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COAL MINE SAFETY INTELLIGENT MONITORING BASED ON WIRELESS SENSOR NETWORK

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Abstract:

Wireless Sensor Network (WSN) analyses the application of the most recent WSN technology in wireless monitoring for coal mine safety, focusing on the three essentials. Technology required for subsurface safety monitoring include transmission routing protocol, location algorithm, and wireless sensor network (WSN) technologies. The use of wireless sensor networks in intelligent monitoring systems of coal mine safety is suggested in this study, which also analyses the principles, benefits, and design foundations of wireless sensor networks in these systems. The design scheme and monitoring mechanism of a coal mine safety intelligent monitoring system are presented in light of the current scenario and existing issues with the low degree of intelligence of that system, as well as the viability of wireless sensor.

Keywords: *Arduino, LCD, Gas sensor, Temperature sensor, Node MCU, LoRa, Wireless sensor network.*

1. Introduction

Concerning worker safety and health, underground mining operations are a dangerous business. These dangers result from the various methods used to extract the various minerals. The risk increases with the depth of the mine. These safety concerns are quite important, particularly for the coal industry. Therefore, whether mining for coal or any other commodity, worker safety should always be a top priority. Due to ventilation issues and the possibility of a collapse, underground coal mining entails a higher risk than open pit mining. However, safety concerns exist in all forms of mining due to the use of large equipment and excavation techniques. In opencast and underground mining, modern mines frequently adopt a number of safety processes, worker education and training, and health and safety requirements, which result in significant changes and improvements. In India, coal has traditionally been the main source of energy, which has greatly aided in the nation's quick industrial growth. Because of this, coal is essential to the energy industry and accounts for over 70% of all power generation. However, the process also creates additional byproducts, which pose a possible risk to the environment and the nearby population. Instead, this study makes a sincere effort to assess the seriousness and create a real-time monitoring system of detection by using LORA technology.

1.1 Contribution of the Work

The environment around mining frequently contains covert threats like poisonous gases that can expose those who work there to serious health risks. For the protection of the miners, these gases must occasionally be identified, and the dangerous condition must be promptly alerted. Although wired network monitoring solutions have made a substantial contribution to mine safety, not all mining environments are ideal for them. A real-time monitoring system might aid in keeping an eye on and managing the mining environment. The majority of the benefits offered by Lora technology make it appropriate for real-time monitoring systems. As a result, it was agreed that the main goal of this project would be to create an effective real-time monitoring system that would enable the identification of various mine gas leaks as they occurred and the development of appropriate preventative measures.

1.2 Related works

There are several existing methods of wireless sensor network-based coal mine safety intelligent monitoring using Arduino.

(i) A suggested design that is based on the MSP430, There are difficult circumstances in the coal mine nowadays owing to global warming and climatic changes. Atomization in the coal mining industry is undoubtedly

required to lower costs, increase production, and enhance the quality of the final product. This will also lessen the workload on the mine workers. In order to monitor the temperature, humidity, gas levels, and smoke status in an underground mine, this article suggests a concept for a wireless sensor network (WSN) using an MSP430xx controller. In accordance with the current climate in the mine field, this system also regulates the ventilation need for mine employees. The MSP430 microprocessor, a temperature sensor, and other low-cost components are used in this system.

(ii) Using a Zigbee wireless sensor network, a monitoring system for coal mine safety. The monitoring system gathers underground coal mine temperature, humidity, and methane readings using Zigbee sensor nodes located throughout the mine, and then transfers the data to an ARM-based information processing terminal. The terminal uses Ethernet to transmit data to the ground, where the monitoring Centre analyses it and makes it available to the LAN for remote users to access. The system may SMS connected safety workers if the data is over its limit. The real-time monitoring of the working surface is now possible thanks to this technology.

(iii) Health monitoring systems have recently gained popularity and significance as a study area. For a variety of uses, including the military, home health care, hospitals, sports training, and emergency monitoring systems, research on health monitoring has been undertaken. In this study, a programmable system on chip (PSoC)-based portable real-time wireless health monitoring system is created. The created acquisition system is used to remotely monitor a patient's temperature, heart rate, and blood oxygen saturation using pulse oximetry, blood pH, and an electrocardiogram. By using a wireless module, this technology enables the doctor to comprehend the patient's circumstance on the computer screen. Here, cheap costs, minimal power usage, and adaptable network structure Remote patient data is sensed using a ZigBee wireless module. We'll be using the PSoC designer tool.

2. Proposed Model:

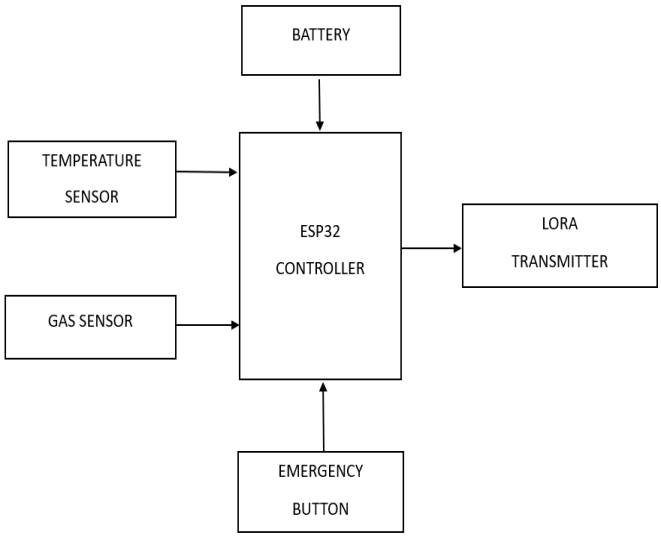
The transmitter side is the part of the system that matters the most. All measurements performed should be the responsibility of this component. The measuring node need to have a wide variety of sensors that can monitor things like temperature and gas levels and return data.

This station will include the requisite hardware (a wireless module and a microcontroller, interfaced to a laptop computer) and software to execute the necessary processing, displaying, and storing of values. These values should then be communicated over a wireless link to the data collection station.

The core of this project, without which it would be impossible to create the intended system, is the collection of various sensors. Sensors get input from the environmental circumstances. With the help of signaling design, the temperature (FU1.1) and gas sensors were developed from the ground up. The individual signal processing circuits for each sensor will be connected to them. In order to get the desired output from the sensors, these circuits will create the essential circumstances. The microcontroller must sample the signals and values that come from these sensors. The central processor or controller of the measuring node is this microcontroller.

The operation of other functional units is governed by the values that are input to and output by the microcontroller. To transfer the sensor data to the data collecting station, a wireless module (FU1.9) will be interfaced with the microcontroller. The wireless LORA protocol will be utilized by this module. According to the past and current data collected from the measurement node, this module will offer the scheme. In a database format, the results of the testing should also be kept. A database should contain records of the measured values.

TRANSMITTER SIDE:



RECEIVER SIDE:

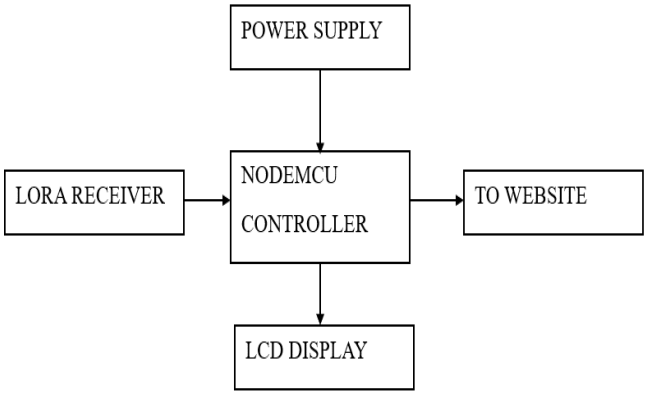


Figure 1.1 Overall Flow of the Proposed Model

- ESP32 Controller: ESP32 is a low-cost System on Chip (SoC) Microcontroller from Espress if Systems, the developers of the famous ESP8266 SoC.
- Li-ion Battery: Lithium-ion (Li-ion) batteries have become the predominant energy storage means for off-grid solar products due to their high efficiency, low cost, high capacity, lack of memory effect, and long cycle life
- Gas sensor: Ideal sensor can be utilized to locate the risk of LPG spill in your automobile or in a provider station, garage tank condition.
- Temperature sensor: This is the sensor which is used to measure the ambient air temperature inside the mine.
- LORA: LORA is a Long-Range conversation module, which can be used for long variety up to two KM based totally on serial Communication.
- Node MCU: Node MCU is an open source IoT platform. Which includes firmware which runs on the ESP8266 Wi-Fi Module from Espress if Systems, and hardware which is based on the ESP-12 module.
- LCD: The liquid crystals can be manipulated through an applied electric voltage so that light is allowed to pass or is blocked.

Overall, the system monitors the condition inside the mines and inform the miners incase of emergency and detect the hazardous gases, check the temperature to examine the survival of coal miners in the underground and to alert the miners in case of emergency.

2.1 ESP32 CONTROLLER:

For those just getting started in the world of embedded systems and microcontrollers, Arduino is a fantastic platform. You may create a number of projects that are either for fun or are even for sale using a lot of inexpensive sensors and modules. New project concepts and implementations emerged as technology developed, and the Internet of Things, or IoT, is one such notion. It is a platform that is connected to the internet so that various "things" or gadgets may exchange information.

Figure2.1 ESP32

Specifications of ESP32

ESP32 has a lot more features than ESP8266 and it is difficult to include all the specifications in this Getting Started with ESP32 guide. So, I made a list of some of the important specifications of ESP32 here. But for complete set of specifications, I strongly suggest you to refer to the Datasheet.

- Single or Dual-Core 32-bit LX6 Microprocessor with clock frequency up to 240 MHz.
- 520 KB of SRAM, 448 KB of ROM and 16 KB of RTC SRAM.
- Supports 802.11 b/g/n Wi-Fi connectivity with speeds up to 150 Mbps.
- Support for both Classic Bluetooth v4.2 and BLE specifications.
- 34 Programmable GPIOs.
- Up to 18 channels of 12-bit SAR ADC and 2 channels of 8-bit DAC
- Serial Connectivity include 4 x SPI, 2 x I^2C, 2 x I^2S, 3 x UART.
- Ethernet MAC for physical LAN Communication (requires external PHY).
- 1 Host controller for SD/SDIO/MMC and 1 Slave controller for SDIO/SPI.
- Motor PWM and up to 16-channels of LED PWM.
- Secure Boot and Flash Encryption.
- Cryptographic Hardware Acceleration for AES, Hash (SHA-2), RSA, ECC and RNG.

2.2 Gas Sensor:

The MQ-2 gas sensor's sensitive component is SnO2, which has a reduced conductivity in clean air. The conductivity of the sensor increases as the concentration of the target flammable gas rises. Please utilize a straightforward electro circuit to translate changes in conductivity into a signal that corresponds to gas concentration. The MQ-2 gas sensor is affordable, versatile, and very sensitive to LPG, Propane, and Hydrogen as well as to Methane and other flammable gases.

Figure2.2 Gas Sensor

FEATURE:

- Good sensitivity to combustible gas in wide range
- High sensitivity to LPG.
- Long life and low cost.

APPLICATION:

- Domestic gas leakage detector.
- Industrial combustible gas detector.
- Portable gas detector.

2.3 TEMPERATURE SENSOR:

This sensor is used to gauge the temperature of the surrounding air inside the mine. Using a load-balanced thermistor circuit, this sensor was constructed according to first principles. Between the applied resistor (load) and the thermistor, this circuit divides the voltage. A thermistor is a variable resistor with a temperature dependence. Despite the fact that all resistors are sensitive to temperature fluctuations, thermistors are particularly so because of the substance they are made of. This substance has a particular resistance. For that substance, this resistance is a constant. Figure depicts the temperature sensor circuit.

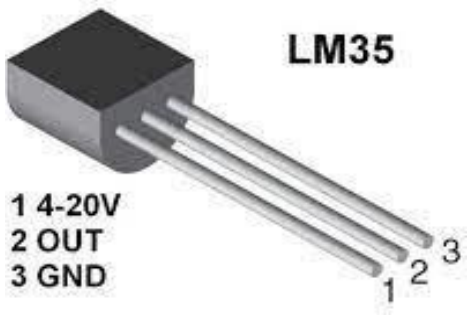
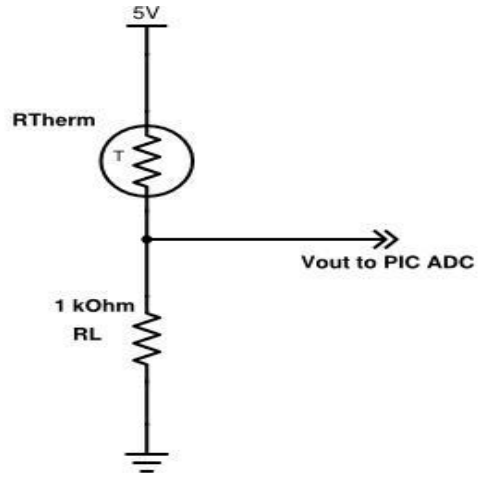


Figure2.3 Temperature sensor

Temperature sensor circuit schematic:

At 25 C, the thermistor's resistance is 2000 ohms. The method of calibration and measurement from this sensor will be described in detail before the selection of the load resistor value is justified. It was calibrated using the 3-Point system. This entails determining the thermistor's resistance at 3 different temperatures. The following values were discovered after solving for the thermistors' characteristic constants ka D 1:69210 3 kb D 1:896 10 4 kc D 4:602 10 7.



2.4 Node MCU:

The ESP8266 Wi-Fi chip is used by the open source NodeMCU LUA-based firmware. NodeMCU firmware includes ESP8266 Development Board/Kit (also known as NodeMCU Development Board) in order to explore the capability of the ESP8266 chip.

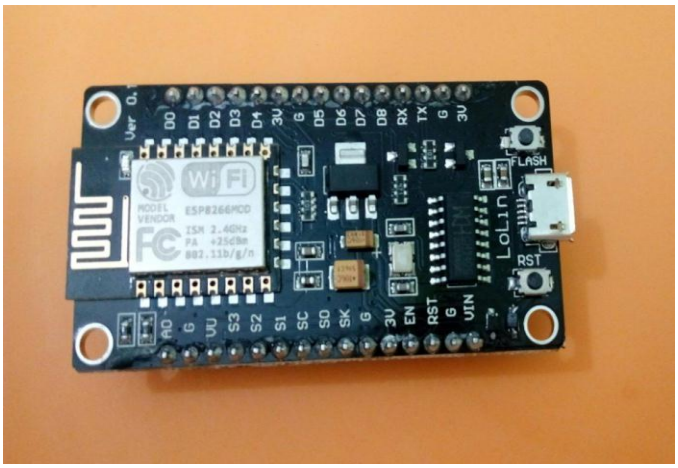


Figure2.4 Node MCU

NodeMCU with ESPlorer IDE:

Lua scripts are generally used to code the NodeMCU. Lua is an open source, lightweight, embeddable scripting language built on top of C programming language.

NodeMCU with Arduino IDE:

Here is another way of developing NodeMCU with a well-known IDE i.e. Arduino IDE. We can also develop applications on NodeMCU using Arduino development environment. This makes easy for Arduino developers than learning new language and IDE for NodeMCU.

Difference in using ESPlorer and Arduino IDE:

- We may state that while building applications for NodeMCU using the ESPlorer and Arduino IDEs, there is a difference in the programming languages used.
- If we use the Arduino IDE to create NodeMCU programmers, we must code in C++, and if we use the ESPlorer IDE, we must code in Lua.
- NodeMCU can readily grasp Lua script because it is essentially a Lua interpreter. Sequential Lua script execution occurs when we build Lua scripts for NodeMCU and submit or upload them to NodeMCU. NodeMCU will not be able to binary firmware file as a result. It will submit the complete Lua script to NodeMCU for execution.

2.5 LoRa:

- LoRa (Long Range) is a wireless technology that offers long-range, low power, and secure data transmission for M2M (Machine to Machine) and IoT applications. LoRa is a spread spectrum modulation technology that is derived from chirp spread spectrum (CSS) technology. LoRa can be used to connect sensors, gateways, machines, devices, etc. wirelessly.

- A business called Semtech launched LoRa. LoRa Technologies operates in many frequency bands in various nations. For example, it uses the 915 MHz band in the USA, the 868 MHz band in Europe, and the 865 to 867 MHz and 920 to 923 MHz bands in Asia.

- LoRa's operation resembles cellular communication more. The block diagram for LoRa communication is provided below. Through a LoRa Gateway, the signal from one LoRa Node reaches another Node. Application server connects to the LoRa Gateway to receive the signal, which the network server then provides to the end user.

- The business SemTech created and trademarked the LoRa technology. Large cells and a variety of application areas, which LoRa is known for, can allow an extraordinarily high density of devices to coexist in a single cell. It has an adjustable data rate, extensive communication coverage, and strong resistance to multipath fading. Its uses range from agriculture to medicine.

- Using LoRa modulation, the MAC layer protocol known as Lora WAN was created. This software governs the timing of message transmission and reception on LoRa devices. This works well for transmitting sparse sensor data over a long distance. Consequently, it is more affordable and has a wider coverage area than its rival wireless communication systems (WIFI, Bluetooth, and Zigbee). With deep indoor penetration and ultra-low power consumption, Lora WAN is accessible indoors and uses licence-free spectrum. It also offers end-to-end security for each node in the network and facilitates roaming by allowing for seamless handover from one network to another.

- Depending on the end devices communicating and the form of communication being used, a specific number of elements must be taken into account. Vehicle to vehicle, cloud to cloud, infrastructure to infrastructure, network to network, and vehicle to grid are just a few examples of the several forms of vehicular communication that can occur depending on the end nodes. The current protocol used in vehicle-to-vehicle communication, DSRC (Dedicated Short-Range Communications), works at a frequency of 5.9 GHz and notifies drivers of impending collisions and exchanges data. Spreading factor, signal bandwidth, carrier frequency, and other variables all have an impact on the transmissions when this type of connection is made utilizing LoRa technology.

THIKSPEAK:

- In this report, we go through how to utilize ThingSpeak, a "Internet of Things" (IoT) "Application Programming Interface" (API) and online service. The ability to identify and communicate with basic items or devices over the Internet is what we refer to here, despite the fact that the definition of what should be defined under the word is evolving over time.

- The ThingSpeak API is an open-source interface that listens to incoming data, timestamps it, and publishes it for both human users (through visual graphs) and computers (via readily parse-able code).

- We examine real-world applications for the Arduino microcontroller as well as interaction with graphical operating systems using a Python script. According to our findings, ThingSpeak is particularly helpful for smaller hardware projects that need Internet access but can't afford to maintain a dedicated communication server. There are other IoT services available, but they frequently charge for some of their features and are not, therefore, open source.

2.5 IMPLEMENTATION

- The ESP32 Microcontroller acts as the brain of the system.

- LORA is used to connect the transmitter and receiver.

- The MQ6 gas sensor detects toxic gases such as CO_2, butane, benzene, andLPG.
- The LM35 temperature sensor detects surrounding temperatures and body temperatures.
- MAX30100 senses the oxygen level and heart rate of miners.
- A panic button can be used, which sends an alert to the control room whenever a worker needs medical attention.
- An ESP32 is a microcontroller that provides a highly integrated Wi-Fisolution and is used to fetch or upload data.
- The live data streams are monitored and analyzed with graphical representation using Thingspeak.
- A 16x2 LCD is used to display the output of the Data.
- A buzzer gives an alert to authorized personnel regarding the detected hazardous event.

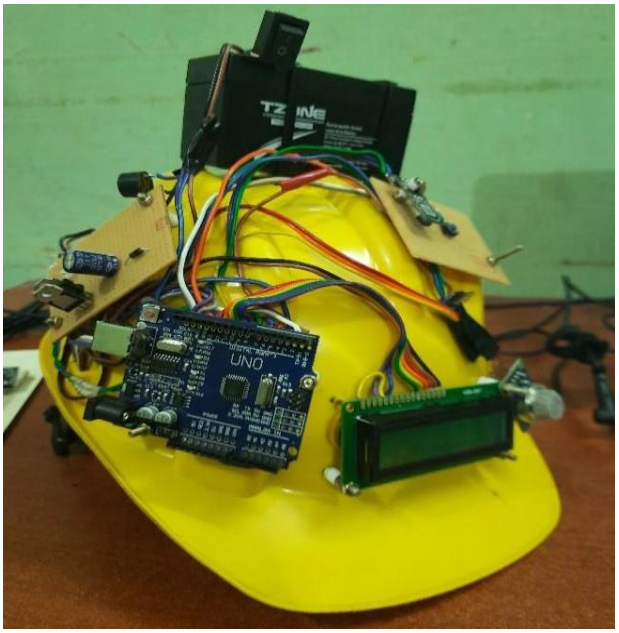


Figure2.5 Hardware of system

3.5 Experimental Results and Discussion

- The outcomes of the suggested system are covered in this chapter. It demonstrates that several sensors were used to monitor various parameters, including body and ambient temperature, oxygen saturation, heart rate, and gas level, on a regular basis. We use ESP8266 to save data in the cloud. The values may be displayed on the cloud and we can examine the data thanks to the creation of the Thingspeak channel. Real-time data streams may be aggregated, visualised, and analysed using Thingspeak's cloud-based platform. Thingspeak immediately visualises the data that is uploaded by our sensors. Run Thingspeak MATLAB code to analyses the data and do live analysis. The values may be displayed on the cloud and we can examine the data thanks to the creation of the Thingspeak channel.
- Think speak is used to download data as an excel file, which is then saved as a record for future use. A warning message and alert sound are transmitted to the control area if the value is abnormal and gas is discovered.

Conclusion

Consequently, a comprehensive mine safety system was created from the ground up to guarantee the protection of miners. This whole system was created to be both portable and modular, combining mechanical, electrical, and specialized software to provide a strong and adaptable system that would best meet the demands of the mining environment.

The device also has cutting-edge technology that enables it to precisely measure a variety of ambient parameters within the underground area. The inclusion of temperature, humidity, vibration, and dust sensors, each of which provides exact readings and improves the system's overall accuracy, makes this feasible.

Additionally, the LORA communication protocol is used in this system to facilitate communication and data transmission between two nodes.

Thanks to such technical improvements, miners can be confident that they are working in a secure environment that is carefully supervised and controlled, which makes their mining experience both efficient and safe.

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