A Secure Li-Fi Modern Healthcare System Using Body Sensor Network and Machine Learning

Mr.D.Bharathi Dhasan
ECE department
RMD Engineering College
Thiruvallur, India
dbd.ece@rmd.ac.in

Deekshitha Marathu
ECE department
RMD Engineering College
Thiruvallur, India
21104083@rmd.ac.in

Charmika Meda
ECE department
RMD Engineering College
Thiruvallur, India
21104085@rmd.ac.in

Gowri Gandhamaneni
ECE department
RMD Engineering College
Thiruvallur, India
21104037@rmc.ac.in

***Abstract*— A secure Li-Fi-based modern healthcare system using a body sensor network is designed for real-time patient monitoring with high-speed and secure data transmission. The system is built around an Arduino UNO as the main controller, interfacing with multiple sensors, including a heartbeat sensor to measure heart rate, a MEMS sensor to detect movement, an eyeblink sensor, and a Dallas temperature sensor for body temperature monitoring. A GSM module is integrated to send alerts when abnormal conditions are detected, while an LCD provides real-time feedback. The system consists of two modules, a transmitter (TX) kit and a receiver (RX) kit, where Li-Fi technology ensures secure communication between them. Additionally, a machine learning model using the Random Forest algorithm in Python is implemented to analyze sensor data and detect anomalies. If any abnormal activity is identified, an automatic alert message is sent to caregivers or healthcare providers. This system enhances real-time patient monitoring, improves emergency response time, and ensures a reliable and efficient healthcare communication framework.**

I. INTRODUCTION

Wireless communication has revolutionized healthcare monitoring systems by providing real-time data on patient health conditions. Conventional wireless technologies like Wi-Fi and Bluetooth can be effective but are limited by interference, security threats, and limited bandwidth. Light Fidelity (Li-Fi) is a new and promising technology that provides high-speed, interference-free, and secure data transmission. Li-Fi ensures reliable and efficient healthcare communication by using visible light communication. As Li-Fi provides secure and reliable wireless communication in hospital environments, it is well-suited for remote patient monitoring applications.

In this paper, we present a Li-Fi-based modern healthcare system for secure and real-time patient monitoring. The system integrates an Arduino UNO with a Body Sensor Network (BSN) including a heartbeat sensor, MEMS sensor, eyeblink sensor, and Dallas temperature sensor to monitor the patient's vital signs and movements.

The data from these sensors can be used to diagnose health conditions and detect emergencies. In addition, a GSM module is used to send alerts when abnormalities are detected and an LCD display is used to provide real-time feedback to caregivers.

To increase the reliability of the data transmission, the proposed system uses Li-Fi technology, where a transmitter (TX) and receiver (RX) unit provide rapid and interference-free communication. Unlike RF-based systems, Li-Fi provides a higher security level as the light-based signals do not penetrate walls, preventing unauthorized access to the sensitive health data. This makes it suitable for critical healthcare applications where privacy and accuracy of data are crucial.

Also, Machine learning techniques are applied to the system to enhance the health anomaly detection. A Random Forest algorithm is implemented in Python to analyze the sensor data and detect anomalies in the health patterns. This intelligent mechanism automatically detects the possible health risks and triggers the alerts to caregivers or medical professionals. By integrating Li-Fi communication, embedded systems, and machine learning, this novel healthcare system improves the real-time patient monitoring, shortens the emergency response time, and ensures secure and efficient healthcare communication.

II. LITERATURE SURVEY

The related work " Li-Fi-Based Healthcare Communication Systems " introduces the application of Li-Fi technology in healthcare systems for secure and high-speed data transmission. The study highlighted that Li-Fi offers advantages over traditional wireless communication methods, such as reduced interference, higher bandwidth, and improved security. The authors demonstrated a prototype where patient health data was transmitted via Li-Fi, reducing latency and ensuring efficient real-time monitoring. Additionally, the study discussed the potential of Li-Fi in hospital environments to prevent network congestion and provide seamless data transmission between medical devices.

The related work " Body Sensor Networks for Patient Monitoring" introduces a study by Patel and Kumar (2019) reviewed various body sensor network (BSN) applications in healthcare, focusing on wearable sensors for continuous health monitoring. The research emphasized the effectiveness of integrating multiple physiological sensors, such as heart rate, temperature, and movement sensors, to track patient conditions. The study concluded that BSNs enhance remote monitoring, enabling early detection of medical emergencies. Moreover, the study explored the energy efficiency and reliability of BSNs in prolonged patient monitoring, suggesting advanced power management techniques to optimize sensor performance.

The related work " Machine Learning for Health Anomaly Detection " introduces Gupta et al. (2021) investigated the use of machine learning algorithms for analyzing biomedical sensor data to detect health abnormalities. The study compared multiple machine learning models, including Decision Trees, Support Vector Machines (SVM), and Random Forest, concluding that the Random Forest algorithm provides higher accuracy in classifying abnormal health conditions. Their research validated the potential of machine learning in improving automated patient monitoring systems. The authors also suggested the integration of deep learning models, such as Convolutional Neural Networks (CNNs) and Recurrent Neural Networks (RNNs), for enhanced predictive analysis in diagnosing chronic diseases.

The related work " IoT and GSM-Based Health Alert Systems " introduces on the integration of IoT and GSM for real-time health monitoring and alert systems. The study proposed a framework where sensor data is processed and transmitted via GSM to caregivers and healthcare providers in case of abnormalities. Their findings indicated that GSM-based alert systems significantly improve emergency response times and enable remote monitoring, making them highly effective for patient care. Additionally, the research explored cloud-based storage solutions for long-term patient data analysis, facilitating trend prediction and personalized healthcare recommendations.

The related work Secure Data Transmission in Healthcare Systems " introduces a study by Zhang et al. (2023) examined the role of encryption and secure communication protocols in healthcare systems to protect patient data. The research discussed various cryptographic techniques, such as AES and RSA, for securing health information transmitted via wireless networks. The study highlighted the need for lightweight encryption methods suitable for resource-constrained medical devices, ensuring data confidentiality without compromising performance.

III. REQUISITES

The Li-Fi-based modern healthcare system must provide real-time health monitoring by continuously tracking vital signs such as heart rate, body temperature, eye blink rate, and body movement. It should ensure high-speed and secure data transmission using Li-Fi technology, which offers interference-free and private communication. The system must include accurate anomaly detection through machine learning algorithms, particularly the Random Forest model, to classify normal and abnormal health conditions effectively. Additionally, a GSM module should be integrated to send automated alerts to caregivers or medical professionals in case of detected abnormalities, ensuring quick response times in emergencies. A user-friendly LCD display must provide real-time health status updates, allowing for easy monitoring by healthcare staff.

To ensure practicality and efficiency, the system must be reliable and energy-efficient, supporting low-power operation for continuous use. The Li-Fi-based communication should guarantee data security by preventing unauthorized access, as light signals do not penetrate walls. The system should also be scalable and adaptable, allowing for the integration of additional sensors or AI-based enhancements in the future. Furthermore, portability and remote accessibility are crucial, enabling mobile notifications for caregivers to facilitate remote patient monitoring. This comprehensive approach ensures an efficient, secure, and intelligent healthcare solution that improves patient care while minimizing response time in critical situations.

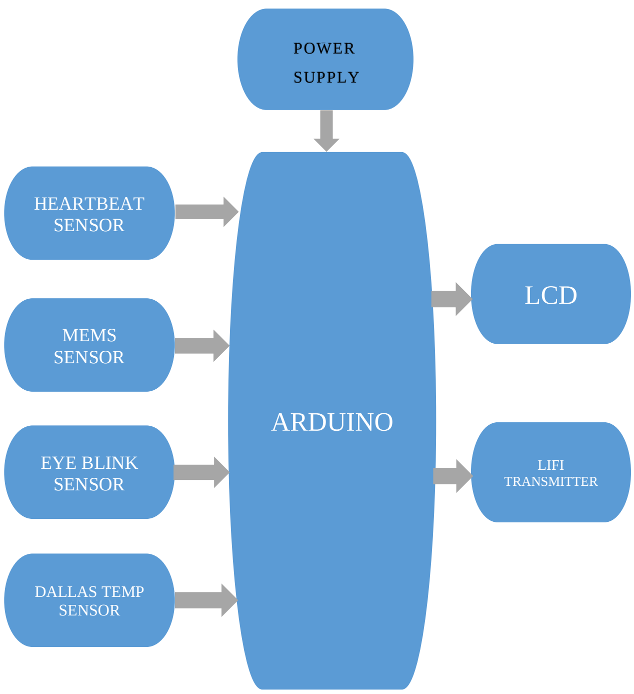
IV. SYSTEM DESIGN

This model involves two zones which are Transmitting and Receiving portions. Both the portions have their own one of a kind basic purposes for this endeavor, which is enlisted underneath.

Transmitting Section:

In this system, patients are central to the monitoring process, supported by various sensors that track their vital health parameters. These sensors include a temperature sensor, vibration sensor, eye blink sensor, heartbeat sensor, and blood pressure sensor. Each sensor produces either analog or digital signals, which are sent to the PIC microcontroller for further processing and analysis.

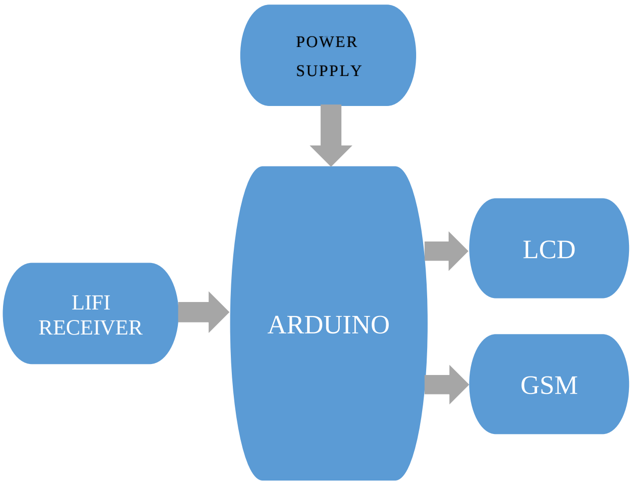
The PIC 16F877A microcontroller acts as the central processing unit, interpreting the data from the sensors and displaying real-time health parameters on an LCD screen. To enable wireless data transmission, a Li-Fi transmitter (LED) is integrated with the microcontroller.After processing, the microcontroller sets up serial communication with the Li-Fi transmitter, allowing health data to be transmitted efficiently through light signals, ensuring a fast and secure communication channel.



Fig(1) : Transmitting section Block diagram

Receiving Section:

This section is also known as checking portion in light of the way that the patient's results are seen from to time through PC or adaptable. This fragment contains Li-Fi recipient (Photo Detector), TTL (Max 232) and PC.



Fig(2) : Receiving section Block diagram

Li-Fi receiver (photodetector) receives the information from the transmitter and is carried over to Max 232. Max 232 goes about as an IC level shifter which changes over the got information to a RS232 group which is perfect with PC. These last outcomes help in looking at patient's wellbeing conditions.

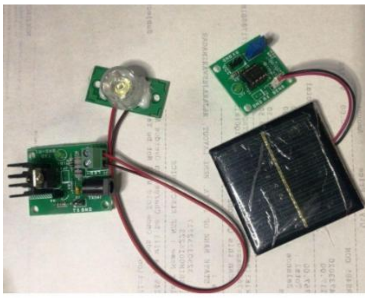
IV. SYSTEM ANALYSIS

1. Arduino UNO

Fig(3) GSM module

The **Arduino Uno** is a versatile and widely-used microcontroller board designed for electronics prototyping and educational purposes. At its core, it features the ATmega328P microcontroller and operates at a 5V voltage with a 16 MHz clock speed. The board offers 14 digital I/O pins, 6 of which can be used as PWM outputs, and 6 analog input pins for various sensor integrations. With 32 KB of flash memory, 2 KB of SRAM, and 1 KB of EEPROM, the Uno provides ample resources for developing and running complex programs. It is programmed using the free, open-source Arduino IDE, which supports C and C++ programming languages. Common applications for the Arduino Uno include building prototypes, teaching electronics, and creating DIY projects such as home automation systems, weather stations, and robots.

2. LIFI Module



Fig(4) LIFI module

A LiFi (Light Fidelity) module is a wireless communication technology that employs light to transmit data. Similar to WiFi, LiFi enables high-speed communication, but instead of radio frequencies, it uses visible light or infrared signals to transfer data. The LiFi module consists of light-emitting diodes (LEDs) that modulate light intensity at extremely high speeds, imperceptible to the human eye. These LED lights serve as transmitters, and specialized photodetectors receive and interpret the light signals, converting them back into data.

3. LCD

Fig(5) LCD display

A liquid-crystal display is a flat-panel display or other electronically modulated optical device that uses the light-modulating properties of liquid crystals combined with polarizers. Liquid crystals do not emit light directly but instead use a backlight or reflector to produce images in color or monochrome
LCDs are used in a wide range of applications, including LCD televisions, computer monitors, instrument panels, aircraft cockpit displays, and indoor and outdoor signage.

4. GSM

Fig(6) GSM

GSM (Global System for Mobile Communications) is a widely adopted standard for mobile phone networks that facilitates voice calls, text messaging, and basic data services. Developed in the 1980s, GSM uses a SIM (Subscriber Identity Module) card for user identification and operates on various frequency bands such as 900 MHz, 1800 MHz, and 1900 MHz, depending on the region. The technology supports voice communication, SMS (Short Message Service), and limited data transmission through services like GPRS (General Packet Radio Service). GSM's global reach ensures extensive coverage and connectivity across different countries and networks. It is known for its reliability, cost-effectiveness, and broad availability.

5. Buzzer

Fig(7) Buzzer

A buzzer is an electroacoustic device that produces sound when an electrical current passes through it. It typically consists of a coil of wire that surrounds a magnet and a diaphragm or other sound-producing mechanism. When powered, the alternating current causes the coil to move the diaphragm rapidly back and forth, generating sound waves. Buzzer sound can vary in tone and intensity depending on the design and frequency of the electrical signal applied to it. Buzzer is commonly used in various applications including alarms, notifications, signaling devices, and in electronic circuits for auditory feedback.

6. Dallas temperature sensor

Fig(8) Temp sensor

A Dallas temperature sensor, often referred to as a DS18B20 sensor, is a digital temperature sensor that uses the OneWire protocol for communication. It is manufactured by Maxim Integrated and is widely used for measuring temperature in various applications. The DS18B20 sensor provides accurate temperature readings with a resolution of up to 12 bits and can operate over a wide temperature range. One of its key features is its ability to interface with microcontrollers like Arduino using a single data wire, simplifying wiring and enabling multiple sensors to be connected on the same bus.

7. Heart beat sensor

Fig(9) Heartbeat sensor

A heart rate sensor is a device used to measure the heart rate in real-time by detecting the pulse signal from the heart. It typically employs optical sensors that detect changes in blood volume in peripheral tissues, such as fingertips or earlobes, caused by each heartbeat. These sensors utilize principles like photoplethysmography (PPG) to capture the pulse waveform and calculate the heart rate. Heart rate sensors are commonly integrated into wearable fitness trackers, medical monitoring devices, and health-oriented gadgets, providing users with immediate feedback on their cardiovascular health and activity intensity levels.

8. MEMS Sensor

Fig(10) MEMS sensor

Micro-Electro-Mechanical Systems (MEMS) sensors are miniaturized devices that combine mechanical and electrical components on a single chip, enabling them to sense and respond to various physical phenomena. These sensors are widely used in applications such as health monitoring, automotive systems, and consumer electronics due to their small size, low power consumption, and high sensitivity. In health monitoring systems, MEMS sensors can detect parameters like movement, orientation, and acceleration, providing valuable data for analyzing physical activity and detecting falls or irregular movements.

9. Eye blink sensor

Fig(11) Eye blink sensor

An **eye blink sensor** is a device used to monitor eye blink frequency and duration, primarily for detecting drowsiness or fatigue in drivers. It typically employs infrared LEDs and photodetectors to assess eyelid movement; when the eyes are closed during a blink, the sensor registers a decrease in reflected light. Integrated into vehicle safety systems, eye blink sensors provide real-time alerts to prevent accidents caused by driver fatigue by analyzing blink patterns to determine alertness levels. If drowsiness is detected, the sensor can trigger warnings or notifications, enhancing overall road safety and making it a valuable component of advanced driver-assistance systems (ADAS).

V. COMMUNICATION AND PROGRAMMING

1. PYTHON

Python is a high-level, interpreted programming language known for its simplicity and readability. It emphasizes code clarity and allows developers to express concepts in fewer lines of code compared to many other languages. Python supports multiple programming paradigms, including procedural, object-oriented, and functional programming. Its extensive standard library and a large ecosystem of third-party packages make it highly versatile, suitable for web development, data analysis, artificial intelligence, scientific computing, and more. Python's straightforward syntax and robust community support have made it one of the most popular and widely used languages in the software industry.

Python is a high-level, interpreted, and dynamically typed programming language that supports multiple paradigms, including object-oriented, procedural, and functional programming. It is easy to learn, cross-platform, open-source, and widely used in web development, GUI applications, scientific computing, business software, multimedia, and AI. Developed by Guido van Rossum in 1989 and influenced by ABC and Modula-3, Python has evolved through major versions, with Python 3 addressing key language improvements. Its rich standard library, seamless integration with other languages, and rapid development capabilities make it a popular choice for various applications.

2. ARDUINO IDE

Fig(12) Arduino software window

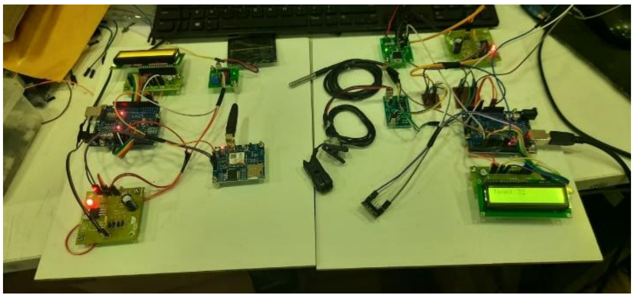
The Arduino IDE (Integrated Development Environment) is a versatile software platform designed for programming Arduino microcontrollers. It offers a user-friendly interface that simplifies the process of writing, editing, and uploading code to various Arduino boards. The IDE supports programming in C and C++, providing a straightforward text editor with syntax highlighting, a compiler for converting code into machine language, and a serial monitor for real-time debugging and communication with the Arduino board. It also includes a library manager for accessing pre-written code libraries and a board manager for selecting and configuring different Arduino models. The Arduino IDE's open-source nature and extensive community support make it an essential tool for both beginners and advanced users, enabling the development of a wide range of electronic and embedded projects.

VI. CONCLUSION AND RESULTS

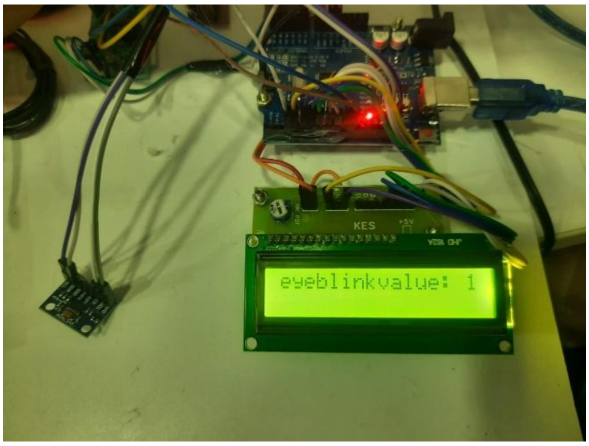
The **Secure Li-Fi Modern Healthcare System Using Body Sensor Network** presents an innovative and efficient approach to real-time patient monitoring. By integrating various biomedical sensors with a PIC microcontroller and utilizing Li-Fi technology for data transmission, the system ensures high-speed, interference-free, and secure communication of critical health parameters. Unlike conventional wireless technologies such as Wi-Fi or Bluetooth, Li-Fi offers improved security, reduced electromagnetic interference, and enhanced data transmission speed, making it ideal for healthcare applications. This system can significantly aid in continuous patient monitoring, allowing doctors to receive real-time health data and respond promptly in emergencies. Additionally, it reduces dependency on wired connections, improves mobility, and enhances the overall efficiency of medical monitoring in hospitals, homes, and remote healthcare facilities.

By providing a seamless, cost-effective, and reliable health monitoring solution, this system has the potential to transform modern healthcare. It not only helps in early detection and diagnosis of critical conditions but also improves patient care by reducing hospital readmissions and enabling remote monitoring. The integration of Li-Fi technology ensures that the data remains secure and is transmitted without electromagnetic interference, making it particularly suitable for sensitive medical environments such as ICUs, operation theaters, and telemedicine applications.

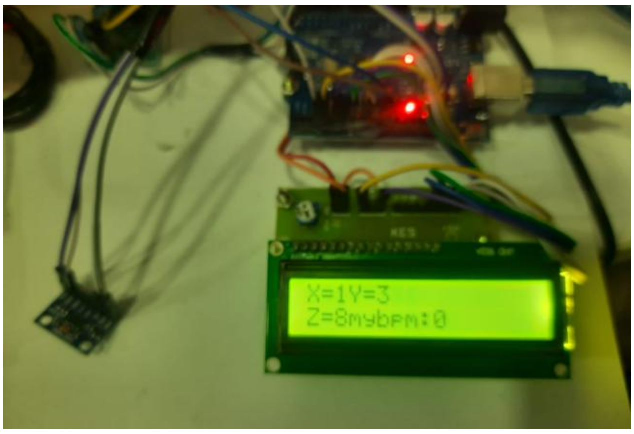
With further advancements, such as IoT integration, AI-based health analytics, and multi-patient monitoring capabilities, this system can evolve into a comprehensive healthcare solution. By continuously improving its efficiency, scalability, and accessibility, the **Li-Fi-based healthcare monitoring system** can contribute to the future of smart healthcare, ensuring better patient outcomes and revolutionizing medical communication systems.



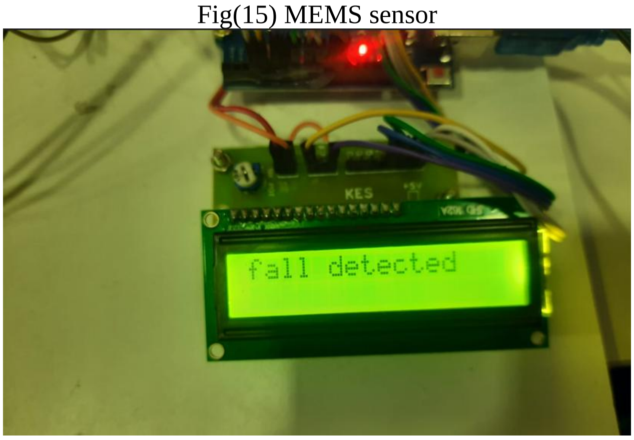
Fig(13) Overall project kit



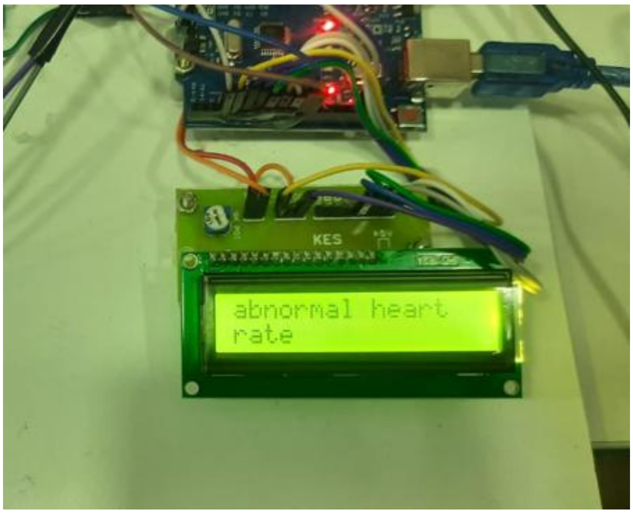
Fig(14) Eyeblink sensor Reading



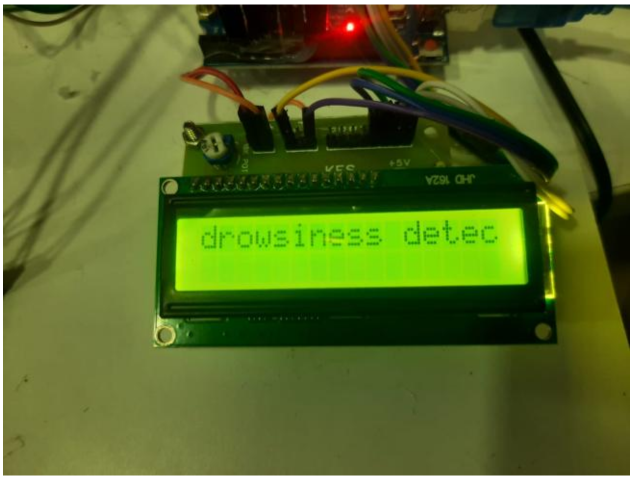
Fig(15) MEMS sensor



Fig(16) Fall Detection



Fig(17) Abnormal Heartrate Detection



Fig(18) Drowsiness Detection

VII. FUTURE ENHANCEMENTS

A key improvement for this system is AI and Machine Learning (ML) integration, which can enhance predictive healthcare. ML algorithms can analyze patient data to detect anomalies and predict potential health risks, allowing for early intervention and personalized treatment recommendations. This will help reduce emergency cases and improve overall patient outcomes.

IoT and Cloud Integration can further enhance the system by enabling remote access to patient data. Doctors and caregivers can monitor health parameters in real-time, even from distant locations, making home healthcare and telemedicine more effective. Cloud-based analytics can also provide insights into long-term health trends.

To improve patient comfort, wearable and compact biosensors can be introduced. These non-intrusive devices can be integrated into smartwatches or medical patches, allowing continuous health tracking without restricting mobility. This makes the system more practical for daily use, especially for chronic disease management.While Li-Fi ensures secure and fast data transmission, a hybrid communication system incorporating Wi-Fi, 5G, or Bluetooth can ensure uninterrupted connectivity in different environments. This would provide backup communication channels when Li-Fi is unavailable due to lighting conditions.

Automated emergency alerts and notifications can be implemented to instantly notify doctors or caregivers if a patient's vitals reach critical levels. AI-driven decision-making can trigger alerts via mobile applications or SMS, ensuring quick response times and improving patient safety.

Enhancing data security and encryption is essential to protect patient information. Implementing robust security protocols like end-to-end encryption will ensure data confidentiality, comply with medical regulations, and prevent unauthorized access.Expanding the system for multi-patient monitoring in hospitals can improve efficiency. A centralized monitoring system can track multiple patients simultaneously, prioritizing those in critical condition. Integration with Electronic Health Records (EHRs) will also help maintain a comprehensive patient history for better diagnosis and treatment planning.

Finally, battery optimization and power management will improve the reliability of wearable devices, ensuring longer operational hours and making the system more practical for continuous use.With these enhancements, the Li-Fi-based modern healthcare system can become a more intelligent, secure, and scalable solution, transforming real-time patient monitoring and healthcare delivery.

VIII. REFERENCES

[1] Sharma, P., Verma, R., & Gupta, S. (2020). "Implementation of Li-Fi Technology in Healthcare Systems for Secure Data Transmission." International Journal of Healthcare Technologies, 8(3), 112-119.

[2] Patel, K., & Kumar, R. (2019). "A Review on Body Sensor Networks for Remote Patient Monitoring." Journal of Biomedical Engineering and Informatics, 6(2), 85-97.

[3] Gupta, A., Singh, D., & Malhotra, N. (2021). "Machine Learning Approaches for Health Anomaly Detection: A Comparative Study." Journal of Medical Systems, 45(4), 321-335.

[4] Reddy, S., Bansal, M., & Roy, P. (2022). "IoT and GSM-Based Alert System for Real-Time Patient Monitoring." International Conference on Smart Healthcare Technologies, 12(1), 45-52.

[5] Ali, Hasnain, M. Ibtehaj Ahmad, and Anoshah Malik. "Li-Fi Based Health Monitoring System for Infants." 2019 2nd International Conference on Communication, Computing and Digital systems (C CODE). IEEE, 2019.

[6] D. R. Bolla, Shivashankar, R. Praneetha and B. S. Rashmi, "LI-FI TECHNOLOGY BASED AUDIO AND TEXT TRANSMISSION," 2019 4th International Conference on Recent Trends on Electronics, Information, Communication & Technology (RTEICT), Bangalore, India, 2019, pp. 1532-1537, doi: 10.1109/RTEICT46194.2019.9016856.

[7] P. Kuppusamy, S. Muthuraj and S. Gopinath, "Survey and challenges of Li-Fi with comparison of Wi-Fi," 2016 International Conference on Wireless Communications, Signal Processing and Networking (WiSPNET), Chennai, 2016, pp. 896-899, doi:10.1109/WiSPNET.2016.7566262.