

## Mobile Based Emergency Alert System for Intensive Care Unit (ICU) Staff

<sup>1</sup> Kaushalya Thopate, <sup>2</sup> Mukund Kulkarni, <sup>3</sup> Sagar G. Mohite, <sup>4</sup> Snehal Karad, <sup>5</sup> Vaishali Rajput, <sup>6</sup> Pramod B Dhamdhare

<sup>1,2,5</sup> Vishwakarma Institute of Technology, Pune-411037, Maharashtra, India, <sup>3</sup> Bharati Vidyapeeth Deemed University College of Engineering Pune, Maharashtra, India, <sup>4,6</sup> Marathwada Mitramandal's Institute of Technology, Lohgaon, Pune- 411047, Maharashtra, India.

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### Abstract

The advancement of technology has led to the development of innovative solutions to improve Patient care in Intensive Care Units (ICUs). New innovative ideas in technologies are becoming very helpful in making medical life easier. The system aims to provide a timely and effective way of notifying healthcare providers during critical patients. This paper presents the design and implementation of an IoT-based ICU alert system that aims to enhance the monitoring and management of critically ill patients in ICU. The system integrates various IoT devices such as sensors and smartphones to gather real-time oxygen level and heart rate of patients and transmit it to the care team in a timely manner. The system helps if there are any critical changes in the patient's condition then Live update will get on the mobile phone of the doctor. The results of the implementation show that the system effectively improves the overall patient care and reduces the response time in case of emergency situations. The study concludes that the mobile-based emergency alert system has the potential to enhance the quality of care and patient outcomes in ICU settings. The findings of this paper can be used as a reference for implementing similar IoT-based solutions in other healthcare settings.

**Introduction:** This paper presents the development of a reliable SpO<sub>2</sub> (oxygen saturation) measurement system using advanced sensors and microcontrollers. SpO<sub>2</sub> is a vital health indicator, reflecting the oxygen level in the blood, and accurate monitoring is crucial in medical settings. The system leverages the Beer-Lambert law to calculate SpO<sub>2</sub> based on light absorption by hemoglobin. Through careful selection and optimization of components, algorithm development, and rigorous simulation and experimentation, this research aims to deliver a precise, non-invasive solution for continuous oxygen saturation monitoring, contributing to advancements in healthcare technology.

**Objectives:** The objective of this paper is to design and implement an accurate and efficient SpO<sub>2</sub> measurement system using advanced sensors, microcontrollers, and a refined calculation algorithm. The research focuses on optimizing component selection, developing a robust algorithm based on the Beer-Lambert law, and validating the system's performance through simulations and real-world experiments. By ensuring precise and reliable oxygen saturation monitoring, this paper aims to contribute to the advancement of non-invasive medical devices, offering valuable insights for future research and development in healthcare technology.

**Methods:** The methodology for developing the SpO<sub>2</sub> measurement system involves several key steps to ensure accurate and reliable performance. First, the system design is centered around the selection of appropriate components, including advanced sensors for detecting red and infrared light absorption, and a microcontroller to process the signals. The SpO<sub>2</sub> calculation is based on the Beer-Lambert law, utilizing the ratio of AC to DC components from the red and IR signals to estimate oxygen saturation levels. The algorithm is developed and refined to ensure precision across different conditions. The

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system's functionality is first validated through detailed simulations, allowing for optimization and adjustments before physical implementation. Finally, real-world experiments are conducted to test the system's accuracy and reliability, followed by a comprehensive analysis of the results to ensure the system meets the necessary medical standards. This method ensures a robust, non-invasive solution for continuous SpO<sub>2</sub> monitoring.

**Results:** The results of the SpO<sub>2</sub> measurement system demonstrate its effectiveness in accurately monitoring oxygen saturation levels. Experimental data show that the system consistently provides precise SpO<sub>2</sub> readings across various conditions, with minimal deviation from expected values. The simulations and real-world tests validate the system's reliability and performance, confirming that the chosen components and developed algorithm work effectively together. The system's accuracy and responsiveness make it a valuable tool for non-invasive oxygen monitoring in medical applications.

**Conclusions:** The discussion highlights the strengths and potential improvements of the SpO<sub>2</sub> measurement system. The results validate the system's design and functionality, showing its capability to deliver reliable oxygen saturation measurements. However, certain limitations, such as sensitivity to external factors and calibration needs, are noted. Addressing these issues through further optimization and testing can enhance system performance. The paper suggests future research directions to refine the technology and explore its applications in broader healthcare settings, aiming to improve overall patient care and monitoring efficiency.

**Keywords:** Health Monitoring, ICU, Doctors, Emergency.

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## 1. Introduction

Health monitoring through technology is the key factor for the remote health diagnosis system [1, 2]. In this system sensor is used to monitor the numerous health parameters to realize the recovery rate, abnormalities in health condition using WiFi. In the normal patient health monitoring and diagnosis, patients always consult the doctor physically and have to give all the information through the physical examination. This paper presents continuous monitoring and displaying health care data of patients by using IoT based concepts. So There is no need for a nurse or any other person to be physically present in the ICU for 24 hours in a day.

This system sends the health condition of sufferers with appropriate time and date for end result evaluation. A health monitoring system using IoT can help individuals, healthcare providers, and caregivers to better monitor and manage their health, prevent health issues before they occur, and improve overall well-being. This research paper [3] introduces a system of health care monitoring by the use of IoT with the GSM technology mainly for the COMA patients. The numerous sensors working together give the data of various health parameters which is sent to the cloud services by which it can be accessed anywhere and at any time. This research paper [4] introduces an efficient system where the physiological parameters are monitored & displayed. Making easier communication between patient and doctor using the Bluetooth Technology. This research paper [5] gives information on using LPWN (low power wireless network) in Iot for Health monitoring systems also it has a lot more focus on the security in Health Monitoring systems. The Research paper [6] gives the study of design and implementation of Iot based health monitoring using the Arduino and bluetooth technology.

Also, this system has an LCD panel which allows the patient itself to keep track of their health. An overview of combining all MHM, RHM and WHM under the SHM(Smart Health Monitoring ) system for better and efficient health monitoring[7]. In today's dynamic world wearable devices which monitor your health are an integral part of day-to-day life and the wearable device in the Healthcare system is progressing rapidly [8]. The paper[9] discusses the whole idea and demonstrates the idea of cloud storage which is a buzz trending word for the remote healthcare monitoring system. This research paper provides insightful information regarding how the heart patients can be treated and monitored for heart failures using an end to end healthcare monitoring system and analytic system for heart failure patients[10].

## 2. Objectives

The primary objective of this paper is to develop a reliable and accurate system for measuring SpO<sub>2</sub> (oxygen saturation level) in blood using an innovative approach that leverages advanced sensors, microcontrollers, and algorithmic methods. SpO<sub>2</sub> is a critical indicator of respiratory and circulatory health, and its accurate measurement is essential in various medical settings, from routine monitoring to emergency care. This paper seeks to address several key objectives to contribute to the advancement of non-invasive oxygen saturation monitoring.

**Design and Implementation of SpO<sub>2</sub> Measurement System:** The first objective is to design and implement a functional SpO<sub>2</sub> measurement system that can accurately capture and process the necessary data. This involves selecting appropriate components such as sensors, microcontrollers, and communication modules, which will work in tandem to achieve precise readings. The system must be robust, reliable, and capable of functioning under various conditions, ensuring that the measurements are consistent and dependable.

**Component Specification and Optimization:** A critical objective of this paper is to provide detailed specifications for each component used in the SpO<sub>2</sub> measurement system. This includes the selection of sensors that can effectively detect and differentiate between the red and infrared light absorbed by hemoglobin, as well as microcontrollers that can handle the complex calculations required for accurate readings. Additionally, the optimization of these components is crucial to minimize power consumption, reduce costs, and improve the overall efficiency of the system.

**Development of Accurate SpO<sub>2</sub> Calculation Algorithm:** The paper aims to develop and refine an algorithm for calculating SpO<sub>2</sub> that is both accurate and efficient. Based on the Beer-Lambert law, the algorithm will use the ratio of the AC and DC components of the red and infrared signals to estimate oxygen saturation levels. Ensuring the algorithm's accuracy across different physiological conditions and patient profiles is a key focus, with the goal of minimizing errors and providing reliable data for medical professionals.

**Simulation and Validation of System Performance:** Before physical implementation, the system's performance will be simulated under various conditions to predict its behavior and identify potential issues. The objective here is to validate the design through detailed simulations that mimic real-world scenarios, allowing for adjustments and improvements to be made in the early stages of development. This will be followed by experimental validation, where the system's performance will be tested in real-world settings to verify its accuracy and reliability.

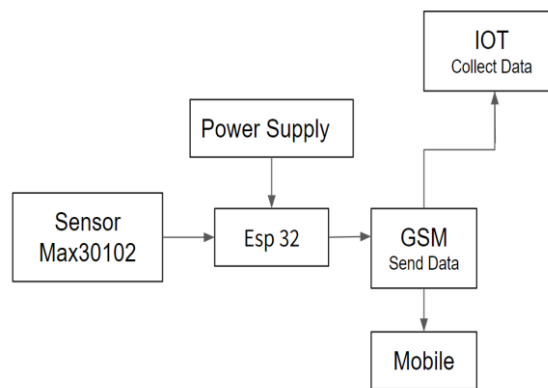
**Analysis of Experimental Results and System Calibration:** A comprehensive analysis of the experimental results is another key objective of this paper. The data collected during testing will be thoroughly analyzed to assess the system's accuracy, consistency, and overall performance. Based on this analysis, the system will be calibrated to enhance its accuracy,

ensuring that it meets the necessary standards for medical devices. The paper will also explore the potential limitations of the system and propose solutions to overcome them. Contribution to the Field of Non-Invasive Monitoring: Finally, this paper aims to contribute to the broader field of non-invasive medical monitoring by providing a detailed exploration of the design, implementation, and validation of an SpO<sub>2</sub> measurement system. By sharing the findings and methodologies, the paper seeks to advance the understanding of oxygen saturation measurement and inspire further research and development in this critical area of healthcare technology.

### 3. Methods

**ESP32 microcontroller:** This is the main processing unit. It is responsible for running the operating system, handling user input, and communicating with the other components.

**Sensors:** Max 30102 sensors are used to collect data about the environment and provide input to the ESP32 microcontroller.



**Figure 1:** Block Diagram

Figure 1 illustrates the block diagram of the proposed methodology. The power supply serves to provide energy to the ESP32 microcontroller and other associated components. The GSM module enables the controller to connect to a cellular network, facilitating the ability to make and receive alerts. The mobile phone, as the physical device that the user interacts with, includes essential features such as the display, keyboard, buttons, and speakers.

**SpO<sub>2</sub> Calculation:** SpO<sub>2</sub> represents the oxygen saturation level in the blood. It is calculated by comparing the absorption of red and IR light by hemoglobin. The formula for SpO<sub>2</sub> calculation is typically based on the ratio of AC and DC components of the red and IR signals. One commonly used formula is the Beer-Lambert law:

$$SpO_2 = -46.7 \times \frac{R}{IR} + 110$$

The calculation of SpO<sub>2</sub>, which represents the oxygen saturation level in the blood, is based on the principle of light absorption by hemoglobin. Specifically, it involves measuring the absorption of red and infrared (IR) light. Hemoglobin absorbs different amounts of light at these two wavelengths depending on its oxygenation level. The SpO<sub>2</sub> calculation is typically derived from the ratio of the alternating current (AC) and direct current (DC) components of the red and IR signals. In this formula,  $R$  represents the ratio of the AC to DC components for the red light signal, while  $IR$  represents

the same ratio for the IR light signal. This calculation provides an estimate of the blood's oxygen saturation level, which is a critical indicator of respiratory and circulatory health.

**Heart Rate Calculation:** Calculate the heart rate by measuring the time between successive peaks in the AC component of the signal. You can use the following formula:

$$\text{Heart Rate}(bpm) = \frac{60}{\text{Time Between Successive Peaks}(seconds)}$$

To ensure accurate SpO2 measurement and reliable performance of the system, selecting the right components is crucial. The following section provides detailed specifications for each component used in the design, including the microcontroller, sensors, and other essential modules. These specifications are carefully chosen to meet the requirements of the SpO2 calculation process, ensuring both precision and efficiency in real-world applications.

**Table 1:** Component Specification

Components	Description
Esp8266	ESP8266 is a powerful microcontroller and Wi-Fi + Bluetooth combo chip designed by Espressif Systems. It is a perfect choice for IoT(Internet of Things) projects, as it has a range of features and capabilities that make it versatile and easy to work with.
MAX30100	The MAX30100 is an integrated pulse and a heart rate sensor module. It has input Voltage 3.3V. The MAX30100 sensor provides a complete system solution to ease design-in process for mobile and wearable devices.
Jumper Wires	Jumper wires are flexible and there is no need for soldering. Easy to connect with each other
Bread Board	It's a construction base.

Understanding the functionality of each component is essential to grasp how the overall system operates. In this section, we will delve into the working principles of the key components used in the SpO2 measurement system. This includes an explanation of how each component interacts with the others, contributing to the accurate calculation of oxygen saturation levels. By exploring the roles and mechanisms of these components, we can gain a comprehensive understanding of the system's operation and its effectiveness in practical applications.

*Key Components:-*

- 1.ESP8266
2. MAX30102

1. i) Pulse Oximeter :

To discover the blood oxygen concentration (%), it is to begin with imperative to know that interior our blood hemoglobin is mindful for carrying oxygen. When understanding holds the sensor ruddy

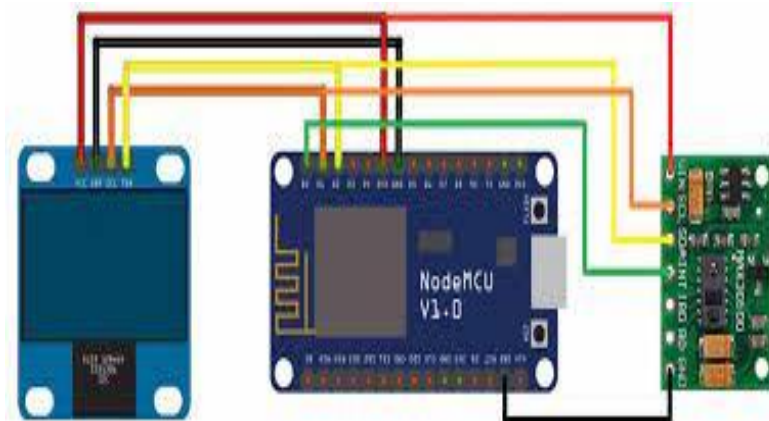
light will radiate from the gadget and passes through the blood of quiet .This framework utilized to calculate oxygen level of persistent by calculating the changes in assimilation of light in both oxygenated and deoxygenated blood.MAX30102 sensor has Ruddy LED,IR Driven and photodiode. these LEDs are offer assistance to degree SpO2.These two LEDs radiate light at distinctive wavelengths, ~660nm for the ruddy Driven and ~880nm for the IR Driven .At these level of wavelengths, retention properties of the oxygenated and deoxygenated hemoglobin are exceptionally distinctive. The oxygenated hemoglobin will retains more IR light and reflects back the ruddy light on the other hand the deoxygenated hemoglobin retains small bit higher level ruddy light and will reflects back the IR light.MAX30102 sensor peruses these sort of retention to discover oxygen level. The proportion of IR and Ruddy light gotten by the photodetector gives us the blood oxygen concentration.

#### ii) Heart Rate Measurement :

For calculation of heart rate as it were IR Driven is required there's no require of red LED. This is often since oxygenated hemoglobin retains more infrared light. The proportion of time between two continuous pulse is known as pulse rate. When a finger is put before this beat sensor at that point the reflection of infrared light is changed based on the volume of blood alter interior capillary vessels. This implies amid each pulse, the volume of blood in vessels will go up to tall level and after that will come to moo level after each heartbeat.So, by changing this volume, the Driven light is changed. This changes take put in Driven light measuring the pulse rate of a finger.

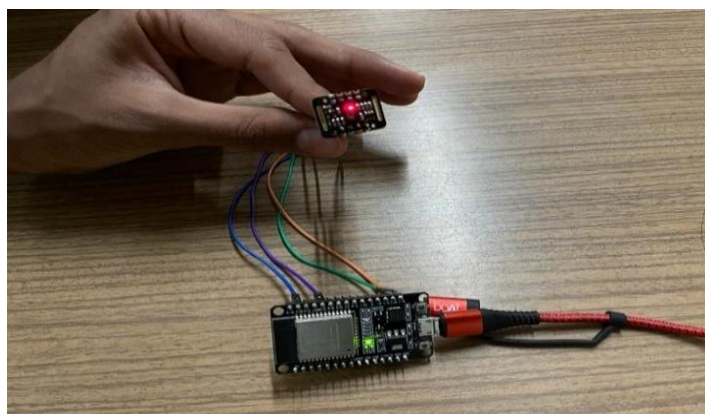
The data will be shown in the mobile with the help of WiFi module that is inbuilt in the ESP After measuring the vitals of the patient using a sensor, it will be sent to the ESP 32, which will convert the analog data into digital. After that, the data via WiFi will appear on the mobile. The ESP 8266 is connected to a device with the help of a USB, which will help to power the system. The proposed method is designed by using an IoT based website that is known as ThingSpeak. In case if there is any change in heart rate or oxygen level of the patient then the doctor will get notification on their mobile phone.

To validate the design and performance of the SpO2 measurement system, simulations and experiments are conducted. This section outlines the methodologies used for simulating the system's behavior and the experimental setup for real-world testing. Through simulations, we can predict how the system will respond under various conditions, allowing for fine-tuning before physical implementation. The experimental results provide empirical data that verify the accuracy and reliability of the SpO2 calculations, ensuring the system performs as intended in practical scenarios.



**Figure 2:** Circuit Diagram of HealthCare Monitoring System

Figure 2 shows a circuit diagram with a NodeMCU V1.0 board connected to a sensor and a display. Wires connect the components together, allowing data to flow between them, providing detailed representation of system.



**Figure 3:** Diagram of HealthCare Monitoring System

The circuit diagram shown in Figure 3 explains a MAX30102 sensor connected to an ESP8266 microcontroller via four wires. The ESP8266 is then connected to a cloud server, likely ThingSpeak, for data transmission and visualization. This setup allows for real-time monitoring and analysis of sensor data.

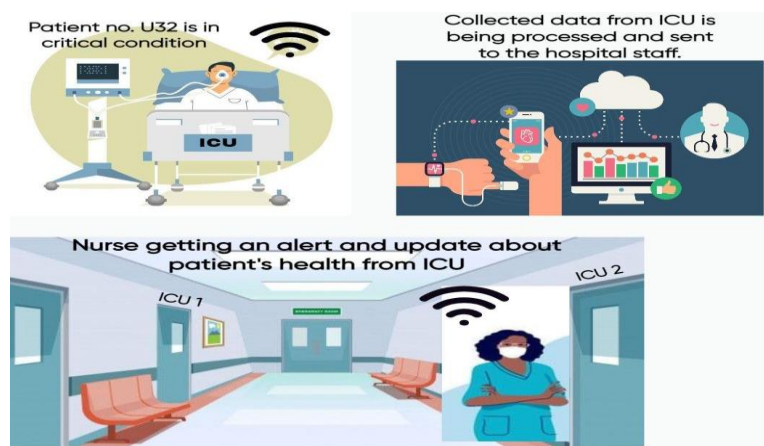
IR=1025, BPM=28.56, Avg BPM=20 No finger?	IR=113947, BPM=78.95, Avg BPM=93
IR=1025, BPM=28.56, Avg BPM=20 No finger?	IR=113971, BPM=78.95, Avg BPM=93
IR=1030, BPM=28.56, Avg BPM=20 No finger?	IR=114021, BPM=78.95, Avg BPM=93
IR=1025, BPM=28.56, Avg BPM=20 No finger?	IR=114077, BPM=78.95, Avg BPM=93
IR=1033, BPM=28.56, Avg BPM=20 No finger?	IR=114146, BPM=78.95, Avg BPM=93
IR=1020, BPM=28.56, Avg BPM=20 No finger?	IR=114210, BPM=78.95, Avg BPM=93
IR=1024, BPM=28.56, Avg BPM=20 No finger?	IR=114260, BPM=78.95, Avg BPM=93
IR=1034, BPM=28.56, Avg BPM=20 No finger?	IR=114254, BPM=78.95, Avg BPM=93
IR=1035, BPM=28.56, Avg BPM=20 No finger?	IR=114217, BPM=78.95, Avg BPM=93
IR=1041, BPM=28.56, Avg BPM=20 No finger?	IR=114163, BPM=78.95, Avg BPM=93
IR=1044, BPM=28.56, Avg BPM=20 No finger?	IR=114111, BPM=78.95, Avg BPM=93
IR=1045, BPM=28.56, Avg BPM=20 No finger?	IR=114057, BPM=78.95, Avg BPM=93
IR=1037, BPM=28.56, Avg BPM=20 No finger?	IR=114028, BPM=78.95, Avg BPM=93
IR=1040, BPM=28.56, Avg BPM=20 No finger?	IR=114016, BPM=78.95, Avg BPM=93
IR=1045, BPM=28.56, Avg BPM=20 No finger?	

**Figure 4:** Input and output

Figure 4 represents the output of our project it detects if the finger is there or not and gives us the Average BPM. The mobile interface implemented here is based on 'Thingspeak' IoT website. After completion of the IoT platform setup, it is then deployed onto the mobile device, whereby all the data is linked with the application. Upon successful connection of mobile to Wi-Fi, a confirmation message for the same is popped up. Subsequently, as the system initializes, the measured data is transmitted to the serial monitor of the Arduino IDE.

#### 4. Results

The creation of patient accounts, editing of existing accounts, data collection using different measuring equipment, connection over WiFi, and other wireless methods are all carried out. Similar processes apply to the creation of doctor accounts as well as to editing, data trans-receiving, data analysis, and patient's condition analysis. The MAX102 collects and transmits data from sensors such as oxygen levels, temperature, and pulse rate for study by doctors. As compared to the conventional approaches, some mistakes were found in the results, but the values are still accurate. This results in improved medication adherence and improved patient's quality of life.



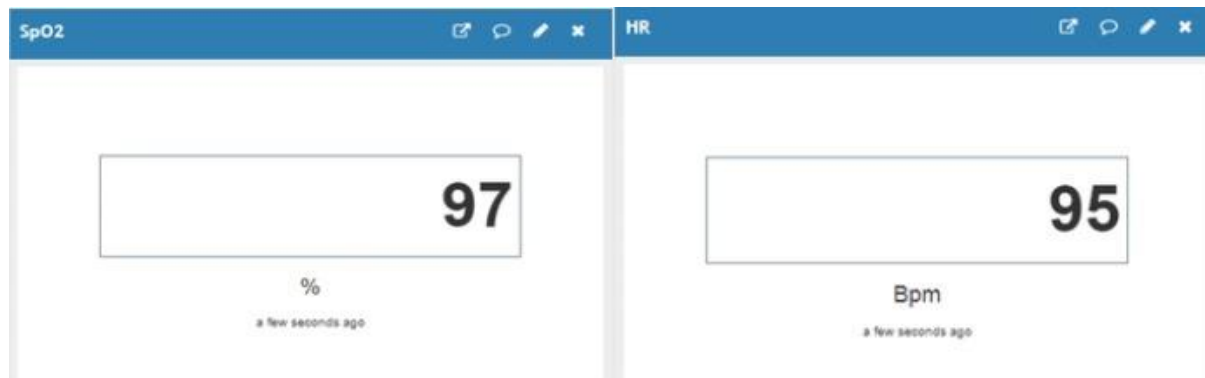
**Figure 5:** Animated representation of system

Figure 5 Represents the pictorial representation of our mobile based health care system for icu patients. This figure shows us the detail about how the whole system works.



**Figure 6:** Oxygen Saturation graph in ThingSpeak

This graph shows the oxygen saturation of a person over time. The oxygen saturation is measured as a percentage of the blood that is saturated with oxygen. The graph shows that the person's oxygen saturation is generally within a normal range, but there is a brief dip to 90% at around 18:25.



**Figure 7:** BPM and SpO2 value in ThingSpeak

This fig shows the graphical and numerical representation of the data collected by sensors on ThingsSpeak. Shows that the normal representation of heart rate in Bpm and Oxygen saturation level in percentage.

## 5. Discussion

Framework would offer assistance in distinguishing and early treatment of person patients in ICU. Here, we considered fundamental viewpoints related to wellbeing centering on later patterns. The proposed strategy work analyzes the variable wellbeing parameters values which are taken from sensors. At whatever point the parameters such as oxygen level or heart rate go underneath or over from the typical run at that point the specialist will be able to see on their portable phone. This framework is accommodating for patients who require healthcare administrations at 24/7. In future, chatting can be consolidated into the application to form effective communication with specialists to require relative measures for appropriate wellbeing care. Considering coexistence of impedances from high-power remote systems working within the same recurrence band, hazard calculate examination and client assessment, based on essential and auxiliary end-users, can expand the consider, which is our future focus. As we know, the IoT is exceptionally valuable and most alluring within the wellbeing checking framework and the foremost vital point is that a specialist or nurture can screen the wellbeing of any understanding from their cabin or at any separate.

## References

- [1] Thopate, K., Gawade, M., Savale, V., Cholke, A., & Musale, P.. (2023). Smart Cradle: A Technology-Enabled Solution for Safer and Better Infant Sleep. *International Journal on Recent and Innovation Trends in Computing and Communication*, 11(7), 223–228.
- [2] Thopate, K., Shinde, S., Mahajan, R., Bhagat, R., Joshi, P., Kalbhor, A., Kulkarni, A., & Jadhav, S. (2023). Keyless Security: The Smart Solution for Home with a Smart Door Lock. *International Journal on Recent and Innovation Trends in Computing and Communication*, 11(8s), 170–174.
- [3] S. Sampeter, S. Padmavathi “An improved health monitoring system for coma patients using internet of things”, (IJETIE) vol.5, pp.408-412, 2019

- [4] K. Thopate, S. More, K. Thakare, R. Waware, J. Gangurde and A. Ghuge, "Smart Street Light Monitoring System for Enhanced Energy Efficiency," 2023 4th International Conference on Electronics and Sustainable Communication Systems (ICESC), Coimbatore, India, 2023, pp. 1798-1805.
- [5] S. Seifi, A. Khatony, G. Moradi, A. Abdi and F. Najafi, "Accuracy of pulse oximetry in detection of oxygen saturation in patients admitted to the intensive care unit of heart surgery: comparison of finger, toe, forehead and earlobe probes", BMC nursing, vol. 17, issue 1, pp.15, 2018.
- [6] Joel J.P.C Rodrigues, Dante Borges De Rezende Segundo, Heres Arantes Junueira, Murilo Henrique Sabino, Rafael Maciel Prince, Jalal A1-Muhtadi, Victor Hugo C.De Albuquerque,, "Enabling Technologies for the Internet of Health Things" Access IEEE, Vol. 6, pp. 29-13141, 2018.
- [7] A. Page, O. Kocabas, T. Soyata, M. Aktas, and J.-P.Couderc, "Cloud Based Privacy-Preserving Remote ECG Monitoring and Surveillance," Annals of Noninvasive Electrocardiology
- [8] R. Paradiso, G. Loriga, and N. Taccini, "A wearable health care system based on knitted integrated sensors," Pantelopoulos and N. Bourbakis, "A survey on wearable sensor- based systems for health monitoring and prognosis," IEEE Trans. Sys., Man, and Cybernetics vol. 40,no. 1, pp. 1–12, Jan 2010.
- [9] S. Babu, M. Chandini, P. Lavanya, K. Ganapathy, and V. Vaidehi, "Cloud-enabled remote health monitoring system," in Int. Conf. on Recent Trends in Inform. Tech. (ICRTIT), July 2013, pp. 702-707.
- [10] M. Lan, L. Samy, N. Alshurafa, M.-K. Suh, H. Ghasemzadeh, A. Macabasco-O'Connell, and M. Sarrafzadeh, "Wanda: An end-to- end remote health monitoring and analytics system for heart failure patients," in Proc. of the Conf. on Wireless Health, ser. WH '12. New York, NY, USA: ACM, 2012, pp. 9:1–9:8.