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Design of IoT based Autonomous Wireless Body Area Networks to Monitor Vital Signs of COVID-19 Patients

Journal of Electrical Systems

Abstract: - The coronavirus disease pandemic (COVID-19) posed a serious threat to worldwide healthcare systems. Social distance, quarantining techniques, and other hygiene methods are also consistently used all over the world to prevent disease transmission. Frequent patient appointment visits are avoided as a result of full acceptance of the foregoing monitoring activities. On the other hand, certain people's physiological critical needs necessitate regular monitoring of their health state. Patients who are unable to receive continuous monitoring equipment face serious repercussions, including death. Smart home connectivity and integrated healthcare networks are being encouraged by recent breakthroughs in the Internet of Things (IoT) technologies. The wireless body area network (WBAN) is gaining popularity for IoT-connected healthcare applications as more wearable devices hit the market. On existing portable ECG systems, a literature review is conducted. This study presents a health management device for COVID-19 patients and also for normal patients that can measure electrocardiograms, oxygen levels, heart rate, and body temperature and communicate the information to medical workers over an IoT cloud network. The unit also has a solar cell, making it energy efficient and suitable for usage in any remote location. Experiments show that crucial data may be successfully transmitted to an IoT cloud platform, where it can be displayed and analyzed further.

Keywords: ECG (Electrocardiogram) • IoT • SPO2 • WBAN • Pulse rate • Solar panel • ESP-8266 • Link Software

1. INTRODUCTION

Every person strives to be self-sufficient and convenient, regardless of age, race, location, or health status. What can be done is constrained by age, illness, medication, hospitalization, pandemics, and other variables. Health management services have evolved to aid in more convenient safe living, more open interaction between healthcare practitioners and people for careful monitoring, evaluation of critical health indicators, regular consultation, and enhance healthy living. In addition, with the introduction of the Internet of Things (IoT) in the development of information and communication technologies, smart health tracking and support systems have a greater potential for growth and suitability for enhanced safe living.

COVID-19 has produced a seismic effect in our utilization of wireless body area and technology. Education, healthcare, communication, socializing, entertainment everything has become an online pursuit in the lockdown period. This brings an amended lifestyle to the entire globe. The less production and utility of medical facilities have a surge in the positive cases throughout the world. However, the doctors available to treat the deceased are deficient, which leads to a drastic increase in self-monitored medical

A plethora of patients shift to wireless medications like using BP measuring devices, oxygen indicators, and so on making them self-concerned about their health and lifestyle regardless of running to the hospitals,

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seamlessly. Many changes took place in the medical field to replace the doctor's role to wireless in consideration of human loss (as COVID-19 is an infectious virus). Implementing this wireless technology to health care with the help of IoT to transfer the collected data from home or diseased helps in easy analysis of the patient.

The pandemic's emergence posed a severe threat to global healthcare systems. The disease spread quickly enough that medical facilities to treat affected persons were in short supply. In India, this situation exists. India was not one of the first countries to be impacted by the pandemic in the early days of the epidemic, not until January 2020, when the first case of COVID-19 was reported. India was projected to have a high risk for COVID-19 despite having a low case burden for a variety of reasons. The spread can be accelerated by a high particular period. devices. Wireless technologies have made their way far more efficient and most flexible for the users in this population density, particularly in metropolitan settings. Lockdown was implemented to prevent the sickness from spreading further. Quarantined individuals, on the other hand, face some difficulties.

Despite the implementation of lockdown, it is expected that the national healthcare system's capacity to treat patients would be insufficient and that there will be a large number of people who require proper health screening gadgets. While emergency personnel's tireless efforts are commendable, there are many more people who want immediate aid. Early diagnosis and precise vital sign monitoring could help doctors plan and offer timely treatment to patients before their condition worsens and they die. With the use of enhanced clinical screening instruments, patients can be separated into groups based on the severity of their condition for prioritized care.

Patients can live an active and relaxing lifestyle at home instead of in nursing homes, clinics, or other confined institutions, thanks to the emergence of smart home technologies. The healthcare module can improve healthcare services for patients at home or in remote places outside of hospitals as part of the smart home automation plan. As a result of their seclusion in hospital wards, patients' depressed symptoms have decreased. Doctors will be able to watch patients remotely, give medications, and monitor crucial health factors all from the comfort of their own offices.

Furthermore, the smart home healthcare industry's rapid growth in digital and hardware technology allows patients to effortlessly monitor various household equipment using smartphones and computers.

Multiple computing systems that operate proactively on behalf of patients make up a smart home-based healthcare environment, which makes it ubiquitous. As a result, customer background and expectations are some of the essential characteristics to consider when making a selection in a smart home healthcare environment.

We present a portable Wi-Fi-based portable ECG gadget that can transmit the collected data to medical personnel via an IoT Cloud platform in this work. During a pandemic, such as the present COVID-19 outbreak, the suggested device allows patients to remotely gather important health data such as heart rate, oxygen levels, and temperature for aided diagnosis by their doctor. The device also includes a solar cell to address concerns with data transmission across a Wi-Fi network that is connected to energy efficiency.

The following is how the remainder of this article is organized: Section 2 contains a literature review of portable ECG and smart health tracking devices, as well as the proposed system's architecture. Sections 3, and 4 discuss the hardware and overall hardware setup of the proposed system, respectively. Section 5 depicts results, and discussions and Section 6 provides the Conclusion and Future Scope.

II. LITERATURE SURVEY

The research work done in [1] provides an adequate sensor network consists of solar power harvesting and Bluetooth low energy (BLE) transmission that allows an autonomous WBAN to be implemented. To assess the subject's body temperature distribution, heartbeat, and detect falls, myriad sensor nodes can be placed on different parts of the body. For presenting sensor data and fall notifications, a web-based mobile application has also been created. A flexible solar energy extractor with an output-based power tracking methodology (MPPT) is employed to fuel the wearable sensor node to extend its life. Experiments demonstrate that the wearable sensor node performs effectively when it is fueled by a solar energy harvester. By the testing results, a self-contained 24-hour operation is possible. The suggested solar energy collecting system indicates that long-term continuous medical monitoring via WBAN is achievable if the individual spends a little amount of time outdoors each day.

The study presented by [2] proposes an optimum energy harvester for a wearable body sensor network that employs a flexible photovoltaic module to extend battery life in both indoor and outdoor settings. The suggested sensor network employs a low-power Bluetooth low-energy (BLE) module to interact wirelessly with smartphones and monitor patient’s vital data. The device may effectively adjust to a human body shape to concurrently capture PPG and ECG signals compact size and flexibility. The system includes a newly developed Optimum Energy Harvester, which can gather solar energy at quite a maximum reliability to extend battery life indoors and charge the battery outside. Even in indoor settings, the suggested booster can harvest energy, and this MPPT can easily track the MPP using fuzzy logic and achieve the true MPP. Under all lighting situations, the suggested system works in extending battery life.

The capacity to monitor crucial events in real-time in several aspects of everyday life is driving the demand for wearable gadgets. For many of these gadgets, electricity is the limiting element. One element is the power source using batteries, which poses problems owing to weight, total size, and battery disposal. Harvesting ambient energy to power devices directly is a feasible option to outracing the constraints of batteries as a power source [3]. A suggested wearable device via an energy harvesting unit for vital sign monitoring has been conceived, produced, and tested in the article. A flexible solar panel is present in the energy-harvesting module useful for direct power the electrical circuit board. The suggested instrumented autonomous T-shirt is described in [3], which is powered by a flexible solar panel that is attached directly to the T-shirt. The T-shirt is equipped with sensors that can track breathing, heart rate, and bodily movement. The experimental findings indicate that the system works even in low-light outside situations and under specific interior limitations. Tests were carried out to compare the output data from the instrumented T-shirt with data collected via equipment as gold standards and illustrate that the entire system described in this work can provide accurate results.

The majority of gadgets required to be recharged for every few hours or perhaps even days, falling short of the standards for a satisfying end-user experience. The design, implementation, and in-field assessment of InfiniTime, a unique sensor-rich smart bracelet driven via harvesting solar energy, are presented in [4]. Solar cells with low interior lighting conditions and thermoelectric generators (TEGs) with minimal thermal gradients from body heat are used to achieve self-sustainability. Besides accelerometer and temperature sensors being used in modern applications, the wearable equipment has a microphone and an ultra-low power camera. The fully functioning prototype's experimental characterization reveals a variety of energy optimization strategies utilized to achieve self-sustainability using solely collected energy. InfiniTime achieves self-sustainability with interior lighting levels and body heat for a few practical programs involving data collection from an onboard camera and other integrated sensors, as well as visualization and wireless connectivity, according to simulations using energy intake metrics from solar and TEG modules.

The major problems in using wearable wireless sensors on humans are the heavy and stiff style of the system, which makes it hard to fit on the human body contours and the short operating lifespan of batteries with finite energy supply. An autonomous wearable wireless sensor node with a flexible energy harvesting method that can adjust to body contours is presented in [5] for biometric monitoring. A flexible energy harvesting mechanism is paired with an ultralow-power management circuit particularly built on a flexible PCB to be completely sustainable and versatile. The flexible circuit can transport nearly all of the electrical energy from an input solar power source to the supercapacitor, where it is stored for use in powering the wireless sensor node. Because of its self-sustaining and flexible nature, this is considered ideal for wearable, biomedical applications that do not require bulky power circuits or batteries. The adaptable design may then be modified to integrate additional harvesting techniques in a later stage.

Based on the above-mentioned authors' contributions to WBAN applications, we propose to make better use of current technology to develop WBAN applications at a lower cost and with more efficacy.

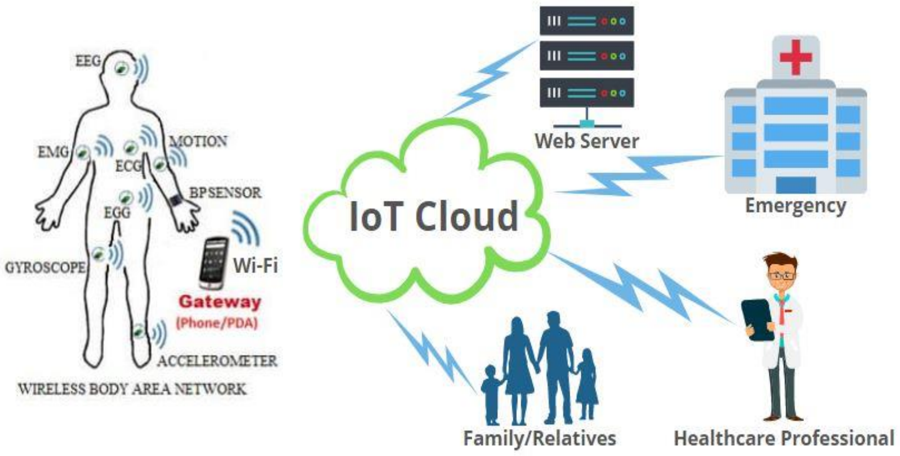


Figure 1. Architecture of WBAN with IoT Cloud

Figure 1. depicts how Wireless Body Area Networks (WBAN) may be utilized to send crucial data from a patient to an IoT Cloud through Wi-Fi. The data can be saved on a Web Server for future access by medical experts to diagnose and consult with patients. Prioritization of data may be done using various algorithms and approaches to separate patients based on the severity of their condition.

If the patient is in severe condition, an emergency signal can be sent to the hospital, providing enough information to medical staff and directing the deployment of an ambulance to fetch the patient. It can also assist notify the patient's family members to respond to the emergency scenario.

III. PROPOSED ARCHITECTURE

The suggested system design is shown in Figure 2. The sensor sector depicts the sensors that are used to measure crucial metrics. As indicated in the transmission segment, the data collected by these sensors is aggregated and transmitted using a Wi-Fi transmission module. As shown in the power supply segment, the device's operation demands the usage of a power source. When a 5-volt external power supply is available, it is possible to use it. If the user does not have access to an external power source, a solar cell is incorporated into the device. The data is transferred to an IoT Cloud platform, where it may be seen by medical practitioners for additional analysis and patient counseling. Details of hardware circuits and implementation of application software are described in the following sections.

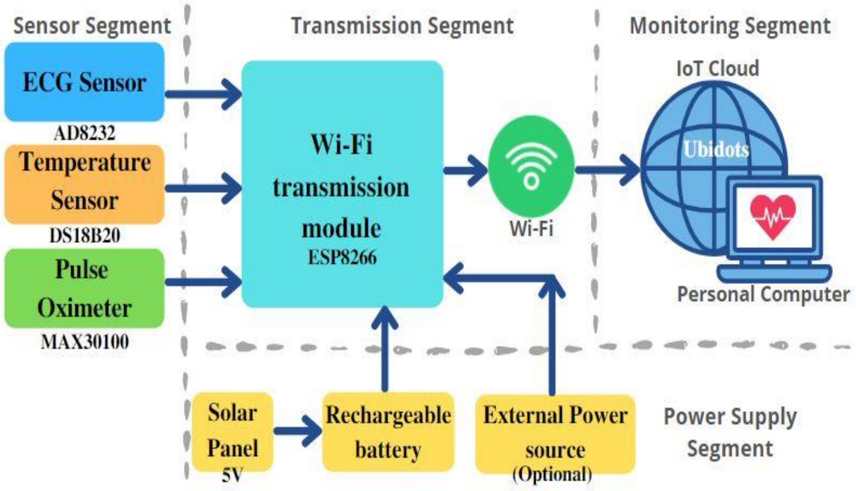


Figure 2. Proposed System Architecture

Software Execution

The vital sign sensors are powered by a 5V power supply given by either a rechargeable battery linked to the solar panel or an external power source with the three sensor modules connected to the human body. As data is acquired from the sensors, the Wi-Fi module delivers it to the IoT Cloud. Monitoring staff can now access data stored in the IoT Cloud from anywhere in the world using their username and password.

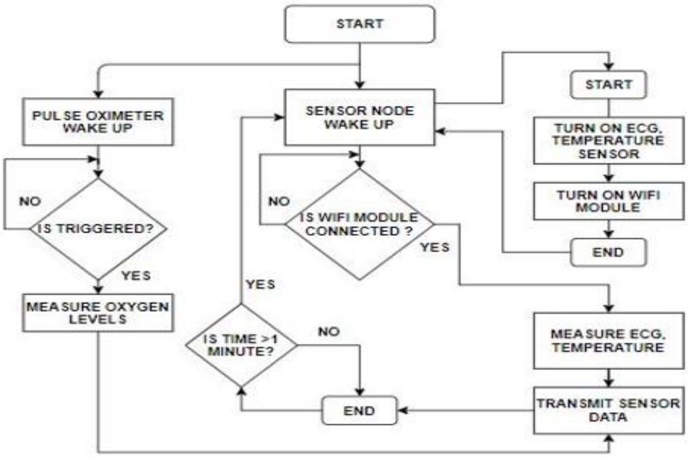


Figure 3. Flowchart showing the software execution

Monitoring personnel may now enter the data that is saved in the IoT Cloud using their login credentials from anywhere in the world. Figure 3 depicts the process occurring in the proposed system.

Hardware Description

In our work, we develop a hardware system with the sensors that are especially required for the COVID-19 cases as these sensors are used for measuring temperature, heart rate, and oxygen levels in the human body, which places a pivotal role in identifying the fatality or illness of the affected person. These sensors are wirelessly connected to form a network and used to be placed on the surface of the human body with minimal connecting wires. The hardware developed also uses a solar panel which is of wireless charging system. Meanwhile, the energy can be taken in either of the form .i.e., solar or a battery charger which results in maintaining the lifetime of the network.

AD8232 Integrated signal conditioning

A signal conditioning block along with integrated signal conditioning was used for the 3-lead ECG electrode in Fig. 4(a) and for other bio-potential measuring applications as shown in Fig 4 (b). As the patient needs continuous monitoring, a 3 lead ECG is used for recording 24 hour reading of the patient. The three ECG leads are connected to the chest part of the body. These leads are connected to the chest using a sticky conductive gel to maintain the electrodes getting attached to the body for monitoring the electrical signal that the heart makes. It is intended to amplify, filter, and extract tiny bio-potential signals in a noisy circumstance, such as those caused by mobility or distant electrode placement. The output signal may be easily acquired using an analog-to-digital converter (ADC) with an ultralow power or an embedded microcontroller with this architecture.

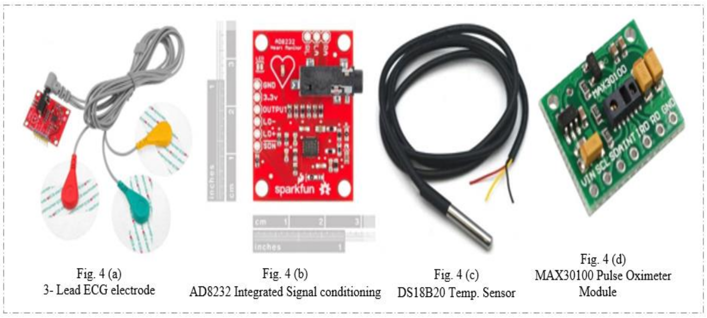


Fig. 4 (a)
3- Lead ECG electrode

Fig. 4 (b)
AD8232 Integrated Signal conditioning

Fig. 4 (c)
DS18B20 Temp. Sensor

Fig. 4 (d)
MAX30100 Pulse Oximeter Module

Figure 4. Proposed Hardware Sensor Modules [Adopted https://www.thingbits.in/, https://botland.store/, https://www.electronicscomp.com/, https://www.electronicscomp.com/]

A two-pole high-pass filter on the AD8232 can reduce motion artifacts as well as the electrode half-cell potential. This filter is tightly linked with the instrumentation design of the amplifier, allowing for both high-pass and high-gain filtering in a single stage, saving both space and money. The AD8232 builds a three-pole low-pass filter with an uncommitted operational amplifier to reduce noise. The frequency cutoff of all filters can be adjusted to match different types of applications.

It has a powered right leg driven amplifier to increase the common-mode rejection ratio (CMRR) and noise due to 50 Hz power line interference as well as noise from myoelectric signals. The AD8232 has a rapid restoration feature that shortens the settling tails of high-pass filters. The AD8232 comes in a 20-lead LFCSP package with a footprint of 4 mm. The device is ideally suited for temperatures ranging from 0°C to 70°C.

DS18B20 Temperature Sensor

DS18B20 is one of the thermal sensors that measure temperatures in 9-bit to 12-bit Celsius and features an alert feature with non-volatile customer-programmable higher and lower trigger points. The DS18B20 connects with the central CPU through a 1-Wire bus, which by interpretation requires only a single data line. Furthermore, the DS18B20 may draw power directly from the data line, obviating the requirement for an additional power supply. The overview of this sensor is in Fig. 4(c).

Every DS18B20 contains its 64-bit serial code, allowing many DS18B20s to operate on the same 1-Wire bus. As a result, it is straightforward for utilizing a single microprocessor to operate on a large number of DS18B20s spread across a vast region. The sensors have a quoted accuracy of +/-0.5 deg C in the range -10^{o}C to +85^{o}C.This sensor is extensively used to calculate temperature within rigid environments which includes mines, chemicalsolutions, otherwise soil, etc. We can use it in the thermostat controls system also.HVAC (Heating, ventilation, and air conditioning) environmental controls, temperature monitoring systems within buildings, equipment, or machinery, and process monitoring are among applications that can benefit from this functionality.

MAX30100 Pulse Oximeter Module

The Maxim MAX30100 as in Fig. 4(d) includes both pulse oximetry, commonly known as SPO2 (Saturation of Peripheral Oxygen), and a pulse rate sensor. It's an optical sensor that takes measurements by utilizing two LEDs to generate two wavelengths of light - red and infrared - and then using a photo-detector to detect the absorption of pulsing blood. This combination of LED colors is great for reading data with your fingertip.

The mentioned sensor combines two LEDs, a photodetector, optimized optics, and low-noise analog signal processing to detect pulse oximetry and heart-rate signals. We consider the mentioned sensor for our work as the accuracy rate of the Max30100 measurement is 97.11% and 98.84%, for heart rate and oxygen saturation (SpO2), respectively, and will be best suited to carry out the measurement. Wecan use this sensor with any microcontroller like Arduino**,** ESP8266or ESP32 and easily measure the patient’s health parameters. Many factors make the device very common among researchers: cost of the device, its usability are few important factors. This is an inexpensive pulse-oximeter that operates from 1.8V and 3.3V power supplies and can be powered down through software with negligible standby current, permitting the power supply to remain connected at all times. The other features of the sensor are Consumes very low power (operates from 1.8V and 3.3V), Ultra-Low Shutdown Current (0.7µA), fast data output capability, Interface Type: I2C.

ESP-01 ESP8266 Serial Wifi Wireless Transceiver Module

The ESP-01 ESP-8266 Serial WIFI Wireless Transceiver Module is a self-contained SOC that connects any microcontroller to a Wi-Fi network using an inbuilt TCP/IP protocol stack. The ESP8266 can execute a program or delegate Wi-Fi networking operations to a different CPU. Each ESP8266 module is pre-programmed so that we may achieve almost the same Wi-Fi capabilities as a standalone Wi-Fi Shield by just connecting it to an Arduino microcontroller. The ESP8266 microcontroller is a popular low-cost microcontroller with a large user base as shown in Fig. 5(a) and 5(b). The processing and storage capabilities of this module allow it to link several sensors and circuit modules via its GPIOs with minimal development and runtime overhead.

An excellent on-chip integration present in it allows for minimal external circuitry, including the front-end module, which is set to take up as little PCB space as possible. This ESP8266 supports APSD for Bluetooth co-existence and VoIP applications interfaces, and it has a self-calibrated RF that allows it to function in all operational situations with no extra RF components.

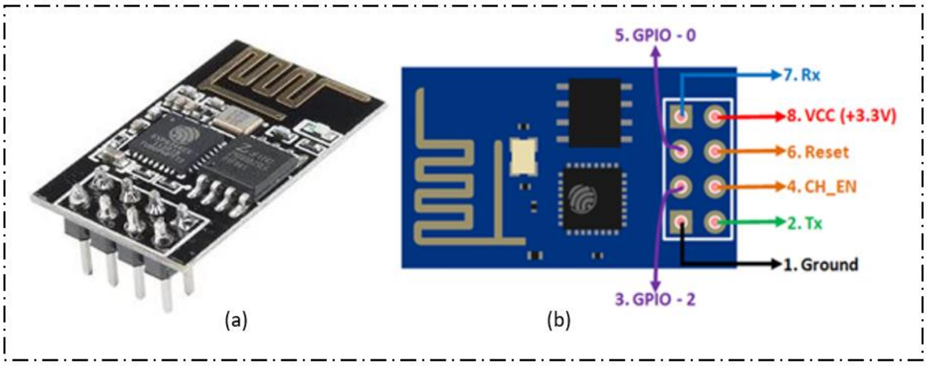


Fig. 5 (a) ESP-01 ESP8266 Wi-Fi Module (b) ESP-01 Pin description [Adopted from https://rees52.com/]

The Fig. 5 has a glance of pins to be connected accordingly in the PCB with general purpose input and output pins, transceiver, receiver, reset, power supply, ground. There is an enable port which is activated when circuit is connected to it. There is an almost limitless fountain of information available for the ESP8266, some of which have been provided in specifications and features.

SOLAR PANEL WITH BATTERY

Nowadays solar panels have a boom and rapid increase in their uses, many health care applications use them to have a backup electrical usage. To cope up with the energy usage, we tried an arm sized solar panel in our network design and got succeeded in that process. The solar panel used is fixed to the network and placed on the surface along with the prototype developed. As the solar panels are low power consuming and last for a long period, it has a great effect in reducing cost and increasing utility. As these can power your devices rather than to pay for an electricity grid.

The Solar panel capacity is 5 Volts and the Lithium-ion battery is rechargeable and has a recharge period of up to 6 hours. The battery has a capacity of 2600 mAh and a shelf life of up to 3 years. It can be recharged 1000 times and has a working temperature range of -4 to 122 degrees Fahrenheit. Fig. 6(a) shows the front view of the solar panel been used for the developed network and Fig. 6(b) describes the battery involved in this proposed device. These specifications being taken into considerations, we consider the most flexible and cost-friendly, eco-friendly method in our work as a power source.

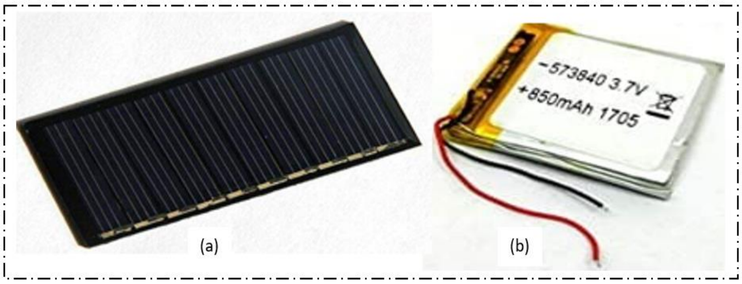


Figure 6 (a) Solar Panel (b) Battery [Adopted from https://www.szaspower.com/, https://www.twinschip.com/]

IV. PROPOSED HARDWARE SETUP

The Figure 7 depicts the overall hardware setup mentioned in the previous section designed on a printed circuit board. The numbers in the figure indicate the components in the proposed system. The total hardware arrangement described in the previous section is depicted in the accompanying Figure-10, which is designed on a circuit breadboard. The components of the proposed system are indicated by the numbers in the diagram.

All these are combined to form a network as shown in Figurw 8(b). Each component presented here is interlinked and combined inside the glove as it may be hazardous or may cause any disturbance in the network settings if kept open for the atmosphere as the device is useful for health care in remote areas, where care tackers or physicians are absent or unavailable.

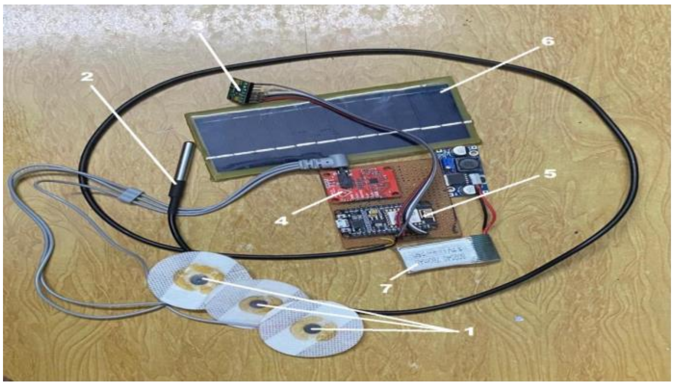


Figure 7. Proposed Device hardware setup

1. ECG Electrodes.
2. DS18B20 Temperature Sensor.
3. MAX 30100 Pusle Oximeter Module.
4. AD 8232 – ECG Amplifier Module
5. ESP-01 ESP8266 Wi-Fi Wireless Transceiver Module.
6. 5V Solar Panel.
7. Rechargeable Battery

The hardware setup is made in a narrow way to have space free environment. The setup placed on the surface of the body collects the required data for often 24 hours collecting the vitals and sending them to an IoT device using WiFi. The 3 lead ECG electrodes can be placed in either of the two ways as shown in Figure 8(a).but when compared to the first placement parts, the second identified parts outraced the results observed in the first part. The overall placement of hardware setup is mounted as in shown Figure 8(b). The sensors placed in are described with the numbers.

Electrode Placement on The Human Body

To place the electrodes on the human body, we can use any of the below procedures shown in Figure 8 (a). The closer the measurement is to the heart, the better. So that we choose the second path for placing the electrodes on the subject and collect the vitals. The ECG uses three lead ECGs where the cables are colored particularly for their placement on the human body and easy identification. Using a sticky substance the electrodes are fixed to the body manually.

The cables are color-coded to aid with appropriate positioning.

- Red – Right Arm or Right hemisphere of Chest.
- Yellow – Left Arm or Left hemisphere of Chest.
- Green – Neutral.

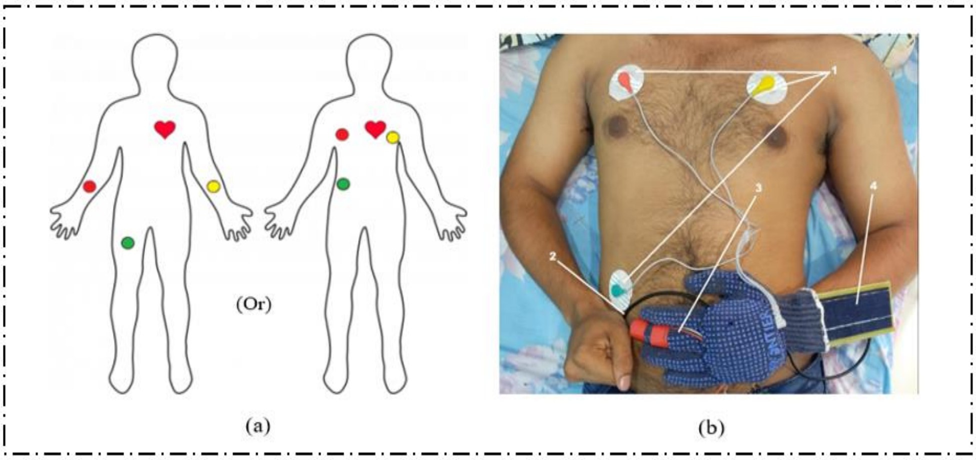


Figure 8. (a) ECG Electrode placement on the body (b) Placement of all sensors on the subject

Figure 8(b) shows the overall placement of the sensors of the proposed device on a healthy human subject. The numbers indicate the following components:

1. ECG electrode placement on the human body is denoted in Figure 8 (a)
2. Temperature Sensor held in the right hand of the subject.
3. A Pulse Oximeter is placed on the middle finger which is integrated with a wearable hand glove.
4. A 5V Solar panel that can charge the rechargeable battery is shown in Figure 8(b)

Energy Consumption

Energy consumption is a key concern in the use of wearable devices, as they are often intended to be used for extended periods. A switch can be added to the suggested wearable sensor node to turn it on or off to manage energy usage when no measurements are to be taken. Table1 gives a brief overview of operating current ranges for the proposed device at different modes of operation.

Table 1. Sensor node currents at different modes of operation

Stage	Mode	Current (mA)
1	ESP Module (Active mode)	100 – 400
2	ESP + ECG + Temperature + Pulse Oximeter	433 - 852
3	ESP Module (Stand by)	70

The battery is completely charged in 3 hours 47 minutes using a solar energy source. With all sensors turned on, it empties in 1 hour and 30 minutes. Every minute, the gathered data is sent to the IoT Cloud. The proposed device module accepts power input ranging from 100mA to a maximum of 400mA, and the operational current with sensors is about 85.2 mA.

Application Software

Link is an Internet of Things (IoT) platform that connects devices and helps in the visualization of data. It allows people to send data over the internet. We can transfer patient data gathered from the ECG module, thermal sensor, and SPO2 to the concerned medical staff via Link App using the ESP Wi-Fi module. Although the ability to collect non-intrusive data is important, it is the seamless delivery of information to users depending on their preferences, that truly defines Link as a powerful decision-making aid. Link offers a wide range of data visualization options as well as a user-friendly interface. The Link platform used in our work is represented in Figure 9 for a clear understanding and introduction to theplatform.

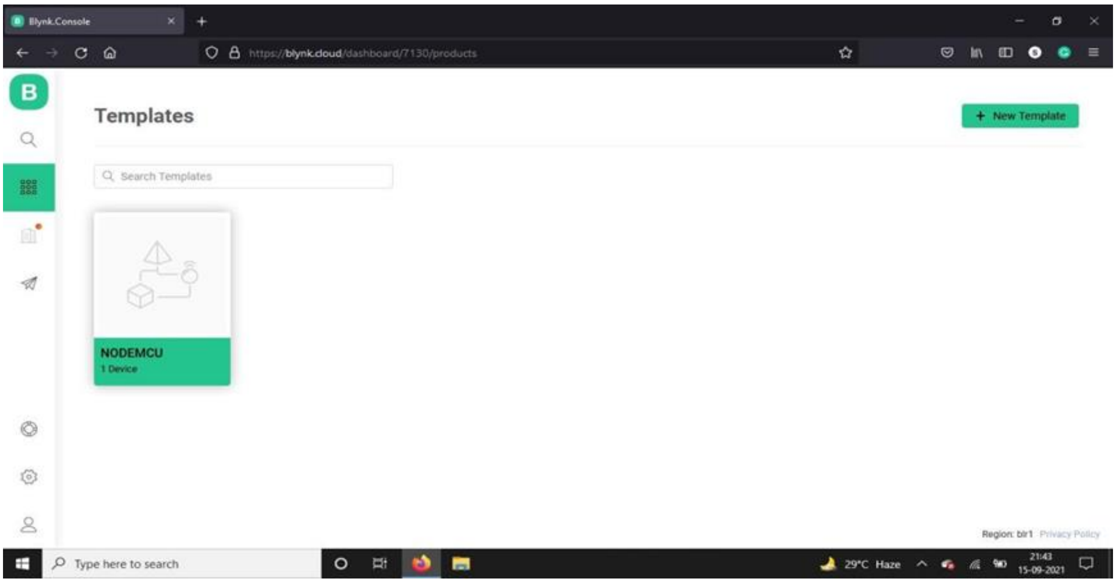
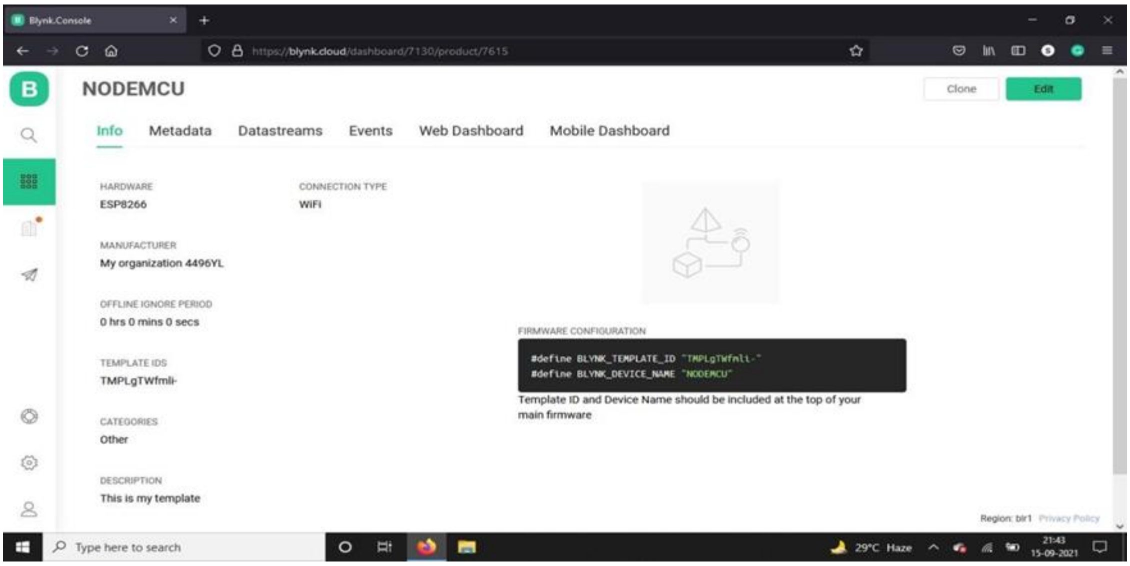


Figure 9. Link Platform



HARDWARE
ESP8266

CONNECTION TYPE
WiFi

MANUFACTURER
My organization 4496YL

OFFLINE IGNORE PERIOD
0 hrs 0 mins 0 secs

TEMPLATE IDS
TMPLgTWfmli-

CATEGORIES
Other

DESCRIPTION
This is my template

FIRMWARE CONFIGURATION

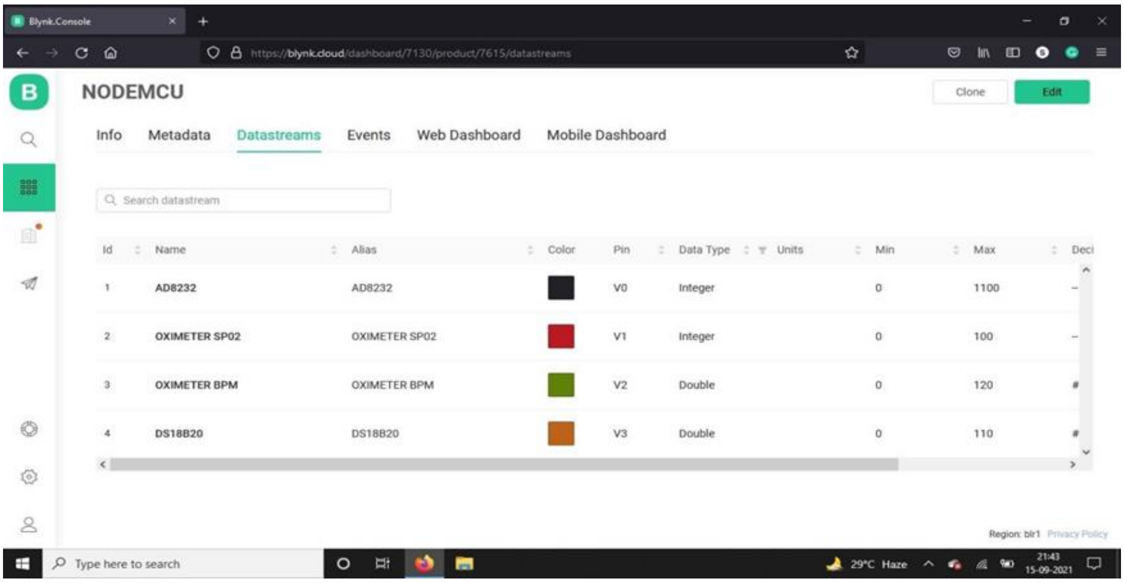
```
#define BLYNK_TEMPLATE_ID "TMPLgTWfmli-"
#define BLYNK_DEVICE_NAME "NODEMCU"
```

Template ID and Device Name should be included at the top of your main firmware

Figure 10. Adding New Device

Link is developed to build the IoT using the Arduino. It is a user-friendly app for many applicants. The Procedure of how the Link continues and works in an app format is shown in Figure 10. Create a New Blynk Account and Sign up with your details. Navigate to the web dashboard where we can create New template where it can be implemented in the number of devices click on 'New Template', then Enter a name for Project and choose Hardware and Connection type, then click the Done button and it will create a template for us then here inside the template add multiple information.

Next, go to Metadata and give additional information about your project to the device to make its own unique identity.



Id	Name	Alias	Color	Pin	Data Type	Units	Min	Max	Deci
1	AD8232	AD8232	⬛	V0	Integer		0	1100	–
2	OXIMETER SP02	OXIMETER SP02	🟥	V1	Integer		0	100	–
3	OXIMETER BPM	OXIMETER BPM	🟩	V2	Double		0	120	#
4	DS18B20	DS18B20	🟧	V3	Double		0	110	#

Figure 11. Building Dashboard

Datastream is a space in the Blynk. Cloud, where time-stamped values from the hardware devices are stored .you, can use it for sensor data, any other elementary, or actuator states. Once you have created a template you would need to go to the Datastreams tab and Click on 'Add Datastream' as shown in Figure 11. Then choose a' virtual pin 'option in the dropdown menu. The virtual pin is a more flexible Datastream type that allows you to send integers, doubles, and strings. skip all the other settings. When done, press 'Create' and the new datastream will becreated. We can monitor or add new devices of user interest and needs as shown in Figure 12.

Device name	Device owner	Status	Device model	Actions
Wireless EOG	Sai Kiran	● Offline		

Figure 12. Selecting Variables

V RESULTS AND DISCUSSIONS

This section contains illustrations of the patient's vital data as it is delivered by the device to the Link IoT Cloud pipeline, where it is processed adequately and displayed on the mobile or PC. The name of the variable, its ID, and the range into which monitoring staff can enter specific values to detect any abnormalities that will aid in the analysis of the patient's condition are all displayed in the left column of the figures. The variable's name, ID, and the range into which monitoring staff can enter specific values to detect any abnormalities will be displayed in the right column of the figures. In addition to the graphical representation, the table below shows the values that were collected at each point of time on the date of signal transmission from the device to the IoT Cloud. Access to the platform's vital information is restricted to those who have been provided with login credentials to the platform. To facilitate understanding of the data, the IoT Platform provides several graphical representations that can be shared with others. As a result, data integrity is in the hands of those who are in charge of the monitoringteam.

As indicated in the previous section, the sensors are placed on the human subject, and two case studies are observed in the same subject in two distinct settings, namely:

1. Case-1 Normal Patient
2. Case-2 COVID Patient

Normal Patient (Case-1)

The data acquired from the device are viewed in the IoT Cloud for a normal patient with all the sensors and leads connected to the surface of the body. Fig.13, Fig. 14, Fig. 15, and Fig. 16 show the ECG waveform, Oxygen Levels, Heart rate, and body temperature (in Fahrenheit) respectively. The signal is sent every minute. ECG signal is acquired for 500ms. Pulse oximeter values are transmitted only when triggered. As temperature measurement is a slow process the values obtained are only considered per minute duration. The rate of transmission depends on the speed of the internet from which the user is transmitting the data to the IoT Cloud. In Figure 13, the ECG count is monitored on the left side of the device, with all other information including the ID of the receiver/user, range representing the boundaries. The right side of the device represents the output of the system carried out on theperson.

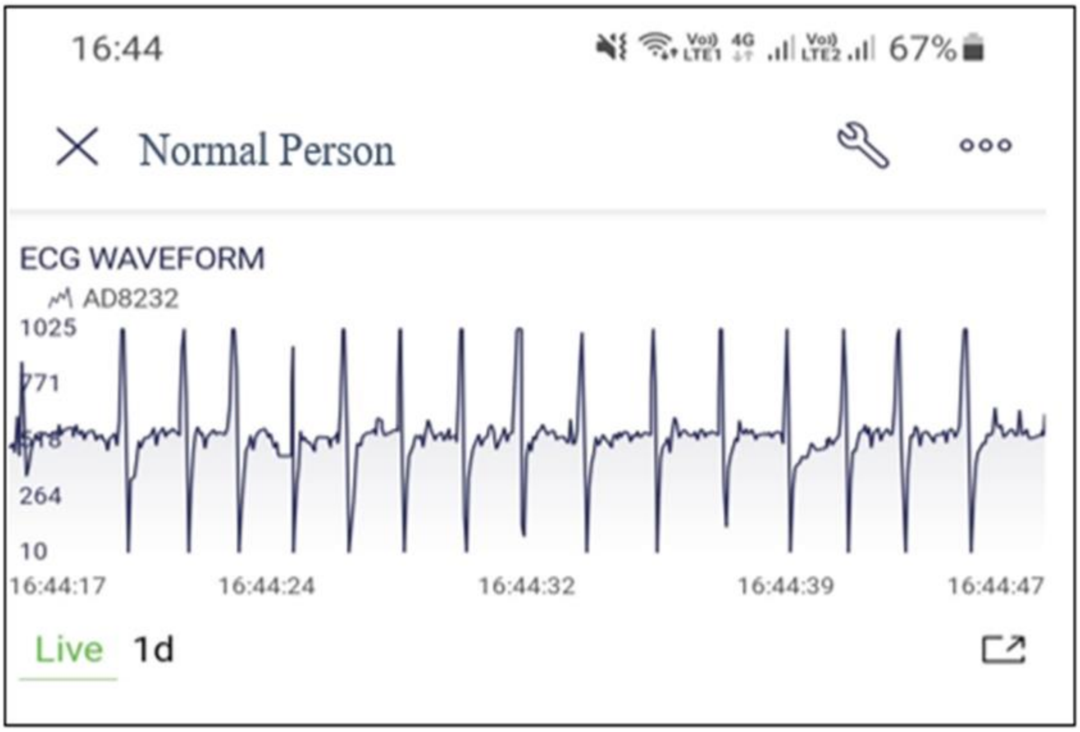


Figure 13. ECG Waveform

The Oxygen levels measured are presented in Figure 14 where the same desktop appears as in the ECG signals, except for the range and application changes for this picture. Also, a value to be noted is represented in both value and graphical form. Either of these two can be used for data processing. These data are recorded accordingly to the time, and date mentioned. so that, the recorded data can be easily identified for the treatment and analysis. Figure 15 is shown below where the temperature of the human body is calculated using the sensor placed in the network, that is placed on the surface of the body. Likely, in the ECG, heart rate, and Oxygen measurement, temperature follows the same process of connecting the device, selecting the variable and representation of collected data. These are the results calculated for a normal patient.

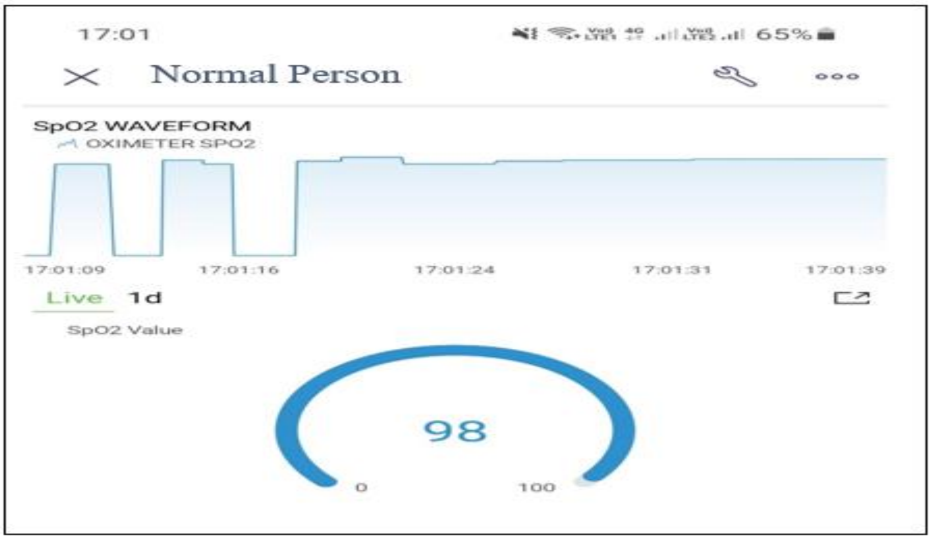


Figure 14. Oxygen Levels (%)

Figure 15. BPM

Figure 16. BPM

COVID Patient (Case -2)

The values acquired from the device are viewed in the IoT Cloud when a COVID patient is in rest or walking position. Figure 17, Figure 18, Figure 19, and Figure 20 show the ECG waveform, Oxygen Levels, BPM oximeter, and body temperature (in Fahrenheit)respectively. The results expressed are monitored and calculated for a COVID patient in both rest and motion conditions.

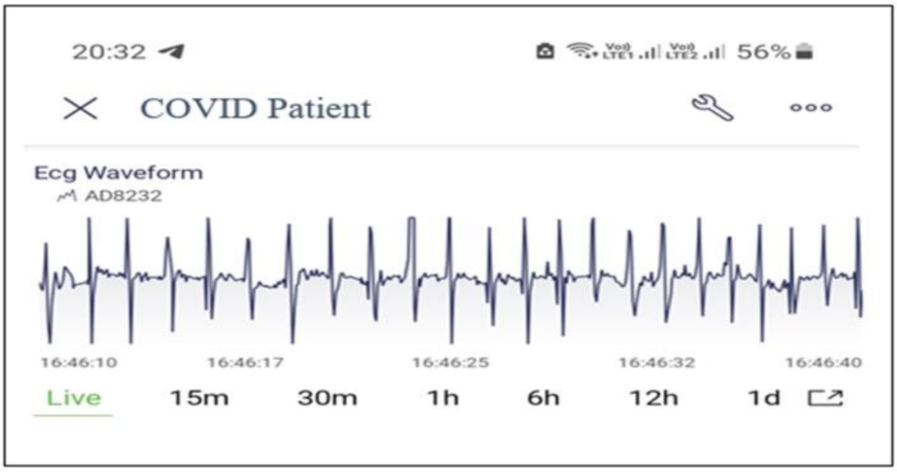


Figure 17. ECG Wave form

The vitals collected is useful for immediate monitoring in the case of the COVID-19 (pandemic) scenario, where a lot of manpower reduces. The ECG of the COVID patient shown in Figure 17 is depicted when a patient coughs while monitoring. The other major cause is loss of network which causes the data transfer to be rarely possible when not in a provident area. The data is collected and stores in the same manner when the human body is in a normal or in COVID infected state. As the heart rate and oxygen levels play a pivotal role in analyzing the health condition of the patient, they are shown in Figure 18 and Figure 19. The app uses the same process of adding a device, a variable, making a note of values in graphical and value representation. But, this can be used in any emergency conditions to send the data within a limited timeframe. Also, the temperature of the affected patient is calculated as shown in Figure 20 as this is used as an initial stage of identifying the COVID infection.

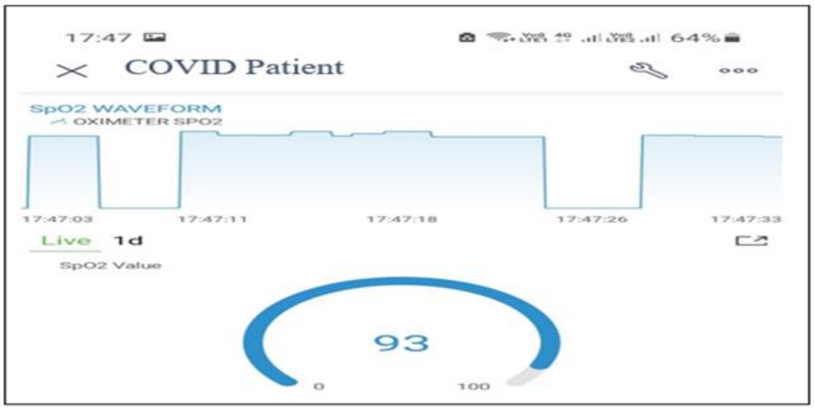


Figure 18. Oxygen Levels

Figure 19. BPM

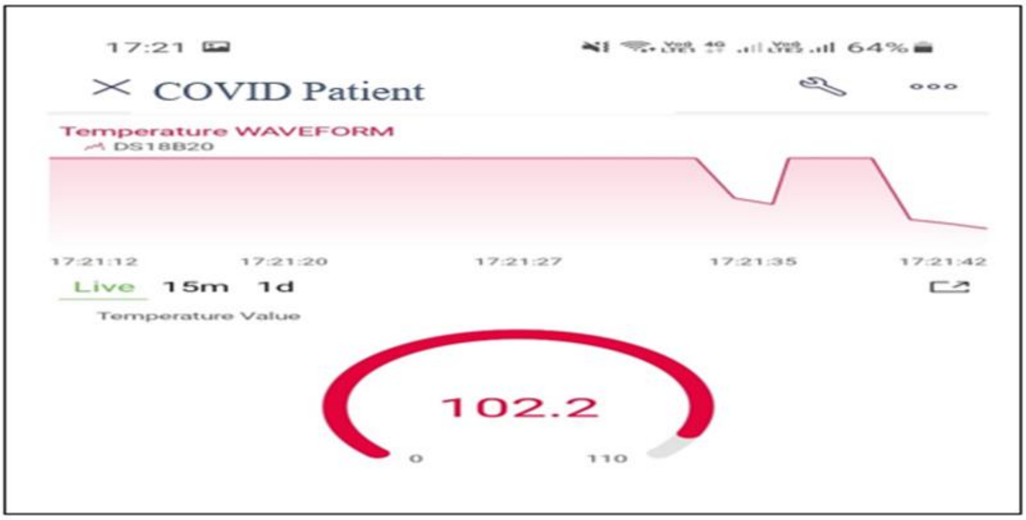


Figure 20. Temperature

Another advantage of Link is that it has a plethora of tools for displaying the gathered data. The figures above show a graphical representation of the data collected from the device. Link platform includes many tools for converting graphical data into other formats, such as a pie-chart, so that the data may be easily analyzed in medical diagnostics.

Table2. Comparison of WBAN applications

Ref. Paper No.	**Year**	**Sensors**	**Wireless Technology used**	**Display/ User Interface**	**Energy Source**	**Energy Source Size (in cm^2)**	**Energy Storage**	**Power Consum-ption**
[1]	2017	Temperature, Heartbeat & Accelerometer	BLE	Smartphone	Flexible Solar Panel	7.2*6	Supercapacitor 12.5 F	1.76 mW
[2]	2016	Heartbeat & Blood Pressure	BLE	Smartphone	Flexible Solar Panel	19*4	Supercapacitor 500 F	41.25 mW
[3]	2016	Respiration, Heartbeat & Accelerometer	MAX1472-433 MHz	PC	Flexible Solar Panel	27*17.5	Supercapacitor 1 F	17 mW

[4]	2016	Temperature, Accelerometer, Camera & Microphone	NFC/RFID	EPD	8 Solar Panels & 7 TEGs	Solar:3.5*1.4 TEG:0.8*1	Battery 3.7 V 40 mAh	Depends on mode of operation
[5]	2014	Temperature	CC2500-2.4 GHz	PC	Flexible Solar Panel	7.2*6	Supercapacitor 100 mF	3.91 µW
Proposed Work	2021	ECG Sensor, Temperature Sensor, Pulse Oximeter	ESP 01 ESP 8266	PC/ Smartphone	Fixed Solar Panel	12.9*14.9	Battery 5 V 2600 mAh	Depends on mode of operation

The suggested system can send data related to three vital parameters, namely ECG, Oxygen Levels, and Temperature, over Wi-Fi to an IoT Cloud Platform via WBAN. More research is needed to transform the gathered ECG information to the medical-grade ECG signal that can be used to identify heart problems. The system can transfer data to the IoT Cloud through Wi-Fi at regular intervals and with minimum latency. The suggested system uses IoT technology to communicate ECG signals, Oxygen levels, Pulse, and human body temperature to the IoT Cloud, where the data is stored and can be retrieved by actively monitoring employees from anywhere in the globe using their login credentials. In Table2 interface, wireless technology used, energy source, energy storage, power consumption are tabulated. The ECG is the new variable which is not been developed to date and we imposed it in our work.

Various wireless methods are utilized to transfer sensor data to the appropriate user interface devices for monitoring. Sensors such as temperature, heartbeat, and accelerometer are employed. In our work, we incorporated an ECG sensor to capture ECG signals, which is not implemented in the previous studies. However, experimental results indicate that the obtained ECG data should be transformed to produce a medical-grade ECG signal for arrhythmia diagnosis.

VI. CONCLUSIONAND FUTURE SCOPE

It is described in this study how a solar-energy-based wearable sensor network device can be used to deploy WBANs for Internet of Things Cloud systems. A variety of physical signals, such as the ECG, SPO2 levels, as well as pulse and temperature, can be detected by the sensors in the suggested device, which can then be transmitted to an Internet of Things cloud for monitoring and analysis. The results of the experiments suggest that the proposed gadget can perform effectively when powered by a rechargeable solar panel battery and other renewable energy sources either in normal conditions or pandemic situations (COVID-19). The proposed wearable sensor node could be improved even further in terms of usefulness and wearability, for example. To make the sensor node more wearable, the shape of the sensor node can be altered, for example, to a wristband shape. They can be used in conjunction with apparel to produce a smart T-shirt made of textiles, which allows the solar panel to be exposed to greater amounts of sunlight. The use of additional sensors capable of gathering other vital human physiological metrics may be considered for inclusion. Additionally, it is possible to protect the data integrity of a large number of patients' vital information to prevent cyber-attacks. Using artificial intelligence and medical diagnostic algorithms to improve the accuracy and predictability of patient evaluations, such as detecting arrhythmic patterns in ECGs and anticipating fatalities before they occur, we will be able to improve the overall quality and length of patients' lives, as well as improve the quality and longevity of their lives.

Conflicts of Interest

Authors declares that he/she has no conflicts of interest.

Data Availability Statement

Data sharing not applicable to this article as no datasets were generated or analyzed during the current study.

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