# IoMT Cloud-Based Body-Area Network for Remote Healthcare Monitoring

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***Abstract*– With the strain on healthcare infrastructure and healthcare workers due to the ongoing COVID'19 pandemic, the need for novel ways to simplify the interaction between patients and physicians has increased. The aim is mainly to reduce face-to-face interactions and free more time and resources for those who urgently need it. This paper presents a Telemedicine system which can be used as an alternative method to a doctor's visit. The proposed system is considered as an interface that remotely connects the patient and the doctor. The system regularly measures and uploads readings from the patient to a database which the doctor can remotely review to decide on the state of the patient. The whole system is based on the internet of medical things (IoMT). In the proposed system, sensors collect and send data over the internet using the WIFI module connected to a node MCU controller. The developed prototype uses two sensors, one is used to measure both the percentage of oxygen in the blood and heart rate while the other sensor measures the temperature of the human body. The aim of this work is to help patients, by offering them this solution which can help them get the care they require from the comfort of their home and at the same time help doctors remotely give them the suitable treatment while reducing the need for unnecessary face-to-face interactions.***

***Keywords-- IoT, telemedicine, sensor networks, IoMT.***

## I. Introduction

Nowadays, the percentage of people who suffer from chronic diseases is increasing daily. They suffer from critical issues such as diabetes, blood pressure, irregular heart rate, to name a few. Consequently, patients that suffers from one of the previously mentioned diseases must check them regularly to avoid any critical issues that could lead to serious complications which can include death. However, most patients are too busy that they forget to check their health status at the required time. More recently, due to the Covid-19 outbreak, temperature and blood oxygen levels have also became important to measure daily as they can help indicate if you are infected or not. As a result, wearable medical devices became a focus of attention that can be used to make lives easier and healthier. Wearable devices allow patients to check their basic telemetry anytime during the day without having to visit a hospital or a clinic. And so, wearable devices became crucial during the pandemic as they can be used as alternative means for anyone to monitor their health by themselves which in turn reduce the strain on the already over-worked healthcare system.

Wireless communications are normally used with wearable devices as it is not feasible to extend a wire to the patient while they are out of the hospital. And so, in order to monitor the health of the patient accurately, a wireless body area network must be created. The network that is created becomes a part of what is known as Internet of Things (IoT). In this case, since the IoT is made specifically for the use in healthcare, it is referred to as the internet of medical things (IoMT). Here, the proposed IoMT is deployed to receive and transmit data directly between the devices and the server seamlessly without human interference.

In this paper, we present a health care monitoring system that consists of very simple and cheap components which measures health readings from a person, sends those readings wirelessly to a server over the Internet. That server can be accessed anytime either by the patient or their physician. This allows the physician to monitor the patient remotely which reduces the need for face-to-face interaction which, in turn, reduces the risk of contamination. Additionally, notifications and alarms can be used in the system to notify the physician or emergency services of any sudden changes in the readings of a certain patient. A simple illustration for the whole system is shown in Figure 1, which begins to work when the patient wears the device and connect the sensors. The device then starts its process of measuring. Next, the measured data is be sent using the Wi-Fi module associated in the controller over the internet until it reaches the database that is stored online, after that the physician can access this information remotely anytime.

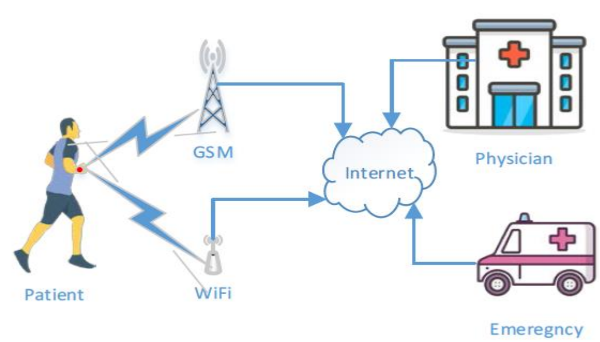


Fig. 1 System overview.

The rest of the paper is organized as follows; Section 2 gives a brief background on the internet of things. Section 3 discusses some of the IoT platforms available in literature. Section 4 introduces the hardware devices used. Section 5 introduces the prototype and results. And finally, Section 6 concludes the paper.

## II. Internet of Things

Drastically over the years, the Internet has changed how people communicate. Currently, there is a higher probability of connection available most of the time regardless of any chronological and geographical restrictions. This was not going to be possible without the revolution and advancements of equipment's in the field of hardware and software. This allowed the creation of the Internet of Things (IoT) which allows literary anything to interact with other things through the Internet [1].

An IoT network involves physical objects electronically embedded with circuits made up of sensors and connected networks that enables these devices to exchange and collect data. This advantage not only provided the basis for the collaboration between humans and things; but also, among the things themselves as well. Consequently, IoT's main aim is to impact each aspect of every-day life. Thus, the evolution of IoT applications becomes challenging as the time passes [2].

The numerous possibilities that the IoT provides opens a wide range of applications involving intelligence and better way of life. Some of which already have been implemented and available nowadays. For example, providing smarter homes, transportation system, offices, hospitals, and factories.

Some of the applications that can be developed from the use of the IoT are shown below in Figure 2. Next, we list some of those applications.

Fig 2 Example applications for IoT.

### A. Wearable devices

Wearable devices are considered an application which is based on internet of things. It allows the remote monitoring of the wearer by the help of sensors that are embedded in the device itself. The work done in this paper is considered a part of the Internet of Medical Things (IoMT). It is the collaboration of some medical devices with the IT systems using online computer networks. For example, when the sensor which is used to measure the percentage of oxygen in blood gets the reading, it sends the measurements using Wi-Fi to a webpage which is created for both the doctor and the patient. Then the doctor can diagnose the patient remotely, if the reading is not similar to the normal case, the doctor will tell the patient about the suitable medicine or inform them to reach out to the nearest hospital according to the case. Wearable devices can be represented in the form of accessories such as a watch, eyewear or it sometimes can be integrated in a piece of clothes. Besides performing the basic tasks of a smart phone or laptop, these devices are also tracking the user's health, so these devices are playing an essential role in some patient's life [3,4]. Recently, wearable devices have been utilized by many corporations because they provide safer work conditions and reduce deadly accidents due to tiredness or other sickness, it mends client support, and it rises output. [5-7].

### B. Smart Medicine Dispensers (SMDs)

Smart medicine dispensers offer computerized reminders and medicinal drug recording functionality for better remedy. Looking at the latest traits in wearable devices and IoT, we can count on a fast surge in applications in the coming years. On this level, we can provide a top-level view of the improvement of wearable gadgets and IoT for health care programs and take their influences on reforming healthcare.

Many systems have been proposed for SMD. In [8], the authors developed an SMD prototype used to help the patients, primarily seniors, take their medications on time in an easy way without the possibility of missing pills and to reduce the risk of accidentally over or under dosing. Not taking medications correctly can have serious consequences such as delayed recovery, illness and even death.

Additionally, the authors of [9] have proposed an SMD system that uses a 4x4 matrix keypad, Microcontroller, LCD display and Real Time Clock (RTC) module, GSM module and an alarm system used to intimate the patients to take proper dosage according to the prescription at right time. The paper showed that their proposed portable and economical SMD system would help aged patients, especially to the illiterate patients

Overall, those smart dispensers can be a instrumental during the Covid-19 outbreak or any other future outbreak because they reduce the load on pharmacies and hospitals not to mention that they, by design, reduce face-to-face interactions.

### C. Monitoring

To monitor the previous mentioned information, monitoring must take place to show the gathered data to users. So, wearable health monitoring gadgets create a unique section of healthcare named as Telehealth or Telemidicine. The primary gain of the Telehealth device is that doctors can collect information about patients in anytime and anywhere which saves time. Many people have smart watches to see their activity, whereas patients have monitoring devices that can be used to control diseases [10].

The term "Telemedicine" or "Telehealth" refers to the remote transportation of healthcare services, such as medical checks or consultations, over the telecommunications infrastructure. Telemedicine allows healthcare companies to evaluate, diagnose and treat patients the use of common technology including video conferencing and smart phones, without the need for an in-person visit.

D. *Smart* Cities

A smart city is an urban area that uses different types of electronic methods and sensors to collect data. Insights gained from that data are used to manage assets, resources, and services efficiently; in return, that data is used to improve the operations across the city [12]. This includes data collected from citizens, devices, buildings, and assets that is then processed and analyzed to monitor and manage traffic and transportation systems, power plants, utilities, water supply networks, waste, crime detection, information systems, schools, libraries, hospitals, and other community services.

Now that more and more cities are joining the smart city imitative, more efficient, and widespread techniques are being developed in order to improve the way critical data is retrieved, processed, stored and disseminated. If this is deployed correctly, it will potentially improve the detection and mitigation of outbreaks while reducing the execution time when taking critical actions [13].

Smart city infrastructure was shown to be very important in containing the Covid-19 outbreak. As sensors were already spread around the city, the data was already collected, and only small updates were needed to help trace and manage the spread of the virus. Additionally, with the cameras, contact tracing became much easier.

## III. IoT Platforms

As mentioned previously, the concept of IoT is to make anything connected to the internet. Anything here includes non-living and living entities, creating a network between them so that they can interact with each other. This connection can only happen if each network is fully identified and available to further networks as well. Availability rises when giving each object a certain identifier, position, and status so that it can be reachable from other networks. There are several prototypes that can be implemented: for example, RFID, sensors, and system on chips, which all help in the evolution for the internet of things [14]. One of the most used platforms is the Thing speak IoT platform [15]. Thing Speak provides software application for IoT systems. It supports the construction of the application, and it functions whenever there are a collected amount of data from sensors. Thing Speak is also an exposed platform. It complements both the existing creative system as well as systems that supports the internet of things. To add, it offers the capability and chance to show your data either with various platform out there, technologies or systems that includes another platform of microcontroller such as Arduino.

When creating an email based on MATLAB workspace, it creates number of channels. Those channels are made to guide and send data. So far, there are 8 channels each can hold up to 8 fields that takes different data types, one status field, and 3 location fields. As this step is completed, we can distribute the data amongst the channels provided. Next, the data are handled, and the data is retrieved back from the application. IoT systems are supported by Thing Speak platform through these different functionalities. Mainly:

1. Collect: this step involves sensing by the sensor; then, collecting the data from it sends it to the internet cloud for further analysis.
2. Analyze: virtual presentation of these data can be analyzed from the received data through Thing Speak.
3. Act: after analyzing step is completed; then, it will prompt the empowering function specified by the user to output the data of the IoT systems.

The work done in this paper uses the Thing Speak platform [15] mainly to collect and show the healthcare measurements and to allow access to those results remotely. Next, we discuss more the hardware devices that were used in this work.

## IV. Hardware Devices

The system used in this work is very simple and user-friendly allowing users to interact with the device without facing any problems. It simply consists of Node-MCU Module, heart rate sensor, temperature sensor, blood pressure sensor, and Oximeter sensor. All the previous mentioned sensors are connected to the Node MCU module which is the controller for the whole prototype.

The operation of this system is to gather the data observed by the sensors, then these data will be sent via the Wi-Fi which is in the MCU module to the constructed webpage. Now, the used components will be discussed in detail.

Fig. 3 NodeMCU module.

It is an open-source board which is developed based on the technology of the Wi-Fi module ESP8266. It allows the users to connect to the Wi-Fi module using Arduino. It is a very versatile device as it is a well-balanced CPU with Wifi capabilities. This has allowed it to be used in many works in literature such as [16] where the authors used it to create prototype for a heart rate monitor that monitors the results from multiple individuals simultaneously. It is also used in [17] as a distance measuring device using RSSI information. As well as an environmental monitoring device in [18].

Fig. 4 Max30100 Sensor.

The MAX30100 is a device that combines two sensors, oximeter, and heart rate sensor. It is used to measure the percentage of oxygen in blood, and the heart rates. The structure of this sensor is that it contains two LEDs, optimized optics, photo detector, and low-noise analogue signal processing to detect the two signals. MAX30100 needs 3.3volts as a power input. Its low cost and small size and power consumption has allowed its use in multiple IoT projects such as [19,20] where it was used as in an IoT oxygen saturation monitor, and in an IoT heart rate monitor, respectively.

The concept of non-contact temperatures values is represented by the MLX90614 infrared temperature sensor. There are two aspects to be taken into consideration, which is the ASSP signal conditioning and the IR sensitive thermopile, which is a chip used for detection both are mounted in the same chip. It consists of a 17-bit Analogue to digital converter, low noise amplifier, high resolution and accuracy, and powerful digital signal processing unit. It is also used extensively in IoT work in literature such as in [21].

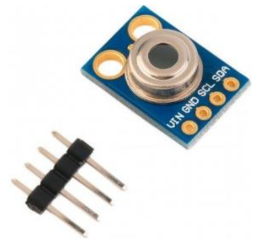

Fig. 5 MlX90614IR Temperature Sensor.

## V. Prototype and Results

In this section, we present a complete prototype of the proposed system and show the results that was collected from the experiments.

The Prototype was made using a NodeMCU device connected to a MAX30100 sensor and a MLX90614R sensor. Using the WiFi capabilities of the NodeMCU module, collected data is sent over the internet to the thing speak website for storage and presentation.

The MAX30100 sensor consists of two LEDs, one of them emits red light, while the other emits infrared light. The first LED is used to measure the pulse rate, while the combination of the two LEDs is needed to calculate the percentage of oxygen in blood (SPO2). The output results from the NodeMCU terminal window after connecting the sensor are shown in Figure 6.

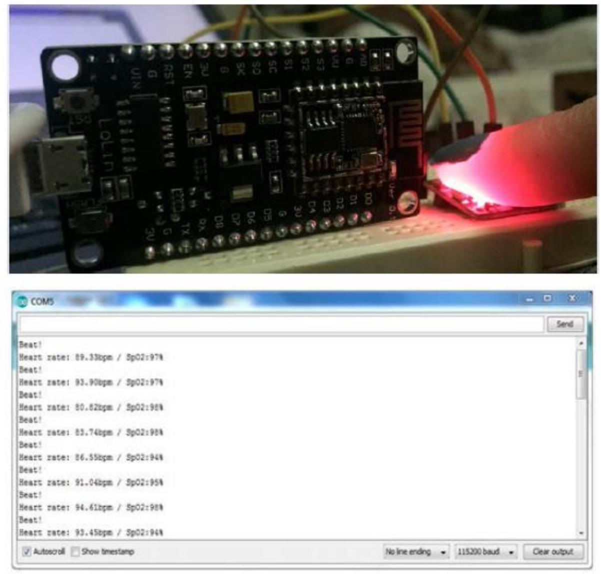


Fig 6 Operation using the MAX30100 Sensor.

MLX90614 is an infrared temperature sensor, which is used to measure human temperature by measuring the amount of infrared radiation that is emitted from the object. It consists of a lens which is used to focus the radiated infrared radiations to the detector. This detector is used to transfer the radiated energy to an electrical signal. So, the previous operation facilitates the measurement of temperature from a distance, without needing to contact with the object to measure. Figure 8 shows the output results.

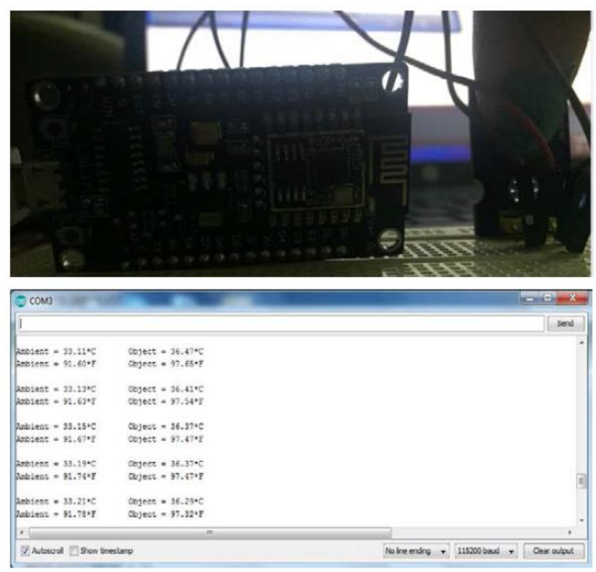


Fig 7 Operation using the MLX90614IR Sensor.

As mentioned earlier, all data connected from the sensors are sent over the internet to the think speak website. The output from the thing Speak website are shown in Figures 8,9, and 10.

Fig 8 SPO2 results.

Fig 9 Heart Rate results.

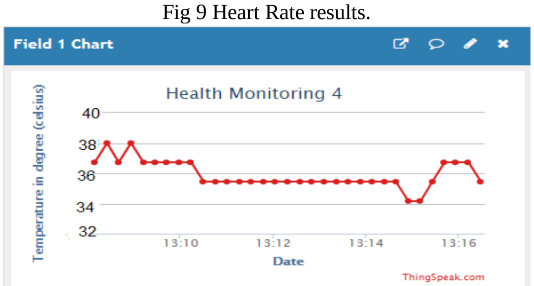

Fig 10 Temperature results.

The final circuit is shown in Figure 11.

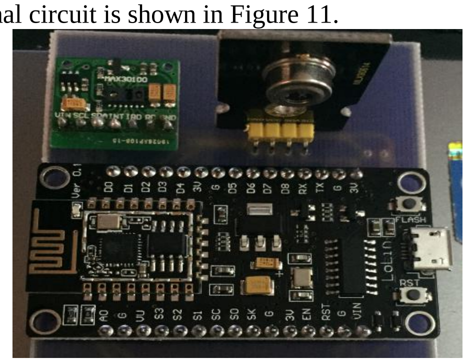
Fig 11 Final circuit

## V. Conclusions

This paper discussed wearable devices that are considered very important in every human life, as they facilitate to the patients that suffer from chronic diseases and need to be constantly monitoring their telemetry and change their medications accordingly. The need those devices has increased drastically because of the Covid-19 outbreak which led to a strain on the healthcare systems all over the world. The work done in this paper aims to reduce some of that stress by creating a remote healthcare system that reduces or even completely removes the need for face-to-face interaction between patients and physicians. The proposed system measures basic telemetry such as, temperature, heart rate, and blood oxygen level. Sends those measurements to an online data base which can be accessed by the physician remotely. The system is small, cheap and can be easily installed and operated with minimal technical experience.

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