# Data Transmission by Li-Fi in Coal Mining


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**Abstract**

There are many dangerous threats in a coal mining industry such as gas explosion, and temperature and humidity variation which can be difficult to be monitored and controlled. In this paper, we proposed and designed a method to utilize the Li-Fi technology for data transmission which are equipped with sensors to provide real time situation stat to the coal miners to ensure their safety. One of the most dangerous gases in coal mining is the carbon monoxide (CO). Hence, specific type of sensor is used and connected to a core component which is the microcontroller and placed at different parts of the coal mine. When the concentration level exceeds a certain threshold value, the buzzer will be triggered, and the notification is sent to the central database to inform the workers. Li-Fi provides the solution for slow data transmission or data loss which enhances the safety and improve the working condition of labors in coal mining sectors.



*Keywords*: Li-Fi, microcontroller, carbon monoxide sensor, safety.


## 1. Introduction

Safety is one of the most important aspects in all industries, especially in the coal mining industry. The reason is because we cannot guarantee zero error in the mining process of coal mines, as even a small mistake may lead to disastrous consequences. Communication is the primary key to observing any risk parameter [1]. At present, due to the complexity of coal mining environment around the world, mining workers are affected by many accidents. Therefore, it is essential to monitor the working environment which can be improved by establishing flexible communication with the workers. In the process of mining, the wire communication system is inefficient as the installation cost is high, and it is easily damaged under the influence of natural disasters such as earthquakes. The wireless communication used in this paper which is Li-Fi is a good way to minimize these problems.

## 2. Literature Review

Li-Fi technology is an optical wireless communication (OWC) technology proposed by German physicist Harald Haas in 2011 [2]. Li-Fi uses the visible part of the electromagnetic spectrum to transmit information at a very high speed. The working principle of Li FI begins with visible light as the emission source of the signal by controlling the ‘on’ and ‘off’ state of the LED light. When the light is ‘on’, the digital signal represents "1", and when the light is ‘off’, the digital signal represents "0". The LED light emits high-speed light and dark flashing encoded information that cannot be detected by the naked eye. The photosensitive sensor receives these changes and uses the decoding chip to recover the same data information as the sender, so as to complete the transmission and reception of wireless data and translate the optical signal into ordinary electrical signals. Currently, the improved LED light is equivalent to a Li-Fi hotspot. The optical signal emitted by LED lights is similar to the electromagnetic signal emitted by AP (Wi Fi hotspot) devices [3]. To put it simply, it uses light to transmit the network, and when there is light, there is network.

## 3. Proposed System

The entire system is divided into two parts which are the transmitter and receiver and both plays a crucial role in communication between the components. Fig. 1 shows the block diagram of the transmitter and Fig. 2 shows the block diagram of the receiver.

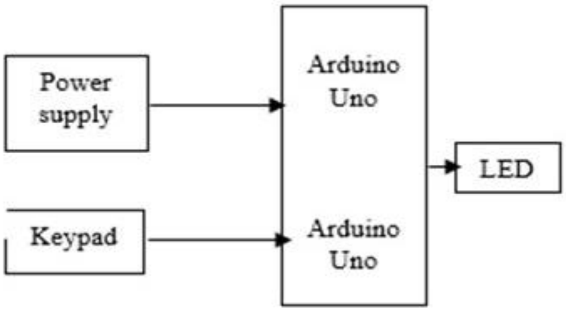


Fig. 1. Block diagram of device at transmitter side

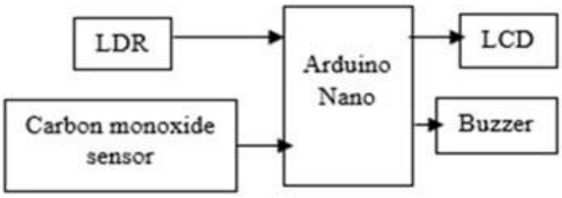


Fig. 2. Block diagram of device at receiver side

The main components that were used to ensure the functionality of the operation design system are listed below:

### 3.1. *Arduino uno*


Fig. 3. ATmega328P Arduino Uno

The ATmega328P-based Arduino Uno shown in Fig. 3 is a microcontroller board. It has 14 digital I/O pins, 6 analogue inputs, a ceramic resonator operating at 16 MHz, a USB connection, a power jack, an ICSP header, and a reset button. The microcontroller can start to function by simply connecting it to a computer via a USB cable or power it via an AC-to-DC adapter or battery. As an output, this board is capable of controlling relays, LEDs, servos, and motors and can be interfaced with other Arduino boards, Arduino shields, and Raspberry Pi boards.

### 3.2. *Arduino nano*

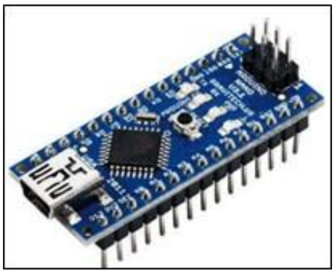

Fig. 4. ATmega328 Arduino Nano

The Arduino Nano illustrated in Fig. 4 is a small, complete, and breadboard-friendly ATmega328-based board. It has similar functionality to the Arduino Duemilanove, but in a different package. It only lacks a DC power jack and uses a Mini-B USB cable rather than a standard one. The Arduino Nano includes a crystal oscillator with a frequency of 16 MHz. It is used to generate a clock with a precise frequency by using constant voltage.

### 3.3. *MQ-7 sensor*

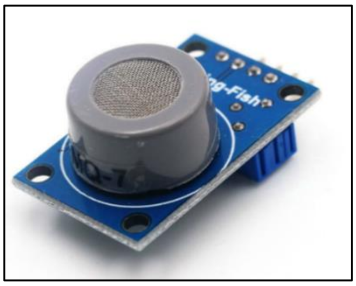

Fig. 5. MQ-7 Gas Sensor

The MQ-7 shown in Fig. 5 is a simple carbon monoxide sensor that can detect CO concentrations in the air. The MQ-7 is capable of detecting CO-gas concentrations ranging from 10 to 500ppm. This sensor is highly sensitive and has a quick response time. The output of the sensor is an analogue resistance. The drive circuit is very simple: we simply supply 5V to the heater coil, add a load resistance, and connect the output to an ADC.

### 3.4. *Keypad*

Fig. 6. 4×4 4×4 Matrix Array/Matrix Keyboard

This keypad has 16 buttons organised in a telephone-line 3×4 grid, plus four extra keys labelled A, B, C, and D as shown in Fig. 6. It's made of a thin, flexible membrane material with an adhesive backing that allows it to be attached to almost anything. Because the keys are connected in a matrix, scanning through the pad requires only 8 microcontroller pins (4 columns and 4 rows).

### 3.5. *Buzzer*

A buzzer, also known as a beeper, is a mechanical, electromechanical, or piezoelectric audio signalling device. Alarm devices, timers, train and confirmation of user input such as a mouse click or keystroke are common applications for buzzers and beepers. Fig. 7 shows the Piezo Buzzer used in this prototype.

Fig. 7. MCKPR3-G4210-4136 Piezo Buzzer

## 4. Development of Li-Fi transmission

This section highlights the procedure used to establish a Li-Fi connection for data transmission usage in the mining sector. The project is divided into four different stages which are planning, designing, execution and monitoring to produce the best possible outcome.

### 4.1. *Planning the suitability of materials and equipment*

There are two types of sources which are widely used, Light Emitting Diode (LED) or lasers depending on the types of propagation mode [4]. Since our project is on a smaller scale, the basic material used as the light source is the LED. Next, Light Dependent Resistor (LDR) is used for light pulses detection on the receiver side. The core of the entire system relies on the microcontroller which is the Arduino Uno and Nano as it is more cost effective and capable of interpreting data such as reading inputs from a sensor and providing an output to another specific device.

Next, carbon monoxide which is produced from incomplete combustion of carbon dioxide is an important risk parameter in the mining environment because it is extremely toxic. It may even cause the death of a person in one to two hours if the level gets as high as 0.2% because it blocks the hemoglobin from absorbing and carrying oxygen. It is also flammable and difficult to extinguish compared to other gases [5]. MQ-7 is used to detect the carbon monoxide level and a buzzer is fixed at the receiver to inform the workers once the concentration exceeds the threshold value. There is also a keypad at the transmitter side to ease communication during crucial moments.

Besides that, a Liquid Crystal Display (LCD) is used at the output to display the current carbon monoxide level of the surrounding environment as well as the important data from the keypad input.

### 4.2. *Designing data transmission via Li-Fi*

For such a small-scale design, all the devices are fixated onto breadboard. When the user presses a number on the keypad, the Arduino Uno interprets the information and sends the data via the output port to the LED. The LED is connected in series with a resistor to form a voltage divider circuit and to avoid short circuit. The microcontroller controls the blinking of LED which is detected by the LDR as visible light pulses and converts it to interpretable electrical pulses [6]. Then, the LDR is connected to the input port receiver, Arduino Nano, which receives the pulses and converts it to actual data. The MQ-7 sensor which is used to detect the surrounding carbon monoxide collects the data and is connected at the receiver side of the Arduino Nano. The buzzer will be switched on once the sensor detected a value above 100ppm. The LCD will also display the value of carbon monoxide concentration and the keypad value from the input.

### 4.3. *Execution of devices in mining sectors*

The project was designed to be implemented as a real-life application in the mining sector. First, the carbon monoxide sensor is located at different places and levels in the mining operations to have a wider coverage. Next, the sensors are connected to the embedded system which is fixated at the central database for data analysis and interpretation. LEDs are replaced with white light and built along the mining routes. LDR are fixated onto the workers' helmets to ease the detection of light. The data will be displayed on a wrist band worn by the workers which comes with an alarm that produces sound and notify the workers if the concentration of carbon monoxide exceeds the threshold value. Besides, any important announcements that needs to be transmitted to deeper underground levels can be done by pressing the numbers on the keypad from 1-9 at the transmitter side which will be received by all the workers immediately.

### 4.4. *Monitoring*

The device needs to be monitored from time to time because some environmental issue may cloud the judgement of the MQ-7 sensor and may require maintenance to ensure high accuracy as well as to protect the lives of the workers in the mining sector. Besides that, nowadays the use of LED is replaced with lasers because they are more powerful, operate at high speeds due to its monochromatic characteristic, allows further transmission of light and has fewer errors.

### 4.5. *Flowchart of the device*

The procedure of the working principle of Li-Fi data transmission follows a designated flow as shown in Fig. 8 below.

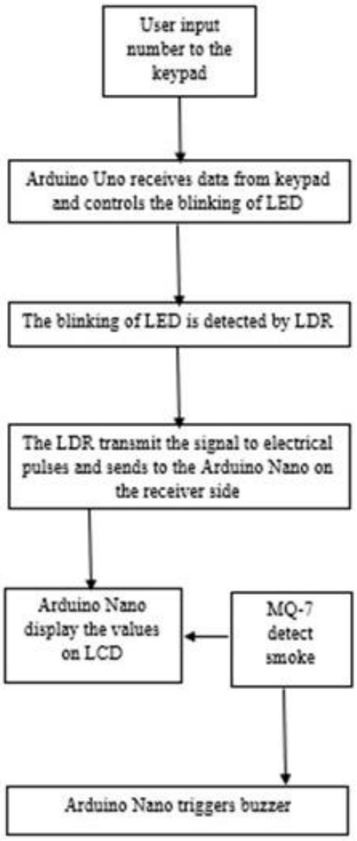


Fig. 8. Flow chart of data transmission

## 5. Results

The result of the experimental setup from the transmitter to receiver was recorded.

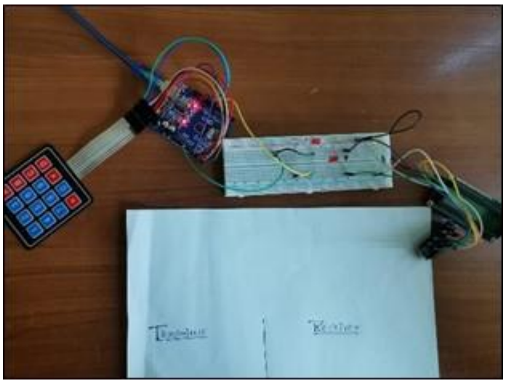

Fig. 9. Hardware setup of data transmission via Li-Fi

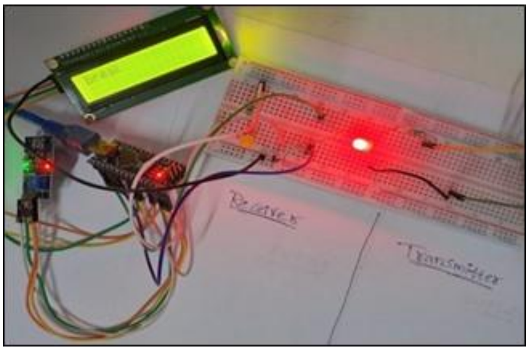

Fig. 10. Data transmission via LED to LDR when keypad is pressed

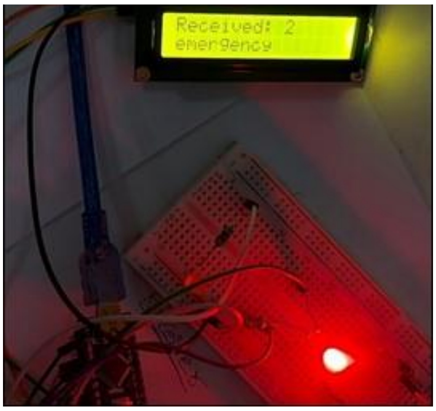


Fig. 11. Input data displayed on LCD screen

## 6. Discussion

Li-Fi is a cutting-edge communication that has the potential to be 100 times quicker than Wi-Fi and uses visible light sources to transmit data which acts as a communication medium. The photodiode serves as a receiver that receives the light signals, while an LED works as a light source. We can communicate specific data patterns by managing the light pulse on the transmitter side. The data is then transformed into meaningful information at the receiver side by the photodiode or Light-dependent resistor (LDR) [7].

As depicted in Fig. 9 the hardware setup of data transmission via Li-Fi has the following steps; when the numbers in the keypad are pressed, the LED lights up. As the numbers in the keypad goes higher, the intensity of light also increases. LDR at the receiver side detects the change in light intensity and sends the signal to Arduino Nano which is connected to an LCD. The LCD module displays the number input in the keypad based on the difference in light intensity detected by LDR. Different time delay was set for the LED to remain at the 'on' state as shown in Fig. 10. For instance, when the user input the number '2' from the keypad, the LED lights up dimly and only for a short amount of time. The LCD module display the number '2' at receiver side as shown in Fig. 11. If the user input the number '8', then the LED lights up with much brighter intensity and remains 'on' for a longer time compared to the first number. This is because an increase in incident light's intensity translates into an increase in photon content. When the quantity of incident photons rises, more photo- electrons are likewise released, which raises the photoelectric current.

Carbon monoxide sensor, MQ-7 is used at receiver side to detect the concentration of this particular gas emitted at the surroundings. This sensor has a small heater inside with electrochemical sensor to measure different kinds of gas combinations. The working principle of MQ-7 depends on chemiresistor which has free electrons. These free electrons are attracted to the oxygen molecules and push to the surface of the chemiresistor. This prevents the free electrons from conducting current which helps in the detection of CO [8]. As the gas concentration increases, so does the sensor's conductivity. The sensor may be used to determine which gases contain carbon monoxide and protects the coal miners' health by triggering a buzzer when a threshold value is surpassed.

The keypad serves as input for Li-Fi communications at the transmitter portion. This implies that the keypad will be used to select the text to be conveyed. The control unit, Arduino Uno, processes the input and transforms the data into binary pulses that can be transmitted via an LED source. The LED light uses these data to transmit pulses of visible light to the receiver side. The LDR sensor in the reception part absorbs the visible light pulses and turns them into comprehensible electrical pulses that are fed to the Arduino Nano (Control unit) which transforms it into data and displays it on a 16x2 LCD screen.

### 6.1. *Advantages of Li-Fi*

First, Li-Fi can be expanded in places where Wi-Fi technology is not yet widely used, such as in hospitals, power plants, and other establishments. Besides, Li-Fi only uses light, making it safe to use in places like aeroplanes and hospitals where Wi-Fi is prohibited due to its propensity to interact with radio frequencies. There is also no health concern because optical bands are not harmful unlike the Radio Frequency spectrum. Devices that use Li-Fi have lower power consumption for operation and hence is used in a lot of IoT applications. Lastly, due to line-of-sight data exchange, it offers a high level of security (LOS). Additionally, the Li-Fi signal cannot penetrate through walls. This will prevent unauthorised individuals from gaining access to the signal [9].

### 6.2. *Advantages of Li-Fi*

In order to receive data, there must be a perfect line of sight. This means that the signal is immediately lost if the receiver is occluded by any opaque object. Furthermore, currently, only a few gadgets are compatible with Li-Fi because it is a relatively new technology. It's doubtful that we will see Li-Fi-enabled personal gadgets in the next several years because the majority of the devices we use now still utilise hardware for Wi-Fi networking. Although Li-Fi has a quicker data transmission rate, the best feature of this technology is still unimportant if service providers' Internet speeds are still poor. Deploying a Li-Fi network would be useless in nations with slower internet connections. Coordination between a number of industries will be necessary to promote widespread adoption of this technology [10, 11].

## 7. Further Improvement

The present work focuses mainly on unidirectional data transmission. However, it can be improved further by using another LDR at the transmitter module and LED at the receiver side which will lights up when the buzzer is triggered. With this, the Li-Fi system can now be bi-directional. In the bidirectional communication system, each microcontroller acts as a transmitter and receiver simultaneously. Considering this case, the user at transmitter module (coal miners working closer to surface ground) can send data to the user at receiver module (deep underground) and vice versa.

## 8. Conclusion

Li-Fi has evolved into a ubiquitous system technology that has a wide range of application. Due to its abundance advantages, Li-Fi is capable of improving the safety in many industries especially in coal mine sectors. This paper proposed a method of incorporating such technology to help in efficient monitoring and data transmission which reduce life risks of the coal miners. Carbon monoxide is the prime focus among all other risk factors because it is highly poisonous and can cause death in extreme cases. Li-Fi technology enables the coal miners to understand about the condition of environment at high reliability. It is also cost effective compared to Wi-Fi because it offers significant savings in the long run. However, since the technology is still new and under development, various research and development methods have to be conducted to ensure that the Li-Fi can meet the demand for connectivity.

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He received the B.Eng. degree (Hons.) in communication and electronics engineering from UCSI University, Malaysia, in 2016, and the M.Eng.Sc. degree from Multimedia University, Malaysia, in 2020. His research interests include heterogeneous LTE-advanced cellular networks, user association, metaheuristic algorithms, and antennas design.

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