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Secure Real-Time Health Monitoring with LiFi Communication and Blockchain Integration

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ABSTRACT

In high-risk environments such as mines, factories, and remote industrial zones, ensuring the safety and well- being of workers is a top priority. This paper proposes a novel system for real-time health monitoring and menace detection by integrating LiFi (Light Fidelity) communication technology with Blockchain for secure data management. LiFi, a visible light communication technique, enables high-speed, interference - free data transmission, making it ideal for environments where radio frequency (RF) communication is unreliable or hazardous.

INTRODUCTION

With the increasing demand for labor in hazardous environments such as mining, chemical plants, and construction zones, ensuring the safety and health of workers has become more critical than ever. Traditional monitoring systems often rely on radio frequency (RF)-based communication like Wi-Fi, which can suffer from signal interference, limited bandwidth, and vulnerability to cyberattacks—especially in environments filled with heavy machinery and complex equipment.

To address these challenges, this project proposes a cutting-edge system that combines LiFi (Light Fidelity) technology with Blockchain to enable real-time component of Visible Light Communication (VLC), uses light waves instead of radio waves to transmit data, offering faster speeds, increased security, and immunity to electromagnetic interference. It is especially suitable for use in environments where RF communication is unreliable or poses a safety risk.

Alongside LiFi, the integration of Blockchain ensures that the collected health and environmental data is stored securely, transparently, and tamper-proof. By using wearable sensors to monitor vital signs such as heart rate, body temperature, and oxygen levels—and combining them with environmental sensors to detect hazardous conditions like toxic gas leaks or structural instabilities—this system can immediately alert authorities or control systems to potential threats

By leveraging the advantages of LiFi and Blockchain, this solution aims to provide a robust, secure, and real-time safety net that can significantly reduce risks, improve emergency response, and enhance the overall safety of workers in high-risk environments.

In industries where human labor is indispensable despite technological advancements—such as mining, oil and gas, construction, and heavy manufacturing— worker safety remains a pressing concern. These environments often expose individuals to extreme conditions including toxic gases, high temperatures, lack of oxygen, and the constant risk of physical factors of the human

health tracking and menace detection.LiFi, a injury or structural failure. The absence of real-time monitoring and delayed emergency responses can lead to life- threatening situations, loss of productivity, and long-term health consequences.

To enhance occupational safety and enable proactive risk management, there is a growing need for intelligent systems that can continuously track workers' health conditions and detect environmental hazards in real time. However, the effectiveness of such systems is often limited by the communication technologies they depend on. Traditional wireless systems such as Wi-Fi and Bluetooth operate on radio frequencies, which are prone to interference from industrial equipment and metallic structures. Moreover, they pose significant security challenges due to the ease of signal interception.

LiFi (Light Fidelity), a revolutionary technology based on Visible Light Communication (VLC), emerges as a promising solution to these limitations. By using LED light to transmit data, LiFi offers several advantages over RF-based communication: higher bandwidth, immunity to electromagnetic interference, and enhanced security, as light cannot penetrate walls and is thus confined to a specific area. This makes LiFi particularly suitable for industrial and underground environments where RF communication is unreliable or undesirable.

In parallel, Blockchain technology adds a robust layer of security and transparency to the system. With its decentralized, immutable ledger, Blockchain ensures that all health and safety data collected from sensors remains tamper-proof and accessible only to authorized personnel. This not only enhances trust in the data but also provides a reliable audit trail for compliance with regulatory standards, incident investigations, and performance evaluations. By leveraging the decentralized and immutable nature of blockchain, organizations can ensure transparency and accountability in safety-critical environments

The proposed system combines wearable health-monitoring sensors with environmental detectors to collect vital real-time data such as heart rate, oxygen saturation, body temperature, gas concentration, and motion patterns. This data is transmitted through LiFi channels to a central monitoring unit and securely stored on a Blockchain network. In the event of anomalies or danger, automated alerts are triggered to initiate timely intervention and rescue operations.

By integrating LiFi and Blockchain technologies, this project presents a futuristic approach to occupational health and safety— enabling real-time, secure, and interference- free communication in environments where traditional methods fall short. The system not only aims to reduce the risk of fatalities and injuries but also promotes a smarter, data- driven approach to workforce safety management in hazardous industries.

EXISTING SYSTEM

A. Capacity

Bandwidth: The enormous, deregulated, and unlicensed visible light spectrum (10,000 times larger than RF spectrum).

Low cost: Utilizes fewer moving parts than radio technology while remaining more effective. Energy wise, LED lighting is already effective, and the power needed for data transmission is incredibly low.

B. Efficiency

Environment: Although RF transmission and propagation in water is quite challenging, LiFi functions well in this setting.

C. Safety

Exposure to visible light has aided in the evolution of life on earth. There are no known risks to human health or safety associated with this technique.

Non-hazardous: By using light to transmit information, radio frequencies are avoided, which in some environments can adversely interact with electronic circuits.

D. Security

LiFi signals are confined to a narrow region of illumination and cannot pass through walls, making it impossible to eavesdrop on them.

PROPOSED SYSTEM

Accurate Measurable Body Health Monitoring

Wearable devices attached to the body measure key physiological metrics such as heart rate, body temperature, ECG signals . These measurements are highly accurate due to advanced biosensors that continuously collect data with minimal delay. The data is transmitted using LiFi, which provides high-speed, interference-free low-latency, and RF-sensitive communication

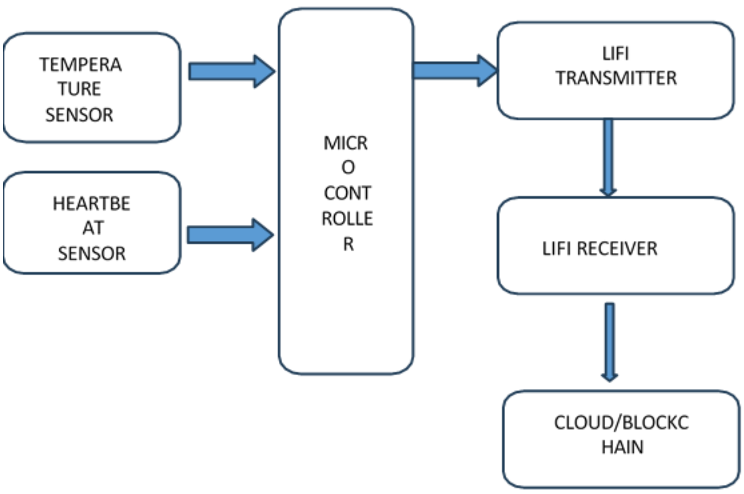

Fig 1 : Proposed System

In LiFi,the Transmitter (TX) and the Receiver are the two subsystems that make up the system (RX). The inputs (keyboard, monitor, mouse, etc.), support software, the electrical control circuit and board for something like the LED, the electrical control circuit and board for the LDR, the software in the TX and RX modules, are just a few examples of the minor duties that constitute each one.

The transmitter module contains PIC16F877Amicrocontroller and the receiver module has an Arduino microcontroller.

SOFTWARE MODULE

Python coding is necessary for operating the transmitter module, and the Arduino IDE is needed regulate the Arduino board adequately. The software diagram that illustrates the intended structure of the code within the transmission module and receiver module is shown below

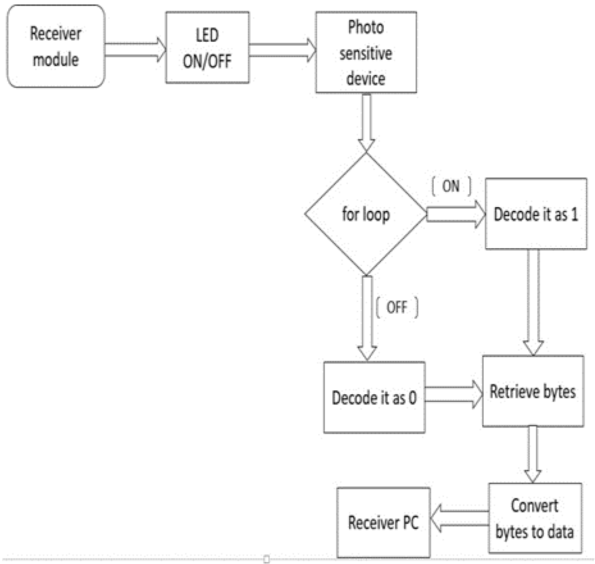

Fig 2 : Transmitter Module

RECEIVER MODULE

The photosensitive gadget will be able to tell when the LED is on and off. An LED that is on will be decoded as 1 and one that is off as 0. The bits will be extracted into bytes, which will then be transformed to data and transferred to the PC receiving it.

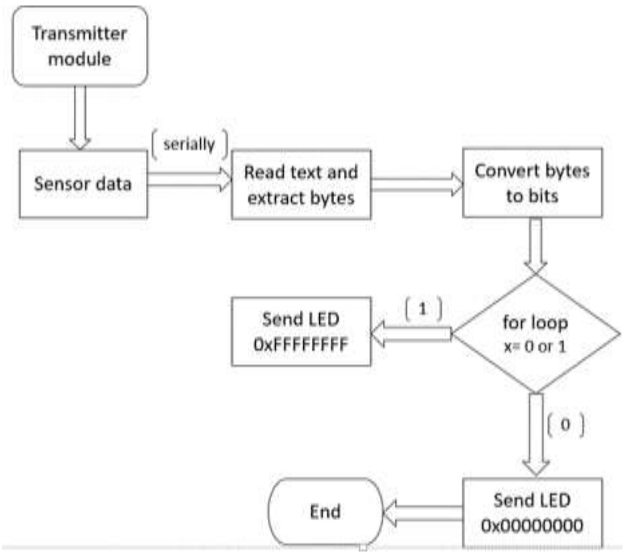

Fig 3: Receiver module

The suggested LiFi-based monitoring system is implemented using both software and hardware components. The hardware components used and the outcomes of each hardware component's testing are discussed.

CONCEPT OF IOT

The Internet of Things (IoT) is a network of interconnected intelligent things that is created by blending physical items into the digital world. LiFi is regarded as an intriguing IoT application since it focuses on turning light into a useful way of connectivity. In order to generate data for analysis and build a LiFi-based IoT system, an architecture for mounting LiFi in diverse indoor and outdoor environments is recommended. On the assessment and processing of the gathered data, a decision is drawn.

HARDWARE ARCHITECTURE

The hardware components used in the data collection process include DHT11 temperature sensor, which measures the temperature of the mining field, pulse sensor which measures the heart rate of the mine workers, MQ135 air quality sensor, to detect the presence of poisonous gases, a PIC16F877A board, MCP3008 ADC, breadboard and connecting wires.

A. PIC16F877A

The transmitter side needs the PIC16F877A to maintain the data collected from diverse sensors, as well as the DS18B20 Temperature Sensor, ECG sensor and the pulse Sensor

B.DS18B20

The DS18B20 is a digital temperature sensor commonly used in embedded systems and IoT applications due to its simplicity, accuracy, and digital interface. It communicates over a 1-Wire protocol, allowing multiple devices to be connected to the same data line, which makes it ideal for systems where multiple temperature readings are needed from different locations.

Fig 4: DS18B20

WORKING PRINCIPLE

The detector consists of an IC on the rear, a heating element NTC temperature sensor, and a capacitive humidity detector. The humidity sensing component, which consists of two electrodes with a moisture- holding substrate in between them, is used to measure humidity. So, the conductivity of the substrate or the resistance between these electrodes changes as the humidity does. To measure temperature, the sensor instead then uses a thermistor or an NTC temperature sensor. The resistance fluctuates along with the temperature in a thermistor, which is essentially a form of variable resistor. "Negative Temperature Coefficient" (NTC) stands for the addition to the fact that resistance decreases as temperature increases. These sensors are made by sintering semiconductive materials like ceramics or polymers in order to achieve significant alterations in resistance with only moderate changes in temperature.

DISCUSSION

A. TESTING AND VALIDATION OF LIFI CIRCUIT

Initially the data transfer using visible light communication was verified by transmitting a single bit by using an LED at the transmitter and an LDR at the receiver .Later the number of LEDs wereincreased and the resultant increase in current and voltage across the LDR was observed. Further the distance between the LDR and LED was varied in terms of 1m and the corresponding variation in voltage and current was observed and the power was calculated.

ToTo ensure the reliability and efficiency of the LiFi- based communication system for health monitoring and menace detection, a comprehensive testing and validation process was conducted. The evaluation focused on key performance metrics such as data transmission speed, latency, signal integrity, coverage range, and resilience in interference-prone environments—which are critical in real-time safety applications like underground mining and industrial monitoring.

B. SIMULATION RESULT

The output graph of transmitter FSM is shown

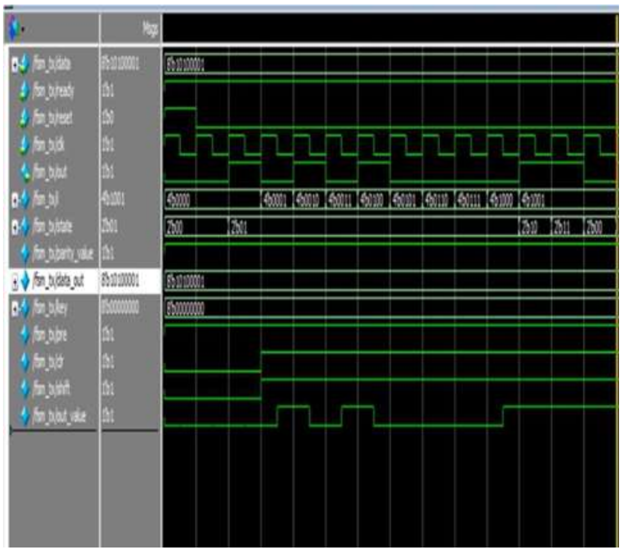

Fig 5: Transmitter FSM

The output graph of recevier FSM

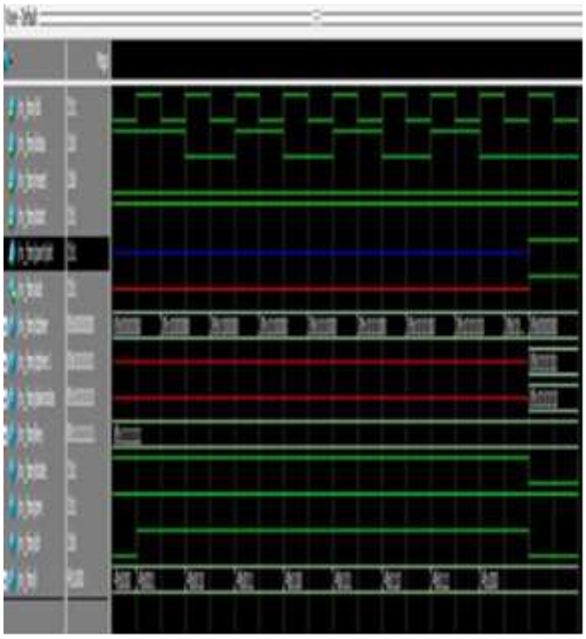

Fig 6: Receiver FSM

C. IMPLEMENTATION OF TRANSMITTER BLOCK

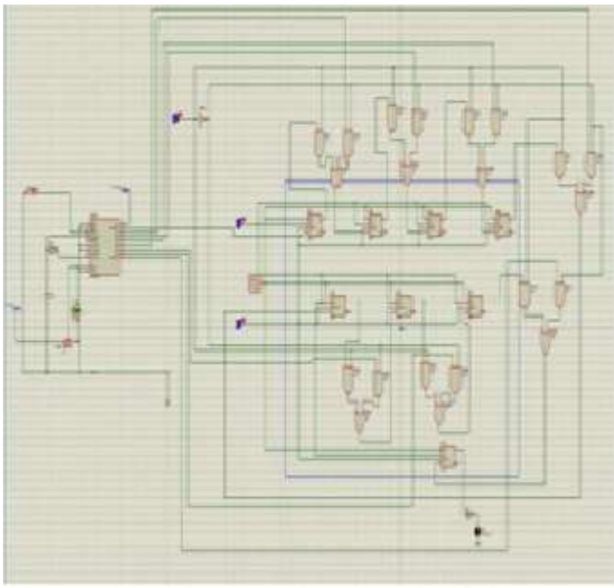

Fig 7: Implementation of Transmitter Block

D. IMPLEMENTATION OF RECEVIER BLOCK

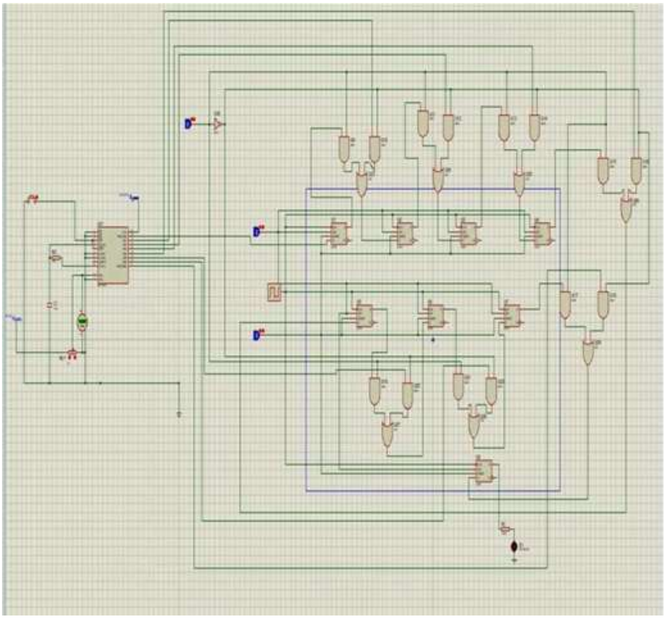

Fig 8: Implementation of Receiver Block

FUTURE ENHANCEMENT

Future developments may focus on expanding compatibility with IoT devices, enhancing scalability, and further reducing latency, thus making the solution more robust and adaptable for widespread adoption in hospitals, homes, and public health infrastructures

CONCLUSION

The integration of Li-Fi and blockchain technologies in real-time health tracking and menace detection offers a transformative approach to healthcare and security systems. By leveraging Li-Fi's high-speed, secure data transmission capabilities and blockchain's decentralized, tamper-proof data management, the proposed system ensures reliable and efficient monitoring of patients' health metrics and rapid detection of threats or anomalies.

This dual-technology framework not only enhances the accuracy and speed of data collection and transmission but also ensures the integrity and privacy of sensitive health information. The system's ability to operate in real-time enables quicker responses to medical emergencies and potential threats, ultimately improving patient outcomes and safety.

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