Li-Fi Enabled Patient Monitoring System based on Embedded Low Power Module

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***Abstract*—An Efficient and Smart Patients' monitoring system is one of the key necessity in the Covid-19 era. The proposed patients' monitoring is based on the Li-Fi technology platform. Biomedical sensor like ECG, heart-rate and temperature sensors are used to take the body samples of the patients. The low power embedded modules along with transmitter and receiver drivers are used to process the data. The Transmitter and receiver drivers are used to convert optical data into equivalent serial frames and vice-versa. Low power module at receiver also enclosed with the where any patient can call up on the doctor in the emergency by raising the signal through push button. The doctor will get the notification in form of buzzer and Led.**

***Keywords*—Li-Fi, Patient monitoring system, ECG**

I. INTRODUCTION

An artificial intelligent based Healthcare organization is the essential key element for designing Smart Cities. Any healthcare unit can be consider as smart enough if its clinical management, infrastructure and patient monitoring system is designed on fully digitized platform. An efficient health care unit signifies the importance of patients' safety. In the recent era of Covid'19, it is clearly observed that a small negligence and ignorance caused several thousands of death cases. Patients' safety comes along with the efficient and un-interrupted patients' monitoring systems. Patient monitoring system falls under the category of Critical monitoring systems where it is used to measure biological signals includes Electrocardiograph (ECG), Human body temperature, Oxygen saturation level in human body (SpO2) etc. During the patient is in under the observation, all these biological signals are varies continuously. These frequently changed biological signals is converted into the symptoms of the disease later on. So it is necessary to build efficient and accurate patient monitoring systems to constantly observed and record the body parameters of the patients. The advanced and accurate sensors as well as electrodes are used to measure the various body parameters. The evolution in the technologies plays vital role in designing accurate biomedical devices. Patient monitoring system consist of various measurable biomedical devices. According to the behavioral functionality of suggested biomedical devices, patient monitoring system is classified into two different categories.

- Single Parameter Monitoring Systems
- Multi-parameter Monitoring Systems

Single parameter monitoring system is the category in which specific biological signal can be measured. This system consider as the traditional and low cost systems. These system consists of ECG monitor, SpO2 etc. Multi-parameter monitoring systems is the category in which all suggested biological signals are measured by the single dedicated systems. This systems can be design using the advanced technological platforms. Multi-parameter systems are costly. Multi-parameter systems are reliable and flexible however manufacturing and maintenance of these system is complex [1].

R. Sahandi and et. al. presented traditional patient monitoring system as shown in Fig. 1. As shown in Fig.1, health care assistant measure patients' body parameters and inform the same to respective nurse. The role of nurse is to record the body parameters of the patients and compare them to the previous one. According the comparative analysis of body parameters, nurse prepare the schedule for measuring body parameters frequently and inform to the respective healthcare assistant. In the case of emergency, nurse take a call to inform the respective doctor. The role of doctor is to coordinate the whole system, examine and calibrate the record of body parameters and take necessary actions [2].

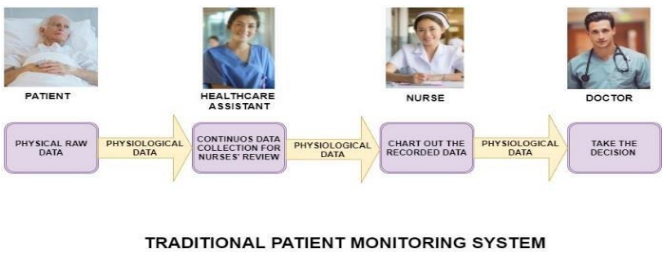

Fig. 1. Traditional Patient Monitoring System [2]

The proposed patient monitoring system is based on the Li-Fi technology. The whole system consist of majorly Transmitter and receiver sections where both the sections can communicate each other using the Li-Fi. The fundamental objective to use Li-Fi technology is to adapt phenomenal technique which transfer the information wirelessly at a very high speed. Here two individual units of microcontrollers are used as the transmitter and receiver sections. ECG and Hybrid temperature-heart rate sensor is used to measure the body parameters. These sensors are interfaced with the transmitter section. Measurable data of temperature-heart rate sensors displayed on the serial monitor and ECG sensor data displayed on the serial plotter of receiver section. In case of emergency, event generated from the receiver section can be notified at the transmitter section in form of buzzer or LED [3].

The proposed article starts with the introduction of the patients' monitoring systems. Section II gives the literature review and analysis of the other existing systems. Section III presented rigorous discussion of the proposed system. Section IV demonstrated the software flow diagram of the system. Section V presented the hardware parameters used for implementing the system. Section VI represents the experimental setup. Section VII discussed test results of the proposed system. Paper concluded in the last section.

II. Literature Review

Li-Fi named as Light Fidelity technology invented by Professor Harald Haas, the Chair of Mobile Communications at the University of Edinburg. Li-Fi technology is a phenomenal method to transfer the information wirelessly at a very high speed. Li-Fi technology is the most effective and secured way of communication among the primary devices. In the Li-Fi technology, data transmission takes place in bidirectional way through the emitted photons of light, which are practically undetectable by the human eye and bears no data loss. As the Li-Fi technology does not emit any harmful electromagnetic radiations, it is the main objective to design Patient monitoring system based on Li-Fi. Li-Fi technology is faster than the Wi-Fi technology.

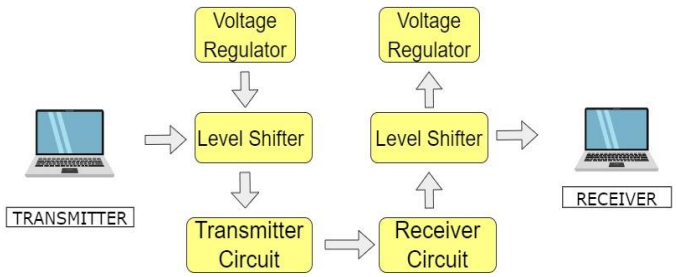

Fig. 2. Working Principle of Li-Fi Technology [3]

The working principle of Li-Fi technology is shown in Fig. 2. The transmitter can be single LED or any source of light along with the level shifter and transmitter driver circuit. The common unit of level shifter and transmitter driver circuit converts light energy into equivalent electrical energy. At the receiver section received electrical energy again converted to light energy and it's received by the photo detector. The proposed patient monitoring system gains motivation from other standard patient monitoring systems [3].

Md. Islam et. al. represented Smart Healthcare monitoring system in the article Development of Smart Healthcare Monitoring System in IoT Environment. The authors suggested the system based on the IoT platform. The system is designed using ESP-32 an IoT module. The Hospital environmental data is created using Heart bit sensor, Body temperature sensor, Room temperature sensor, Co sensor and Co2 sensor. The measured data is then plotted and analyzed on the ThingSpeak cloud [4].

S. Rani et. al. suggested smart healthcare system in the article IoT Patient Health Monitoring System. The authors designed whole system on Embedded Linux Platform as Raspberry Pi. The system is designed using Heart rate sensor interfaced with Raspberry Pi. Patients' body data then transferred to AWS cloud using IoT protocol MQTT. Patients' data can analyzed from AWS cloud and hand held mobile applications [5].

K. Monica et. al. represented GSM & IoT based efficient Patient monitoring system in the article entitled An Effective Patient Monitoring System using IoT. The authors suggested whole system on Arduino and GSM module. The whole system turns into IoT using Intranet platform. System required Heart rate and temperature sensors for taking samples from the human body [6].

S. Naddeo et. al. suggested Real time health monitoring system using wearable sensors and hand held mobile devices in the article entitled A Real-time m-Health Monitoring System. Authors suggested smart wearables for taking patients' body samples'. Smart data analysis techniques suggested by the authors in form of mobile devices [7].

III. PROPOSED WORK

The proposed patient monitoring system is shown in Fig. 3. The whole system is designed using various sensors, actuators and smart low power embedded modules. Two Arduino modules along with transmitter and receiver circuits are used as smart low power embedded modules. The functionality of transmitter and receiver modules is used to convert electrical energy to optical energy and vice-versa respectively. Hybrid Temperature-Heart rate sensor and ECG sensor are used to take patients' body parameters. Heart Rats and temperature data along with ECG samples are measured by Arduino interfaced at transmitter side. Transmitter section convert these data into equivalent optical energy and transmitted the same. The Arduino interfaced at the receiver side, further converted the data from optical to equivalent electrical signal and display Herat rates in Bits per Minutes (BPM) and patient's body temperature on the serial monitor of Arduino interface at the receiver section. ECG data can be plotted on the serial plotter of Arduino. The Arduino at the receiver section also work as the acknowledgement and feedback systems. After observing the heart-rate, temperature data and ECG plot, if patient needs extra care, then one can raised the signal via push button interfaced with Arduino. The LED & buzzer interfaced with Arduino interfaced at the transmitter section can actuate with reference to the signal raised by the receiving arduino.

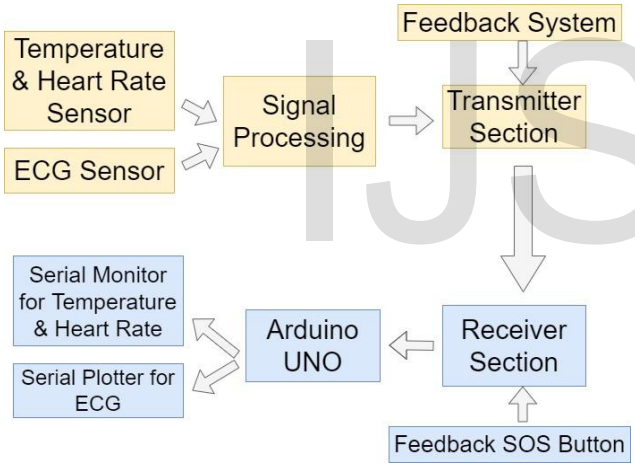

Fig. 3. Proposed Block Diagram

IV. SOFTWARE FLOW DIAGRAM

The whole software is written in Arduino C language on Arduino IDE platform. The software flow diagram is shown in Fig. 4.

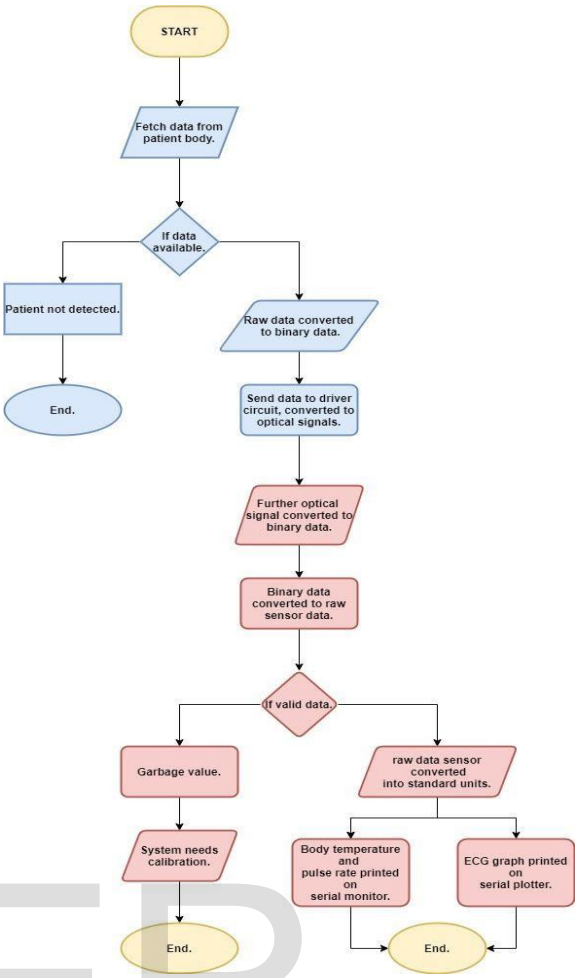

Fig. 4. Software Flow Diagram

V. HARDWARE PARAMETERS

Hardware parameters are consists of low power embedded modules, transmitter and receiver drivers and. The details of hardware parameters are as follows:

A. Low Power Embedded Modules

Arduino Uno boards along with AVR based microcontroller are used as the low power embedded modules. Arduino has on chip ADC which is used to covert analog sensor data into equivalent digital form. Arduino also consists of digital and analog based general purpose input output pins for interfacing sensors and actuators.

B. Transmitter and Receiver Drivers

Transmitter driver are used to convert Electrical energy into equivalent optical energy. LED or LASER will be used as the optical source. Receiver driver consists of integrated platform of diode as well as operational amplifier. It converts optical data into equivalent electrical amplified data.

C. Sensors

Heart-rate sensor is based on the photo plethysmography principle. It measures heart rate & the oxygen level in blood of the patient's body. The change in volume of blood in any organ of the body causes a deflection in the light intensity. Temperature sensor is used to measure the body temperature in ^{0}C or ^{0}F.

VI. Experimental Setup

The Experimental setup of proposed system is shown in Fig. 5. It consists of two Arduinos along with transmitter and receiver drivers, Heart-rate & Temperature sensor, and ECG sensor and feedback system.

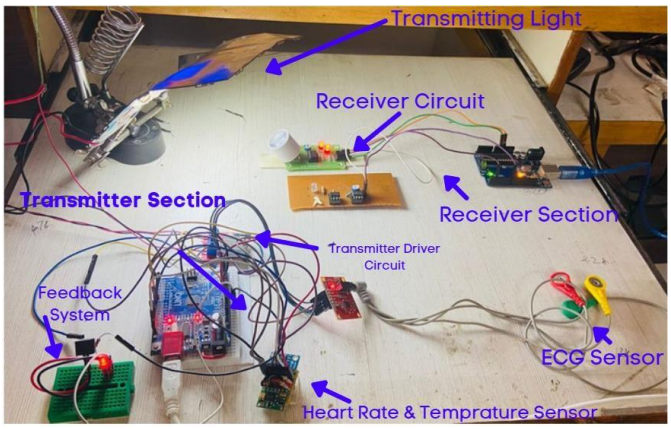

Fig. 5. Experimental Setup

VII. Test Results & Discussions

The collective test results of sensor and feedback systems are represented in Fig. 6 to Fig. 8. As shown in Fig. 6, Receiver section Arduino display Heart-rate and body temperature samples on to the serial monitor. Fig. 7 represents the ECG data on to the serial plotter on the receiver Arduino. The demonstration of feedback system with active state and inactive state is shown in Fig. 8 and Fig. 9 respectively.

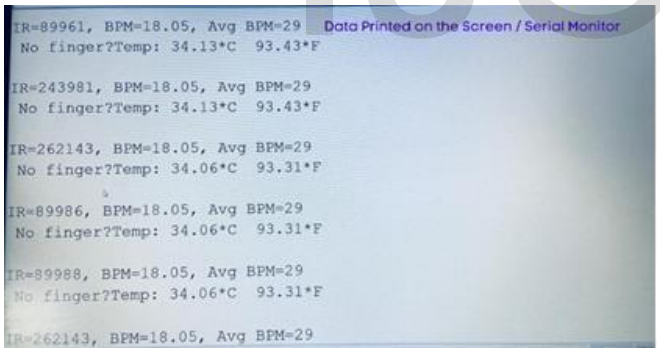

Fig. 6. Patients' Heart rate & body temperature samples display on serial monitor

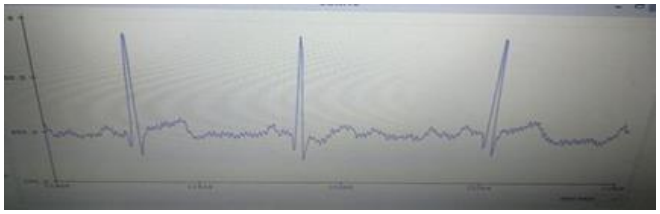

Fig. 7. ECG data on Serial Plotter of Receiver section of Arduino

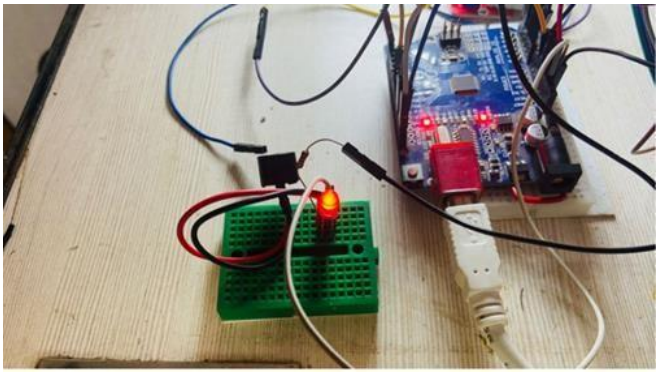

Fig. 8. LED & Buzzer "ON" State indicating Emergency at Patients' Unit

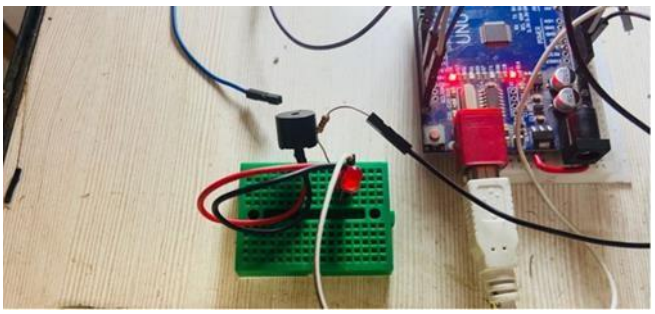

Fig. 9. LED & Buzzer OFF State

VIII. Conclusion

An efficient and advanced patients' monitoring system is presented here. The whole systems is designed on the Li-Fi technology platform. The key reason behind implementing design on Li-Fi technology because Li-Fi is faster than the Wi-Fi technology. Li-Fi technology is least affected from the electromagnetic radiation as compared to Wi-Fi and Bluetooth technology. As Covid-19 pandemic has certainly posed the physical presence, Li-Fi technology is the best option for the doctors to monitor patients remotely with less effect of radiation. The proposed system is designed on the low power embedded boards with heart-rate and ECG sensors. System is efficient enough as in the emergency case, receiver system can send the feedback to transmitter section. Transmitter system get the notification about emergency in form of buzzer and LED. The whole system can be extended on the cloud platform, where doctors can monitor the record of individual patient through mobile application and can send prescription to individuals.

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