more effective. IoT integration could enable cloud- based remote monitoring, allowing supervisors to track real-time safety data from anywhere.

Adding GPS tracking would improve emergency response times by pinpointing the location of workers in danger. Upgrading to LoRa or Wi- Fi communication could increase the range and reliability of wireless alerts. Additionally, machine learning algorithms could analyze sensor data to predict hazardous conditions before they occur. By incorporating wearable safety devices and energy- efficient designs, the system can become even more robust, scalable, and intelligent in the future. promptly, RF signals transmit without loss, and the system maintains low power consumption — confirming readiness for real-world deployment.

REFERENCES

[1]. Lin, B. and Raza, M.Y., 2020. Coal and economic development in Pakistan: A necessity of energy source. Energy, 207, p.118244.

[2]. Jeong, M., Lee, H., Bae, M., Shin, D.B., Lim, S.H.and Lee, K.B., 2018, October. Development and application of the smart helmet for disaster and safety. In 2018 International Conference on Information and Communication Technology Convergence (ICTC) (pp. 1084-1089). IEEE.

[3]. Ghulam E Mustafa Abro, Shoaib Ahmed Shaikh, “PROTOTYPING IOT BASED SMART WEARABLE JACKET DESIGN FOR SECURING THE LIFE OF COAL MINERS”2018 International Conference on Computing, Electronics & Communications Engineering (iCCECE)

[4]. Jiya Tian, Juan Zhu, “POSITIONING SYSTEM FOR MINERS BASED ON RFID” 2011 International Conferenceon Multimedia Technology

[5]. D. Kock and J. W. Oberholzer, THE DEVELOPMENT AND APPLICATION OF ELECTRONIC

TECHNOLOGY TO INCREASE HEALTH, SAFETY, and productivity in the South African coal mining industry,” IEEE Trans. on Industry Applications, vol. 33, no 1997.

[6]. Gaidhane, Mahendra Dhame and Prof. Rizwana Qureshi “SMART HELMET FOR COAL MINERS USING ZIGBEE TECHNOLOGY” Imperial Journal of Interdisciplinary Research (IJIR) Vol-2, Issue-6, 2016 ISSN: 2454- 1362

[7]. CHENG Qiang, SUN Ji-ping, ZHANG Zhe, ZHANG Fan “ZIGBEE BASED INTELLIGENT HELMET FOR

COAL MINERS” World Congress on Computer Science and Information Engineering 2009

[8]. Yongping Wu, Guo Feng, Zhang Meng, “THE STUDY ON COAL MINE USING THE BLUETOOTH

WIRELESS TRANSMISSION” 2014 IEEE Workshop on Electronics, Computer and Applications.

[9] Ghaith Bader Al-Suwaidi, Mohamed Jamal Zemerly, “LOCATING FRIENDS AND FAMILY USING MOBILE PHONES WITH GLOBAL POSITIONING SYSTEM (GPS),” IEEE/ACS International Conference on Computer Systems and Applications, 2009.

[10]. Jesudoss, A., Vybhavi, R. and Anusha, B., 2019, April. Design of smart helmet for accident avoidance. In 2019 International Conference on Communication and Signal Processing (ICCSP) (pp. 0774-

0778). IEEE.

[11]. Mohammed, M.N., Syamsudin, H., Al-Zubaidi, S., AKS, R.R. and Yusuf, E., 2020. Novel COVID-19 detectionand diagnosis system using IOT based smart helmet. International Journal of Psychosocial Rehabilitation,24(7),pp.2296-2303.