Patient Health Monitoring based on Cloud Computing using the Message Queuing Telemetry Transport Protocol

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ABSTRACT:
Recent developments in the field of internet innovation have made it feasible for new methods to be developed for the delivery of medical care. Sharing of resources may be encouraged via the use of network infrastructure and shared points of access. Patient data and clinical information make the Internet an ideal tool for the many applications that include remote patient monitoring. In this paper, we provide an experimental model that was developed for monitoring and checking on the patient's current state of health using sensors. The framework is dependent on an e-health sensor that is connected to a cloud platform. The cloud platform is responsible for collecting the data that is gathered from the sensors through the Arduino microcontroller. The data collected by the sensors includes readings from body temperature, heart rate, and oxygen. The data then is easily available for further processing, including the analysis of certain correlations between the measured parameters and the health status of the patients.

KEYWORDS: Healthcare, Internet of things, ESP32, ICU, Monitoring, ECG, Respiratory monitoring, SpO2, Message Queuing Telemetry Transport protocol, Arduino.

1. INTRODUCTION

In light of the rising need for medical services among the world's aging population, health monitoring systems have come into their own. Many patients are discharged from the hospital after being treated in the intensive care unit (ICU), but they are still strongly advised to rest and be observed, making the framework very effective in these circumstances [1]. In crowded emergency rooms and at catastrophe scenes, observing the vital signs and regions of certain groups of patients may be valuable both on the ground and during transfer. In order to be useful, this kind of inspection has to be quick, cheap, and unobtrusive, so it doesn't annoy emergency workers by, say, sending out too many false alarms [1,2]. The purpose of a monitoring system for vital signs is to collect and transmit data about a patient via a network using a variety of sensors, web services, and global systems for mobile communications (GSM) technologies. The system allows authorized users, such as specialists or physicians, access to the tracked medical data of their patients [1,2]. Focusing on people with chronic illnesses and, by extension, on patients who should constantly be under close observation, it is clear that knowing how the condition has progressed over time would be beneficial not just to the individual patient but also to others experiencing the same or comparable symptoms. The possibility of providing remote health monitoring to individuals at high risk for falls and chronic illnesses has been shown thanks to recent breakthroughs in computer technology such as body sensors and distant connections.

The body sensors circulated in, on, or around the human body are capable of measuring the vital signs in a circumstance where large size and standard medical checking equipment are not accessible; the pervasive utilization of cellular telephones and the Wi-Fi connection empower medicinal informatics to defeat the time and area boundaries [3]. Presently, diabetes is a noteworthy problem since many people are impacted by the illness and it's treatable when it is examined before attaining the risk zone; otherwise, it turns into a huge issue. There's a need to learn how much sugar is in the blood, also known as blood glucose level. Chronic diseases may be managed with regular monitoring and diet as usual [3]. Furthermore, some individuals suffer from breathing difficulties and sleep apnea. Sleep apnea is a sleep issue characterized by the recurrent reduction of airflow during sleep, which therefore produces pauses

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and reduced breathing. Repeating arousals from sleep because of a stop age of the airway creates fragmented sleeping patterns and proceeds to the commencement of the body's sympathetic nervous system [2].

The fundamental purpose of this theory is to give a new cloud-based platform for watching a patient who suffers from this ailment, for example, sleep apnea, diabetes, and others. Those folks require uninterrupted pharmaceutical care which can't be offered outside hospitals.

Facilities that are accessible in this cloud are responsible for collecting, storing, processing, and distributing medical data once sensors attached to patients' bodies collect and send it. We believe this solution provides a feasible scenario for providing a full-fledged telemedicine service, one that uses automation to streamline everything from the initial collection of patient data to the provision of optimal therapeutic decisions in light of the patient's current health status and past medical history. The use of the I2C protocol in this system provides a wireless sensor network well-suited for data transmission and, what's more, enables further data processing, visualization, alerting, and notification. I2C is a great option for wireless connectivity since the sensor nodes are so compact and there is little power consumption. Using the Arduino Uno as a basis, a new e-health sensor platform is developed to streamline the collection and analysis of medical data.

At the point of care, the proposed technological architecture would first gather data from MAX30100 and MLX90614 sensors to get started. Second, the information that is gleaned from sensors is often presented in the form of an analog signal that is then processed by the microcontroller. After that, the data is uploaded to the cloud, where clinical decision support algorithms may be used to analyze it in search of any clinically concerning abnormalities that may have been missed. On the other hand, activating sensors for feedback or warnings via the usage of an I2C protocol is possible. For instance, a sensor that weighs people may determine the weight of an old person while they are sleeping in their bed. A microcontroller will do the processing, and then the data will be uploaded to the cloud. Because the person's weight data has not been received, and because it is becoming late in the night, the sensor in the room of the individual who is the individual's next of kin has been triggered, causing an LED light and an alert to go off, asking them to check on the elderly patient [3].

This project proposes a system with a reasonable budget that is intended to assist medical professionals and guardians in monitoring the well-being and health state of their patients even when they are physically separated from those patients. This is very significant during COVID-19 when it will be necessary to maintain a safe distance from other individuals. The majority of the monitoring systems at the hospital are hooked to the large pieces of equipment that are used for monitoring. In addition, there are monitoring gadgets that may be utilized in the comfort of one's own home. They are also limited in their ability to get closer to the patient since the devices can only be applied to the patient when they are seated in their bed because the cords connecting them to the monitor prevent them from being used anywhere else. Because the patient is unable to move about freely, their normal routine is disrupted, and the medical staff at the hospital will have a difficult time staying current on the patient's status as a result. This theory describes a portable patient monitoring system that is based on the I2C protocol and may be beneficial for patients who are located in distant areas. It does not need the patient to be confined by wires or to be in bed for the whole day. In addition, the gadget is able to assess and show the patient's current health state, which is very important and required for improved medical treatment. The job that sensors conduct consists of transmitting data to a database through Wi-Fi, receiving it there, evaluating it, and then providing the results of that analysis to specialists working in the cloud [4].

However, the wireless network is the kind of technology that may be utilized to inform people in a short amount of time. Through the use of the internet, the nurse or the doctor may check the state of the infusions that are being used. This device may sound an alarm if it determines that the patient is receiving more or fewer drops than is necessary for their condition. Data that has been delivered from a sensor and concurrently saved in a storage location that can be accessed through the Internet may be monitored via the use of a protocol known as Message Queuing Telemetry Transport protocol (MQTT), which enables medical professionals such as nurses and physicians to do so [5].

Because of demographic changes and a sharp increase in life expectancy, the aging of the population is a well-established fact in most developed countries and is being felt also in developing countries. Indeed, a 2013 UN study indicated that the number of elderly people was 841 million and that the number will almost triple by 2050 [1]. The aging of the population causes several problems, particularly in the medical domain. Indeed, the elderly are often affected by chronic diseases, such as diabetes, cardiovascular issues, or high blood pressure, which require careful medical supervision. So, as the number of elderly increases, the ability of hospitals to provide the necessary care for this population could be quickly surpassed. Therefore, innovative solutions for the care of the elderly should be advocated to improve and simplify the daily life of health professionals in the face of expected increasing workload, and at the same time, to facilitate self-reliance and well-being of the elderly, and to avoid their dependence, which costs heavily for countries budget

[6].

The growth of cloud computing improves patient health, staff retention, and organizational quality in medicine. We discuss cloud computing, immersive care homes, big data, and wearable sensors. Without a well-established system design, data limitations, and privacy are difficult [7].

This article is interested in the field of medical supervision of remote patients which can be persons with reduced mobility or located in isolated areas, or others whose state of health requires permanent monitoring. Indeed, we are proposing a system to monitor the health parameters of delocalized patients in real-time. This system uses the most recent IT technologies: Medical sensor devices, the MQTT communication protocol, and Cloud Computing.

Modern healthcare requires both hospital and home patient monitoring. Patients in critical condition must be monitored around the clock with little human interaction to get rapid medical care. Private hospitals offer specialized treatment. Private hospitals are usually vacant since they serve rich patients. In public hospitals, where there are more patients, the staff-to-patient ratio is sometimes imbalanced. The monitoring device can't rouse a sleeping or unconscious patient if they need aid. If the medical team can't examine the patient swiftly, life-saving treatments may be delayed, increasing the risk of death. In this work, we propose a smart integrated patient monitoring system that employs face recognition algorithms, heart rate monitors, and temperature gauges to automatically detect emotional and heart rate changes. [8]. However, in modern society elderly and chronic illness patients who must take their medications on time suffer from dementia, which causes them to forget everyday tasks. This has been studied. Theory analyzing home health care technology is utilized to improve this condition by reminding patients of prescription schedules, remote monitoring, and prescribing new drug data online [16]. Most of the patent cases require continuous tracking for long periods. This eventually reduces the cost of caring and gives a more friendly environment to the patient. The matter of saving people's lives is extraordinarily crucial when related to offering the required service on time. In this concern, this paper proposed an Arduino-based platform to monitor the patient body temperature, heart rate, and oxygen saturation level within the blood (SPO2). The patient requires direct handling as the sensors are attached to the body. The obtained results are wirelessly transmitted to the cloud platform where the observer or the doctor can evaluate the patient's situation and make a specific decision.

2. RELATED WORK

Ref. [10] presented a patient health monitoring system employed network devices that can report on a patient's health online and transfer that information to care via IoT. These advancements are transforming healthcare delivery and invasive surgery. M-Health (Mobile Health) applications and E-Health (ICT-supported social insurance) are helping many people improve their health. This "Patient Monitoring System" monitors core body temperature, pulse rate, and pulse oximetry. The System analyzes sleep and detects falls. The gadget will send sensor data to the cloud, where it will be stored and studied in phases. It can monitor vital signs, transfer them to the cloud, and alert a clinician to a health problem. The authors of [11] also presented a Healthcare Monitoring system that analyzes Context awareness, Quality, Security, and Smart- ness (CAQSS) for numerous health parameters. Context inference in ubiquitous computing causes healthcare research problems. The value is a high-level representation of the entity's activities, relationships, and capabilities. Safe MQTT encrypts communications with and authenticates future healthcare devices using DTLS. This article describes current breakthroughs in IoT-based healthcare designs, networks, and applications. HRV measures the period between heartbeats in [12].

Analyzing heart rate variability is a sensitive indication of chronic degenerative disorders including cardiovascular disease, diabetes, autonomic dysrhythmias like hypertension, and more. HRV's sensitivity to a broad variety of medical illnesses may explain its increasing usage in diagnoses, prognosis, and therapeutic effectiveness. Stroke and cardiac death are key issues for borderline hypertensives, with or without a cardiac episode. High-risk HRV monitoring ensures patients obtain prompt medical care. The authors of this study recommend a cheap and simple IoT-based Remote HRV Monitoring System for hypertension-prone individuals. In the suggested system, a Zigbee-based pulse sensor calculates HRV. Arduino patient data is sent through MQTT. Application server graphs HRV data. SMS may notify the caregiver and doctor of a medical emergency to guarantee fast intervention. The proposed solution uses a remote doctor to fill the gap caused by the absence of HRV analysis tools that alert hypertensive patients of high risk. Zigbee and Wi-Fi networks are proposed. It achieves all the desired features of a life-saving remote health monitoring system: low cost, wide range, security, promptness, and simplicity of use. Human health is a huge global issue. Heart and lung diseases are more common. Practitioners and Doctors must be vigilant while monitoring elderly patients at home or in hospitals. IT has greatly simplified people's life. IoT is transforming healthcare and IT in healthcare. Connected physical things, such as sensors and health monitoring equipment, transform real-world data into digital form over the internet. Using Internet of Things (IoT) capabilities, the recommended system would keep all pertinent patient information and reports consolidated and readily accessible. Low-power sensors and other Internet of Things devices will capture patient data, which will be displayed on an LCD screen and uploaded to the cloud [13].

Mobile health, a subset of e-health, incorporates patient monitoring through wearable equipment. These monitor patients' heart rates and blood oxygen levels away from a hospital or clinic. This article aims to design an inexpensive, tiny wearable gadget for patient comfort. This instrument should exceed expectations. This study also considers cloud-based, real-time, wireless sensor network remote monitoring, where cloud computing and the Internet of Things are coupled to manage huge data flows. In [14], the ESP01, MAX30100, NTC, OLED, and Li-ion batteries were used to make the Wearable Remote Vital Signs Monitoring System (WRVSMS). The WRVSMS connected through HTTP to the cloud server to upload and download data. When a patient's vitals fall beyond a specified range, the WRVSMS sends an alarm to the most important stakeholders in restoring the patient's health. The statistical study proved the device's 99.37% accuracy.

Traditional Internet of Things (IoT) healthcare applications are too sophisticated, technically challenging, and expensive to be practical in low-income nations like Bangladesh. This theory proposes an IoT-based health monitoring system that can be used in both large hospitals in urban areas and resource-limited hospitals in rural areas for continuous screening of patients 24 hours a day, seven days a week. This system is called R3HMS (Remote Reliable, and Real-time Health Monitoring System). The device collects data from the patient's physiological signals (ECG, respiratory airflow, and SpO2) and transmits it to a server. Because of its low power consumption, the ESP8266 Wi-Fi chip was selected for wireless connection, while an 8-bit MCU ATmega328p was used for data collection and processing. Amazon Web Services (AWS) enables safe data exchange between connected devices via the use of the MQTT messaging standard. Specialists, physicians, and other medical professionals may access and analyze this data in real-time to track the patient's condition [15].

However, The patient health monitoring system presented in [10] employed network devices that can report on a patient's health online and transfer that information to care via IoT. These advancements are transforming healthcare delivery and invasive surgery. M-Health (Mobile Health) applications and E-Health (ICT-supported social insurance) are helping many people improve their health. This "Patient Monitoring System" monitors core body temperature, pulse rate, and pulse oximetry. The System analyzes sleep and detects falls. The gadget will send sensor data to the cloud, where it will be stored and studied in phases. It can monitor vital signs, transfer them to the cloud, and alert a clinician to a health problem. The authors of [11] also presented a Healthcare Monitoring system that analyzes Context awareness, Quality, Security, and Smart- ness (CAQSS) for numerous health parameters. Context inference in ubiquitous computing causes healthcare research problems. The value is a high-level representation of the entity's activities, relationships, and capabilities. Safe MQTT encrypts communications with and authenticates future healthcare devices using DTLS. This article describes current breakthroughs in IoT-based healthcare designs, networks, and applications. HRV measures the period between heartbeats in [12]. Analyzing heart rate variability is a sensitive indication of chronic degenerative disorders including cardiovascular disease, diabetes, autonomic dysrhythmias like hypertension, and more. HRV's sensitivity to a broad variety of medical illnesses may explain its increasing usage in diagnoses, prognosis, and therapeutic effectiveness. Stroke and cardiac death are key issues for borderline hypertensives, with or without a cardiac episode. High-risk HRV monitoring ensures patients obtain prompt medical care. The authors of this study recommend a cheap and simple IoT-based Remote HRV Monitoring System for hypertension-prone individuals. In the suggested system, a Zigbee-based pulse sensor calculates HRV. Arduino patient data is sent through MQTT. Application server graphs HRV data. SMS may notify the caregiver and doctor of a medical emergency to guarantee fast intervention. The proposed solution uses a remote doctor to fill the gap caused by the absence of HRV analysis tools that alert hypertensive patients of high risk. Zigbee and Wi-Fi networks are proposed. It achieves all the desired features of a life-saving remote health monitoring system: low cost, wide range, security, promptness, and simplicity of use. Human health is a huge global issue. Heart and lung diseases are more common. Practitioners and Doctors must be vigilant while monitoring elderly patients at home or in hospitals. It has greatly simplified people's lives. IoT is transforming healthcare and IT in healthcare. Connected physical things, such as sensors and health monitoring equipment, transform real-world data into digital form over the internet. Using Internet of Things (IoT) capabilities, the recommended system would keep all pertinent patient information and reports consolidated and readily accessible. Low-power sensors and other Internet of Things devices will capture patient data, which will be displayed on an LCD screen and uploaded to the cloud [13]. Mobile health, a subset of e-health, incorporates patient monitoring through wearable equipment. These monitor patients' heart rates and blood oxygen levels away from a hospital or clinic. This article aims to design an inexpensive, tiny wearable gadget for patient comfort. This instrument should exceed expectations. This study also considers cloud-based, real-time, wireless sensor network remote monitoring, where cloud computing and the Internet of Things are coupled to manage huge data flows. In [14], the ESP01, MAX30100, NTC, OLED, and Li-ion batteries were used to make the Wearable Remote Vital Signs Monitoring System (WRVSMS). The WRVSMS connected through HTTP to the cloud server to upload and download data. When a patient's vitals fall beyond a specified range, the WRVSMS sends an alarm to the most important stakeholders in restoring the patient's health. The statistical study proved the device's 99.37% accuracy.

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3. SYSTEM ARCHITECTURE

The message queuing telemetry transport (MQTT) protocol-based smart healthcare system architecture is shown in Figure 1. Sensors are integral to the architecture of the intelligent healthcare system. including the MAX30100 sensor and the MLX90614 sensor. In the MAX30100 sensor, we measure the level of oxygen in the blood and the number of heartbeats but in the MLX90614 sensor, we measure room temperature and human body temperature. Wires link each sensor to the Esp32 Microcontroller, which has Wi-Fi and Bluetooth connectivity and 36 general-purpose input/output (GPIO) pins. The data collected by the Esp32 microcontroller is sent to an MQTT server that may be accessed through a website or mobile application, as shown in Fig.1 [2].

The first part deals with the sensors and the microcontroller, while the second part deals with the MQTT broker and the presentation of the analyzed data. Part one of the suggested system involves physically connecting sensors to the Esp32 Microcontroller that acts as the network gateway, and Part two involves the designer doing the background operation for the MQTT server installation and connecting this server to the Esp32 through Wi-Fi or Bluetooth. For the sake of safety, MQTT brokers use cryptographic protocols. The last step is database administration, which entails the beginning of logging procedures, such as the creation of the user's name (unique user id for each user) and password to access the necessary data. In a nutshell, this way is preferable since it helps enhance the MQTT protocol system as a whole. The data is then shown through the mobile app and the web page [9].

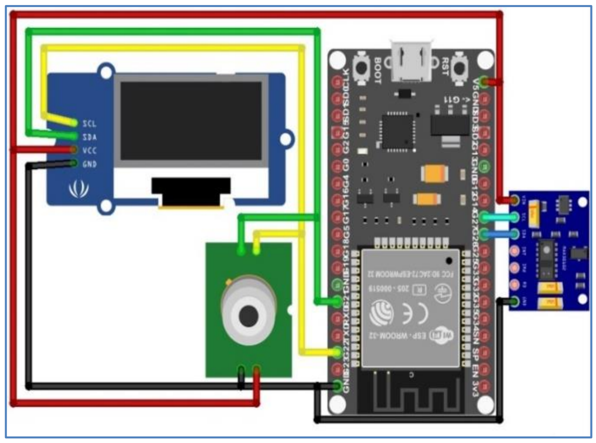

Fig. 1. The practical implementation of the circuit.

3.1. Procedural Steps

The purpose of the suggested system is to gather data from the sensors and transmit that data to the doctor or nurse for constant monitoring of a patient. The doctor requires several different patient parameters, including temperature, heart rate, and movement, to do continuous monitoring. Connecting to the web through Wi-Fi is made possible thanks to the Esp32 Microcontroller's role as a network server. It functions as a network in charge of sensors, always updating its users on the status of each linked sensor's value. The MQTT protocol is safer than others due to its usage of cryptographic methods and the fact that it is a lightweight, low-latency protocol. The MQTT server is constantly updated with the detected data. The MQTT protocol has the benefits of keeping data secure and preventing misleading material from being kept alongside necessary data.

The proposed algorithm starts with connecting to the Wi-Fi and initializing the server connection. Then the sensors will be connected to the servers. The servers then save the collected data to the cloud then the data will be visualized, as shown in Fig 2. in

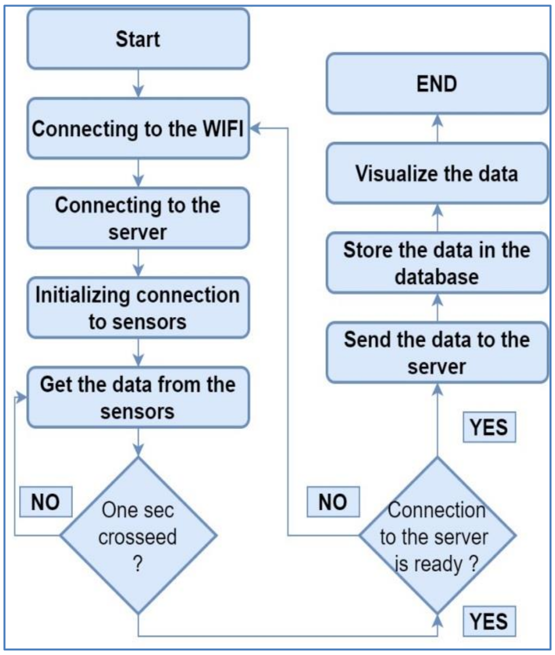

Fig. 2. The proposed algorithm.

4. SYSTEM COMPONENTS

Fig. 3 shows the components of the proposed system and its wireless connection via Wi-Fi.

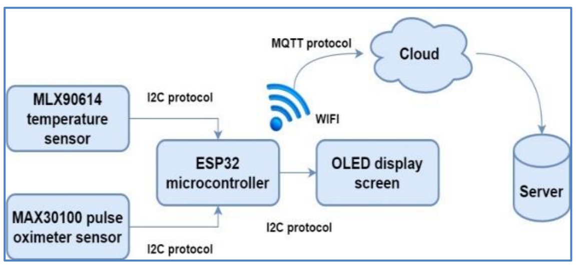

Fig. 3. System connections.

a- ESP32

A power amplifier and antenna switches are included within the Esp32 microcontroller. This microcontroller can connect to wireless networks using both Bluetooth and Wi-Fi. Wearables and Internet of Things applications are ideal for the ESP32 microcontroller, shown in Fig. 4. It has a temperature range of -40 to 125 degrees Fahrenheit. temperature. In addition to being low-priced, it also consumes very little energy because of its use of power-saving technologies such as dynamic power scaling, filters, and power management modules.

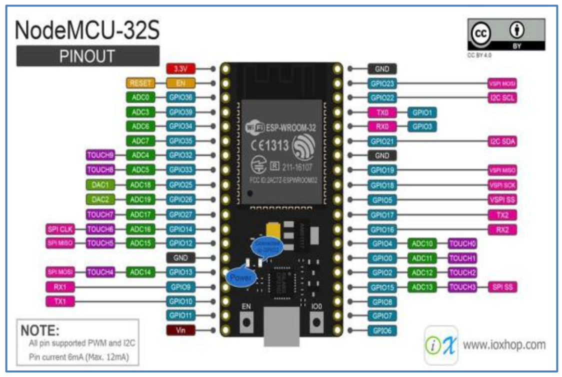

Fig. 4. Esp32 Microcontroller.

b- MAX30100

The MAX30100, shown in Fig 5, measures both blood oxygen saturation and heart rate simultaneously. The VCC of MAX30100 is wired to the VDD of LPC2148 so that it can run on both 1.8V and 3.3V. Figure [9] depicts MAX30100. The device uses low-noise analog signal processing in conjunction with two LEDs, a photodetector, improved optics, and a heart rate/pulse oximeter. The MAX30100 streamlines the design enhances the functionality increases the measuring performance and outputs data quickly. The MAX30100 may be programmed through registers, and its digital output data are queued in a FIFO with the highest priority. The MAX30100 may now be linked to a microcontroller via a shared bus thanks to the FIFO. Max30100's serial interface is made up of a data line (SDA) and a clock line (SCL) (SCL). The MAX30100 and the LPC2148 are able to talk to one another thanks to SDA and SCL. The I2C (Interintegrated Circuit) protocol simply uses a clock and data stream. In this notation, the clock is denoted by SCL or SCK, while the data are denoted by SDA. The LPC2148 will first create a "START" condition, then an address consisting of 7 bits, and finally a Read Write bit. If the MAX30100 recognizes the address, it will transmit an acknowledgment (ACK) on the next clock cycle by pulling the SDA line low; otherwise, it will ignore the address and leave the SDA line high. After receiving a positive ACK, data will be read from MAX30100 using the R/W bit. Any time a byte of data is the last one for a given transaction, it should be followed by a NAK. When this happens, LPC2148 will generate a "STOP" signal. I2C Write Command Sets MODE [2:0] = 0x02 to Activate Heart Rate Mode. Switch to the SpO2 setting. Using MODE [2:0] = 0x03, the I2C Write Command alters the Mode Register. Putting a mask on the HR RDY interrupt. Discretely cover up the SPO2 RDY interrupt. When there is just one slot remaining in a FIFO, an interrupt is triggered to signal impending fullness. The interrupt is cleared once

FIFO data are read. At the position indicated by the new read pointer, a fresh sample is kept. The sample is now the FIFO's first in line (Table XIII). Every second, the FIFO is read, the data shown on the LCD, and uploaded to the cloud, where an alarm is delivered to the caregiver anytime the numbers exceed the threshold.

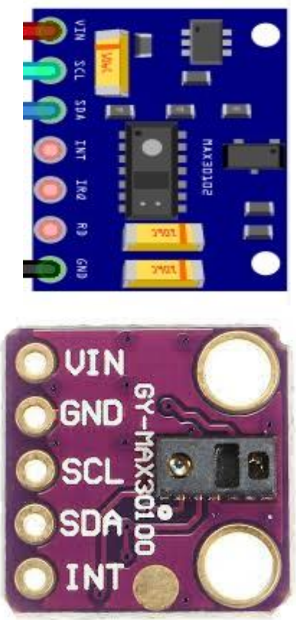

Fig. 5. MAX30100 Sensors

5. RESULTS

Fig. 6 below shows the heart rate of the patients and shows the effect of the sensor's procedure. It shows the rising values due to the effect of heart vibration increased ratio. The heart rate sensor uses an infrared light emitter that shines through a clear area where blood is flowing well. It has a part that sends out infrared light. A photodetector or phototransistor is placed opposite the emitter to collect the light that goes through or bounces back from the measuring point.

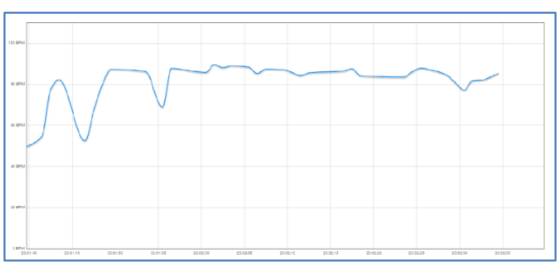

Fig. 6. Heart rate evaluation.

According to the findings of the tests, the performance of the suggested temperature sensor is superior to that of a standard digital thermometer that is purchased commercially. As a direct consequence of this finding, the experiments included measurements of the participants' hand temperatures. In addition, if you have a portable gadget, you will find that feeling the temperature with your hand is much more convenient.

The body temperature evaluation is shown in Fig. 7, it shows the effect of increasing the temperature of the body and shows the sensors increasing values. These results might be recorded to the server via the Wi-Fi, which in turn, stores these data for future use. While the physician or clinician was examining the patient's symptoms hundreds of kilometers away, the temperature measurement device was attached to the patient's hand at home so that it could take the patient's temperature. Six hours of monitoring have been scheduled for the patient. The findings of the snapshot measurement of body temperature taken from the remote monitor database are depicted in Fig. 7.

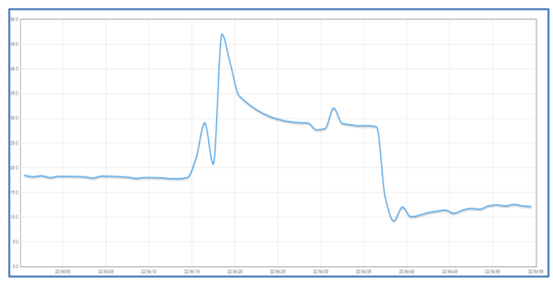

Fig. 7. Body temperature evaluation.

It was necessary to use a wide area network in order to display the results while using a remote monitor database because that was the only way to connect to the database and web application server. Following the uploading of the code, the Arduino will next establish a connection to the Ethernet. The clinician has access to the patient's data as well as all of the metrics that were remotely obtained when they use the web application.

The value that is represented by the symbol SPO2, which is also known as oxygen saturation, shown in Fig.8, is the percentage of the maximum amount of oxygen that your blood is capable of holding. The SPO2 levels of a healthy person should be somewhere in the range of 96% to 99%. The way things are could be shaped by a number of different factors, one of which is elevation. Fig. 8 shows the levels of SPO2 that is recorded for a specific time snaps. It is worth mentioning that these results may vary based on the patient certain case.

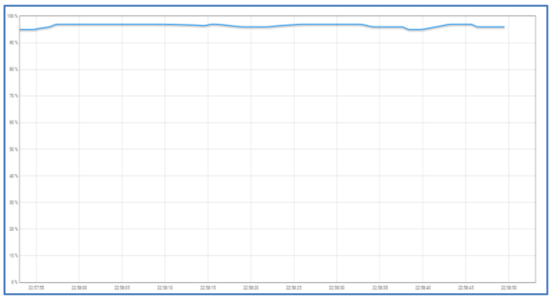

Fig. 8. Oxygen saturation level.

6. CONCLUSION

This study suggested using an Arduino-based platform to track a patient's body temperature, heart rate, and blood oxygen saturation level for health monitoring services and advocating e-health systems and technologies. The presented work used sensors, connected to a microcontroller that sends the gathered data to the cloud platform. The sensors are necessary for the framework to function. The information gathered by the sensors is then readily available for additional processing, such as the examination of specific correlations between the observed parameters and the patient's state of health.

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