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Li-Fi Based Healthcare Monitoring System

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***Abstract*— In hospitals the monitoring of patient is usually done manually with the help of nursing staff for 24 x 7. The availability of nursing staff to monitor the health of critically ill patients or new born infant is very difficult task and requires a lot of man power. In case, of absence or delay the health of patient can become critical and can be fatal. In order to solve this many wireless technologies have been proposed to monitor the patient's condition using different sensors but these wireless schemes are harmful for patients/infants and can even interface with medical devices. In order to develop hospital friendly monitoring system, Li-Fi based health monitoring-based system has been proposed which measure the heart rate, temperature and motion in case of infants and the data is continuously displayed on LCD. In case of any abnormalities, the relevant staff will be notified.**

***Index Terms*: - Li-Fi system, sensing, wireless technology, health care monitoring system**

I. INTRODUCTION

During the last few decades, wireless sensor networks have been used extensively in the field of healthcare to manage emergencies, critical patient monitoring in the ICUs, remote monitoring of chronic patients, and monitoring of premature infants in incubators [1, 2]. Various wireless technologies are being used for data transmission monitoring such as Bluetooth, Zigbee, Wi-Fi, etc. Bluetooth is not a good choice for WSN because of its high-power consumption, limited range, slower speed, and complex networking issues [3]. The Zigbee has been also used for healthcare purposes because of its advantage of low power consumption but at the cost of low range, it can work reliably in the range of 10-100m only. Wi-Fi has also been widely used for healthcare monitoring systems because of its good data rate and range, but it has the same drawback of high-power consumption and poor performance when a large no of devices is connected. In addition to the above-mentioned problems of wireless technologies, the use of RF in the medical hospital can affect the health of the patient because of its hazardous effects. Electromagnetic waves can also affect the performance of medical devices such as ventilators, electrocardiography, Scanners, etc.

Li-Fi can be the solution to all above-mentioned problems. Li-Fi technology uses LED lights, that use light to transmit data at the speed of 800 Mbps. Li-Fi is human-friendly, and thus can't affect the performance of patient health and medical devices. The Li-Fi provides a better data rate, security, and a low-cost solution as compared to standard wireless technologies like Bluetooth or Wi-Fi [4]. As the Li-Fi uses visible light, its spectrum is ten thousand more than the rest of the RF technologies spectrum. The prototype of Li-Fi as shown in Figure 1 can be easily implemented with help of LEDs and photodiodes, hence it offers a very low-cost and easy-to-implement solution [5]. The use of LEDs is human-friendly and acceptable to the hospital environment. The use of Li-Fi for monitoring of infants health in incubators have been reported in [2, 21], in which the heart rate and oxygen saturation level of the infants is monitored. The Phase Shift Keying (PSK) was used for communication purpose, which has the bandwidth limitation and also involve complexity issues on message recovery side. In this paper, a generalized Li-FI-based health monitoring system has been proposed for hospitals. In this work, the patient's heart rate and temperature have been monitored and the information is transmitted using Li-Fi.

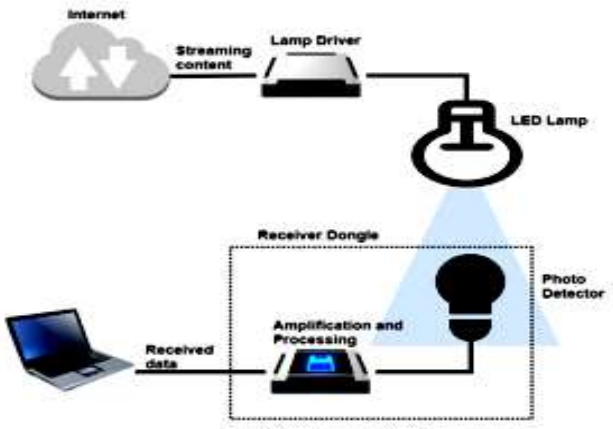

FIGURE 1. Block Diagram of Li-Fi Prototype.

II. LI-FI TECHNOLOGY

The Li-Fi is an optical wireless technology that offers an entirely new example in the area of wireless technologies in the terms of transfer speed, usability, and elasticity, reliability. [1]. Li-Fi is the probable solution to the global problem of spectrum shortage. Li-Fi technology is a fast and inexpensive optical version of Wi-Fi. It is based on Visible Light Communication (VLC) in which LEDs and a photo detector is used for data transmission as shown in Fig. 1 [6, 9, 16]. The VLC is data transmission medium using visible light between 400THz to 375THz as an optical carrier for data transmission and lighting. The data is coded in the light waves to produce a new data stream by varying the wavering rate, to be clearer, by controlling the LED light with the data signals, illustrates the communication source [7]. This is a completely new spectrum of opportunities as compared to the radio waves spectrum and is 10k times more in bandwidth. Visible light is not harmful to vision and is an obligatory fragment of a frame, therefore in large quantities available and certainly accessible. By comparing the number of radio cellular BS (base stations) (1.4 million) to the number of light bulbs (14 billion) installed already the ratio is coincidently the same i.e. 1:10000 [8, 14].

Li-Fi includes frequencies and wavelengths range, from the range of IR through visible and down to the ultraviolet spectrum as shown in Fig. 2. The class of gigabit communication has high speed for short, medium, and long ranges and bi-directional data transfer using line-of-sight (LOS) and is widely used for much more applications [7]. This technology completely utilizes all kinds of light spectrums exactly the same way like white light, and infrared. The Li-Fi technology is not only limited to LED or Laser technologies or a particular reception technique but it is a complete communication framework capable of providing new services to current and future technologies, applications, and end users [9]. Nowadays Wi-Fi is a very commonly used technology in all the public sectors like homes, airports, hotels, colleges, etc. Due to this extensive use the radio frequency is getting limited day by day, at the same time there is exponential growth in the usage of wireless data. Everyone finds easy to use wireless data but the capacity is limited [8]. But the wireless radio frequencies are getting higher and RF interferences is increasing. The solution to these problems is the use of Li-Fi technology. The Li-Fi is a wireless communication system in which light is used as a carrier signal instead of traditional RF as in Wi-Fi [10].

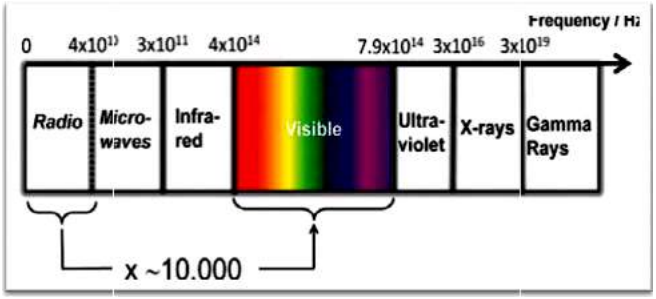

FIGURE 2. Electromagnetic Spectrum.

The use of Li-Fi technology is very safe as compared to Wi-Fi [8], the use of Wi-Fi is very hazardous in the hospital because of the electromagnetic interference with medical equipment, it can lead to wrong readings which can be fatal. However, on the other side, the Li-Fi is free of electromagnetic interference as it uses visible white light for communication. The LEDs can be used for lighting purposes in hospitals instead of conventional bulbs, these LEDs can also be used for communication using Li-Fi technology, and hence no extra equipment is required for communication purposes [10].

A. Working Principle

The main scheme is the communication of 'Data through illumination or lighting' [4, 17]. The amount of the LEDs intensity is varied by varying the current passing through it at a very high rate. These variations have enabled us to use the HIGH-LOW activities of LED lights for data transmission using binary codes. When the LED is OFF, logically it symbolizes the '0' is transmitted and when the LED is ON, logically it symbolizes the '1' is transmitted [6, 7]. This method has been used to produce rapid rhythms of light for data transmission, which is known as VLC (Visible Light communication) [11, 13].

B. Li-Fi Architecture

The Li-Fi design contains several LED bulbs. Several wireless devices such as cell phones, laptops, PCs, IoT devices, some server devices, etc. are connected as shown in Fig. 3. The important parameters while designing Li-Fi are highlighted as follows [12]: a) Representation of Light b) Line of Sight (LOS) c) LED & for the better performance use luminous light, we must have proper combination with server and Internet network, to work efficiently.

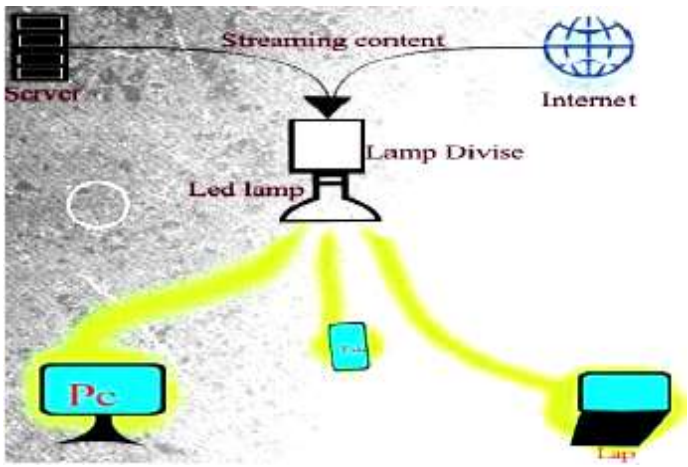

FIGURE 3. Li-Fi design

III. PROPOSED METHODOLOGY

In this section, the proposed work has been explained, and the block diagram of the proposed work is shown in Fig. 5. The block diagram is divided into three parts: Data Acquisition, Microcontroller, Li-Fi transmitter and receiver, and at last the display of transmitted data. The microcontroller will convert the input signal into binary data and then the same data is used for switching of LED at the transmitter side with the help of the microcontroller. Li-Fi is normally executed using white LED light bulbs on the transmitter side. These devices are normally used for lighting purposes only by applying a constant current. However, by generating fast and delicate variations in the current, the optical output can be varied at extremely high speed. This varying characteristic of the optical current has made it possible to use it in Li-Fi setup. The working principle is very simple-, if LED is on, that

means 1 has been sent, if it's off it means 0 has been sent. The LEDs can be swapped on and off very rapidly, which gives nice opportunities for transmitting info. Hence it only requires some LEDs and a regulator that codes data into those LEDs. All that is required is to change the amount at which the LEDs twinkle depending upon the data we want to code. The blinking of the light occurs much faster than human eyes that is why it cannot be detected, so the output appears to be constant visually, and hence looks like a simple LED bulb.

We have used LM35 and MAX30100 for SPO2 and temperature sensing. The accelerometer has also been used as a motion detector in incubators. The receiver side consists of the photodetector, and an analog low pass filter to remove the noise to detect heartbeat and SPO2 signals as shown in Fig. 4. It operates from 1.8V and 5V power and can be powered down through software, permitting the power supply to remain connected at all times. V_{dd}

We have used LCD 16x4 interfaced with Arduino UNO, which allows us to see the consumption and all the settings that are needed. The processed data coming from the Arduino UNO and proteus8 is displayed on it.

The master device in the hardware is the Arduino UNO, program is uploaded into it which is doing all of the processing. When analog data from the sensors is transmitted to the Arduino UNO, it does some processing and the output is then displayed on the LCD. Meanwhile, in the fixed time the data is also sent to the destination the software implementation part is where the application for the data is built, and a database application receives the transmitted data, and stores it into the database with some specifications. Thus, whenever we need to calculate the heartbeat and temperature of a body an application is executed and the data is shown on LCD.

We have used transceivers for communication between the Information Transmitting Shield (ITS) and Information Receiving Module (IRS). The range of the transceiver is 1-2 meters. The baud rate of the transceiver can be set from 1200-115200bps and its working voltage is 5V. The range and the data rate speed can be increased by using the laser light instead of LEDs [18-20]. The PWM modulation technique is used. It can communicate up to 1.2kbps to 115.2kbps. No tuning for the transceivers is required.

There may be many approaches to sending data using a single channel, but in this proposed work we have used the concept of data is being transmitted with a delay different by using Double pole double through (DPDT) switches. The DPDT switching method has two inputs and four outputs, and for different input combinations, four output signals can be generated. We have used the DPDT switching technique as follows:

1. 01 Temperature Sensor data is transmitted and received
2. 10 Heartbeat Sensor data is transmitted and received
3. 00 No data is transmitted and received
4. 11 Motion sensor data is transmitted and received

Using these keys combination, we first switch between data channels, then transmitted and received the corresponding data using a single channel.

There are two main modules (Hardware and Software) and three sub modules of the proposed solution detailed as under:

1. Information Transmitting Shield (ITS) or Transmitting Station
2. Information Receiving Shield (IRS) or Receiving Station
3. Arduino Uno

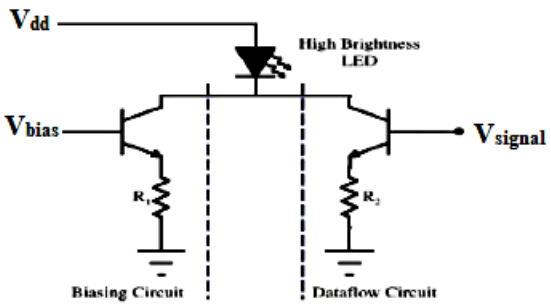

FIGURE 4a. Emitter Prototype.

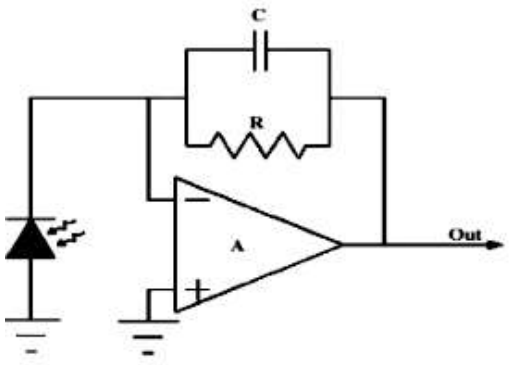

FIGURE 4b. Receiver Prototype.

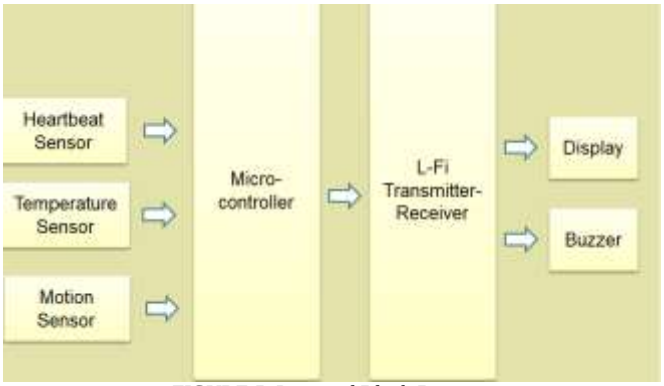

FIGURE 5. Proposed Block Diagram

The hardware required for transmitting and receiving side has been named as ITS and IRS which are detailed under:

A. INFORMATION TRANSMITTING SHIELD (ITS)

This device can be deployed in rooms, offices, or anywhere else, the main power cable will go through the ITS and then distribute. This device is also connected to the Arduino Uno and proteus8 connection points. This device holds the input data that is achieved by the user and returns it to the receiving terminal after a certain period.

B. INFORMATION RECEIVING SHIELD (IRS)

The Information Receiving Module (IRS) is the main device installed in the control room, which receives the data sent by the ITS (s). This device is also connected to the Arduino Uno and proteus8 connection points. And output data is shown on the LCD's Arduino Uno Associate UNO with an RS232 USB cable. The USB connection with the PC is essential to

program the board and not just to power it up. The UNO automatically uses power from either the PC or an external supply. The power LED must be turned on.

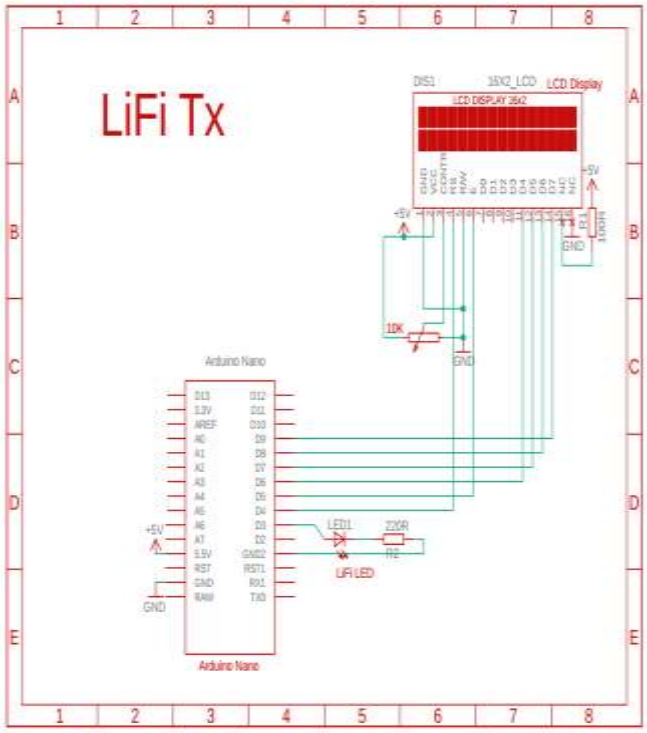

FIGURE 6. Circuit Diagram of Li-Fi based Transmitter

IV. Data Analysis and Results

A. Communication set-up

Li-Fi communication is taking place between the transmitting Station and receiving Station. One-way half-duplex communication. Li-Fi transmitter-receiver is used. The range of this wireless is around 3-5 meters in our case. The operating voltage is DC5V and the data-transmitting rate is 9600bps. We are using Serial Communication in our project, in which there are two Ways. One is Synchronous and the other is Asynchronous. We are doing serial communication using UART, which is a "UNIVERSAL ASYNCHRONOUS RECEIVER TRANSMITTER" detailed below:

1. UART COMMUNICATION:

UART Communication has been used by keeping considering the following parameters:

1. Transmission Speed
2. DATA Length
3. Start and Stop Bits

Features:

1- Baud Rate: 1200-115200bps (Default: 9600);
2- Strong anti-interfere
3- PWM modulation
4- Software speed adopted is 1.2kbps -115.2kbps

B. SENSORS SIMULATIONS AND HARDWARE IMPLEMENTATION:

Our Project contains some parts of the software and the main part is hardware based. Firstly, the devices are tested in proteus8 Simulation software then it will be tested on Hardware. The software simulation and hardware implementation are shown below.

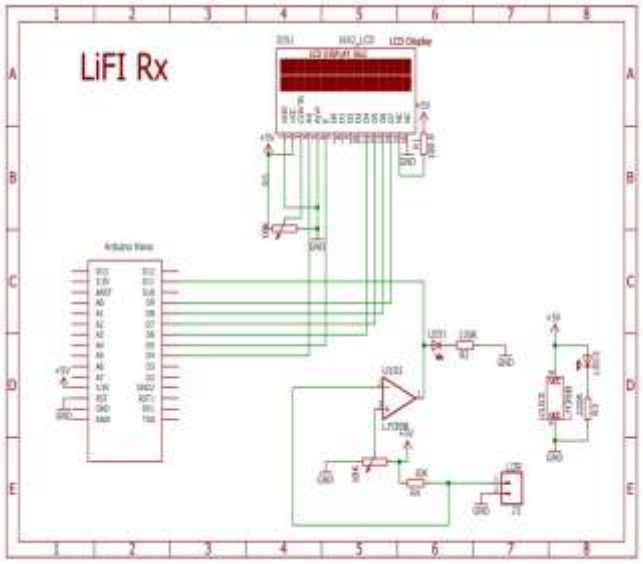

FIGURE 7. Circuit Diagram of Li-Fi based Receiver.

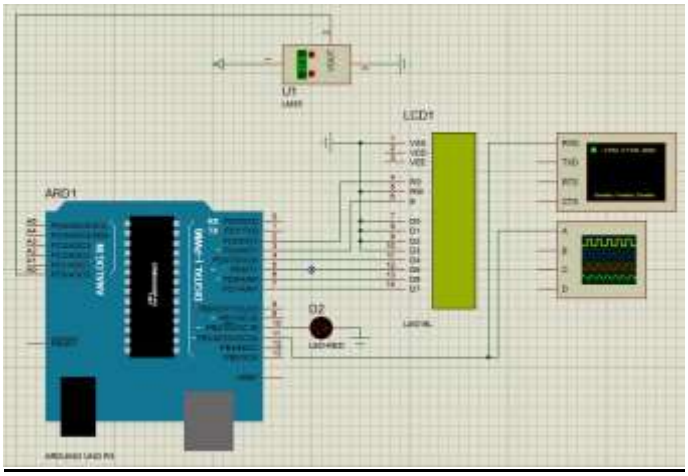

FIGURE 8. Simulation of LM35 Temperature Sensor

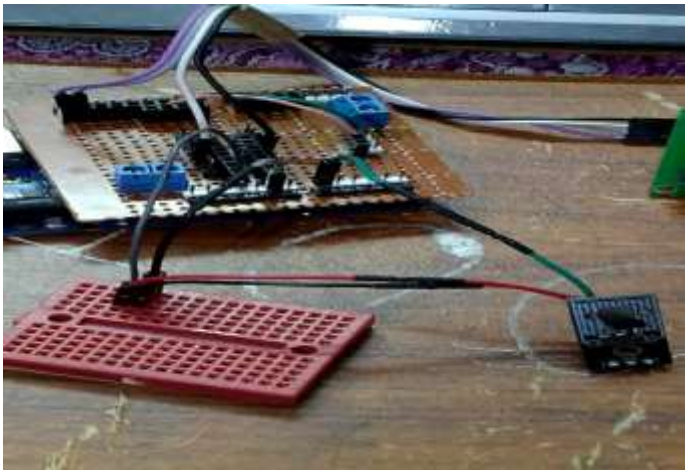

FIGURE 9. Hardware Implementation of LM35 Temperature Sensor

C. RESULTS

In order to validate the working of our prototype, we started sending character-type data. Firstly, we transmit the "HELLOW" word to check whether they received the data properly or not. We noticed that the data is received with >90% of accuracy. But there was a little delay in DATA being received.

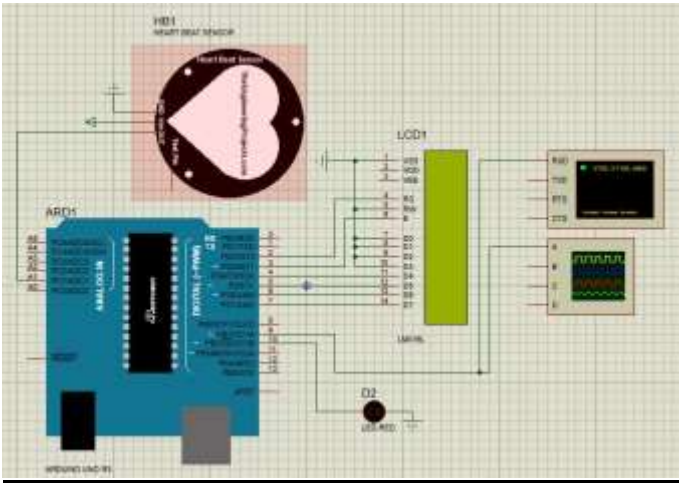

FIGURE 10. Simulation of Heart Rate Sensor

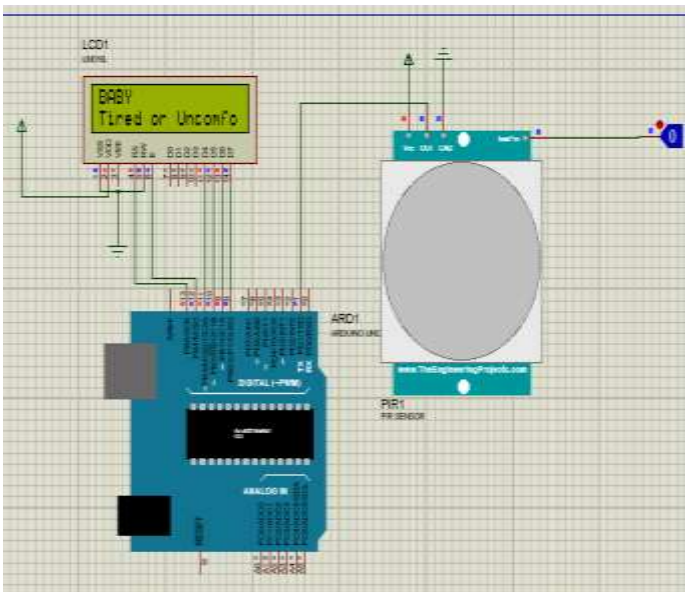

FIGURE 11. Simulation of Motion Sensor

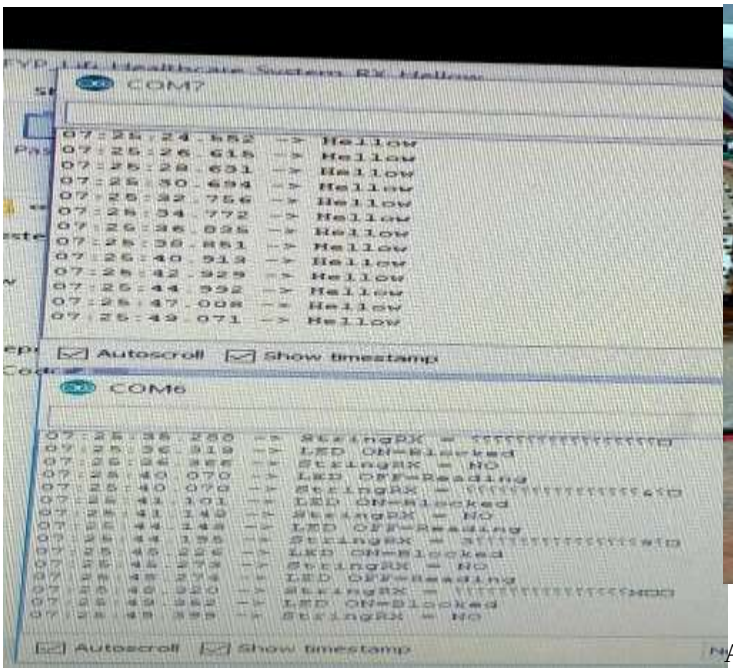

FIGURE 12. Testing Data “Hellow”.

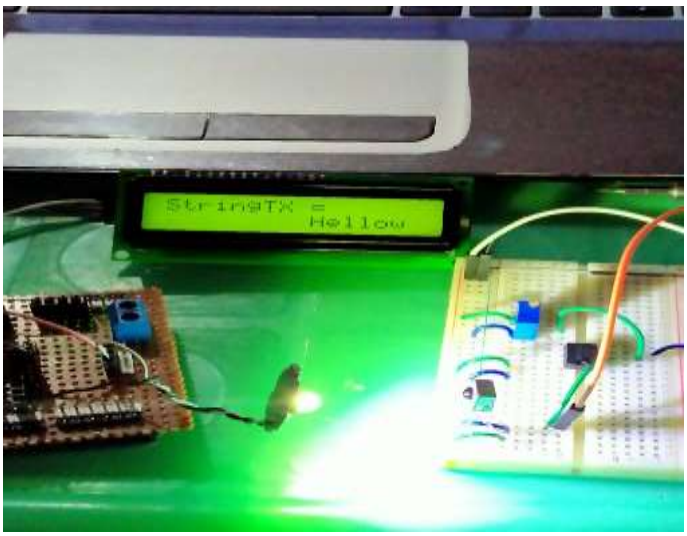

FIGURE 13. Testing Data “Hellow” on hardware.

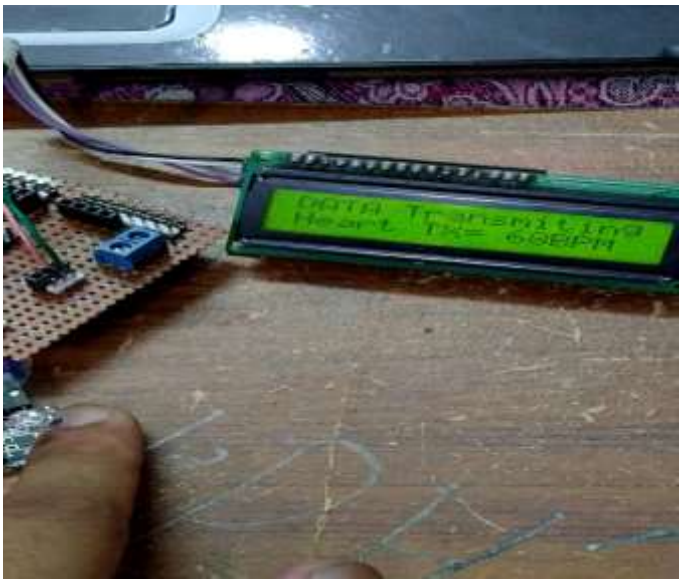

FIGURE 14. Heart Rate Data on Hardware

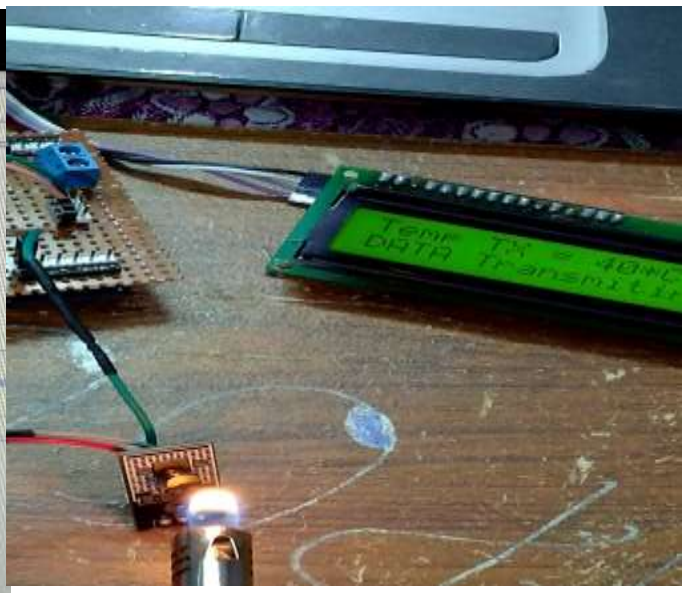

FIGURE 15. Temperature data on Hardware.

After testing data, the sensors data were sent to the experimental setup and the received results are shown in Fig 9.

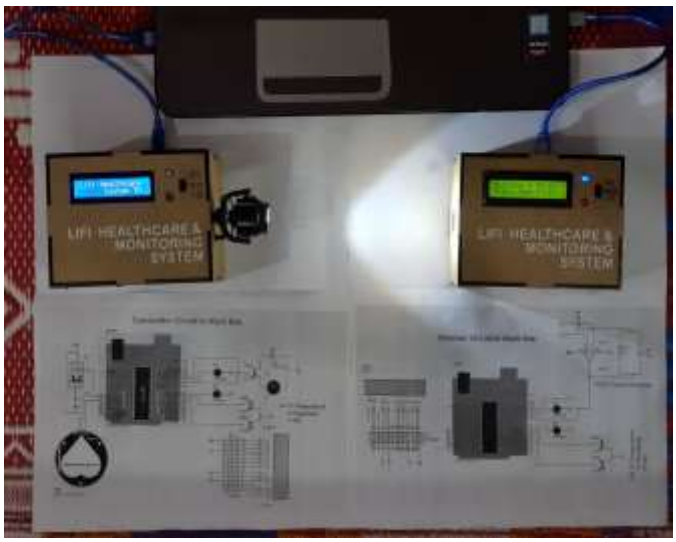

FIGURE 16. Hardware Implementation proposed work.

V. CONCLUSION

In this paper, the working of a Li-Fi-based healthcare monitoring system has been proposed. The simulated and hardware results of the working prototype have been presented. The real-time transmission of heart rate and the temperature has been sent successfully. Therefore, a Li-Fi-based health monitoring has been designed which validates the basic working of Li-Fi for data transmission and also proves its advantage over other techniques such as Wi-Fi etc., in terms of cost and speed. The temperature sensing can also be done via SMI [18, 19]. The limitation of work is the use of Li-Fi in an outdoor environment like under sunlight.

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The authors received no specific funding for this study.

CONFLICTS OF INTEREST

The authors declare they have no conflicts of interest to report regarding the present study.

REFERENCES

[1] H. Haas and C. Chen, "What is LiFi?," 2015 European Conference on Optical Communication (ECOC), Valencia, 2015, pp. 1-3, doi: 10.1109/ECOC.2015.7341879.

[2] 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.

[3] Haas, Harald. "Wireless data from every light bulb." *TED Global. Edinburgh, Scotland* 20 (2011).

[4] R. Mahendran, "Integrated LiFi (Light Fidelity) for smart communication through illumination," 2016 International Conference on Advanced Communication Control and Computing Technologies (ICACCCT), Ramanathapuram, 2016, pp. 53-56, doi: 10.1109/ICACCCT.2016.7831599.

[5] N. Soni, S. Chopra, M. Mohta and T. Choudhury, "A Brief Case Study on Li-Fi Technology," 2019 International Conference on contemporary Computing and Informatics (IC3I), Singapore, Singapore, 2019, pp. 273-278, doi: 10.1109/IC3I46837.2019.9055612.

[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] S. M. Mana, P. Hellwig, J. Hilt, P. W. Berenguer and V. Jungnickel, "Experiments in Non-Line-of-Sight Li-Fi Channels," 2019 Global LIFI Congress (GLC), Paris, France, 2019, pp. 1-6, doi: 10.1109/GLC.2019.8864131.

[8] 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.

[9] M. Monisha and G. Sudheendra, "Lifi- Light Fidelity Technology," 2017 International Conference on Current Trends in Computer, Electrical, Electronics and Communication (CTCEEC), Mysore, 2017, pp. 818-821, doi: 10.1109/CTCEEC.2017.8455097.

[10] [S. Kumar, Sunanda and S. Arora, "Light-Fidelity: Next Generation Wireless Networks- A Survey," 2019 International Conference on Smart Systems and Inventive Technology (ICSSIT), Tirunelveli, India, 2019, pp. 668-671, doi: 10.1109/ICSSIT46314.2019.8987757.

[11] Prakash, Ravi, and Prachi Agarwal. "The new era of transmission and communication technology: Li-Fi (light fidelity) led & ted based approach." *International Journal of Advanced Research in Computer Engineering & Technology (IJARCET)* vol. 3, no. 2, 2014.

[12] T. M. Darshith and C. Bhatt, "Prototyping of a Li-Fi communication system," 2017 International Conference on Wireless Communications, Signal Processing and Networking (WiSPNET), Chennai, 2017, pp. 1804-1807, doi: 10.1109/WiSPNET.2017.8300072.

[13] H. K. Yu and J. G. Kim, "Smart navigation with AI Engine for Li-Fi based Medical Indoor Environment," 2019 International Conference on Artificial Intelligence in Information and Communication (ICAIIC), Okinawa, Japan, 2019, pp. 195-199, doi: 10.1109/ICAIIC.2019.8669041.

[14] T. Cheng and M. Zhang, "Design and measurement of an indoor Li-Fi system based on 802.3 protocol," 2017 9th International Conference on Advanced Infocomm Technology (ICAIT), Chengdu, 2017, pp. 218-221, doi: 10.1109/ICAIT.2017.8388918.

[15] Ali, Salamat, Rabia Nawaz, Sharoon Azad, Muhammad Sadiq Orakzai, Saqib Amin, Zohaib A. Khan, Faraz Akram, and Usman Masud. "Solar Powered Smart Irrigation System." Pakistan Journal of Engineering and Technology vol. 5, no. 1. p. 49-55, 2022.

[16] D. DINEV, V. ALEKSIEVA and H. VALCHANOV, "Comparative Analysis of Prototypes Based on Li-Fi Technology," 2019 16th Conference on Electrical Machines, Drives and Power Systems (ELMA), Varna, Bulgaria, 2019, pp. 1-4, doi: 10.1109/ELMA.2019.8771664.

[17] K. R. Behera, A. K. Lenka, P. Karmakar and G. R. Mati, "Li-Fi transreceiver using low power low cost laser link," 2018 2nd International Conference on Inventive Systems and Control (ICISC), Coimbatore, 2018, pp. 635-639, doi: 10.1109/ICISC.2018.8398876.

[18] Muhammad Sadiq Orakzai, Saqib Amin, Zohaib Ahmad Khan, and Faraz Akram. "Fast and highly accurate phase unwrapping algorithm for displacement retrieval using self-mixing interferometry sensor." Optical Materials vol. 129, p. 112553, 2022.

[19] Muhammad Sadiq Orakzai, Saqib Amin, Zohaib Ahmad Khan, and Faraz Akram. "Fast and highly accurate estimation of feedback coupling factor and linewidth enhancement factor for displacement sensing under different feedback regimes." Optics Communications vol. 508, p. 127751, 2022.

[20] ZA Khan, T Hussain, U Zabit, M Usman, E Ayguade, "PH-RLS: A parallel hybrid recursive least square algorithm for self-mixing interferometric laser sensor", *IET optoelectronics* vol. 15, no. 5, p. 239-247, 2021.

[21] A. Javaid, M. Sadiq and F. Akram, "Skin Cancer Classification Using Image Processing and Machine Learning," 2021 International Bhurban Conference on Applied Sciences and Technologies (IBCAST), 2021, pp. 439-444, doi: 10.1109/IBCAST51254.2021.9393198.