# *IoT-Pulse Oximeter Sensor*

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***Abstract* — For healthcare, internet-focused sensors have become important later. Because the biggest problem in health services is that people have to pay thousands of fees just to get a diagnosis for their illness. It takes a lot of money to get treatment. For governments, the density in health systems creates huge problems. Devices that can be a solution to these are sensors. The most used sensor in healthcare is the oximeter sensor. Oximeter sensors are a sensor focused on oxygen, the basic molecule of our life. Oximeter sensors are used to measure values such as heart rate, and blood oxygen level (SpO2). In fact, by sending these values to the necessary places over the internet (IoT), results can be obtained quickly, and early diagnosis of diseases can be made. Therefore, sensors provide one of the simplest and fastest methods of discovering the oxygen levels in the blood. Another method used is blood testing, but it is inefficient compared to oximeter sensors in terms of cost and time. In outpatient treatments, the oximeter sensor is often better. Usually, finger-type sensors are used. However, there is more than one type. Such sensors are realized by IoT methods and studies. In this article, after a short introduction, we will examine different measurement methods with a literature review and present our design in the finding section. Although it is a simple demonstration, we think that this design will be useful in future studies.**

**Keywords—Oximeter Sensor, Oximeter, IoT based Oximeter Sensor**

## 1. INTRODUCTION

The main problem of the world is health. Without health, the individual does not exist and begins to indirectly affect everything on Earth. It is one of the most basic needs. This needs to be fixed first. Elimination of health problems is also a problem. It requires huge resources. However, countries can't allocate such a large resource to just one sector. Countries compete with each other to find a solution to this. Thanks to the development of technology and the increase in knowledge in recent years, we can say that this problem has been partially solved. The mainstay of this solution is IoT.

Thanks to the ideas brought by the IoT, products that interact with the internet have emerged. Thus, everyone has started to leave data traces on the Internet. Big data operations are required to make sense of these data traces. It has been partially solved with different algorithms.

Our main focus is on how this data is produced. The answer to these is sensors. Thanks to wearable devices, which are wonders of technology, instant health data of people can be kept and analyzed on the internet. The most basic sensor we will focus on from these sensors, which are excellent data collection tools, is the Oximeter sensor.

Oximeter sensors operate in a pulsating manner with a detector with two different wavelength sources. One wavelength is 660 nm (red) and the other wavelength is 940 nm (infrared). Oxygenated hemoglobin (O2Hb) absorbs more infrared light than reduced hemoglobin (RHb), and reduced hemoglobin absorbs up to 10 times more red light. [1] These sensors also find the difference by comparing the amount of light absorbed with the wavelengths. An estimated value of the amount of oxygen in the hemoglobin is then reached. That is, the total hemoglobin content consists of O2Hb and RHb. The amount of oxygen can be reached according to the wavelengths they can absorb. However, errors can occur in these as well. For example, methemoglobin and carboxyhemoglobin absorb wavelengths similar to the parameters mentioned above. Due to this, an incorrect value of the amount of oxygen in the cell can be reached.

As with any sensor, such errors can occur with these sensors. It may be necessary to give examples of different error sources. One of them is physical movements. Moving during measurement may cause erroneous results. Another mistake is lipids and bilirubin values. Many more examples of errors can be given. However, a table is given below as an example. You can view it from there. Taken from the Mardirossian and Schneider article [1]. You can examine it in more detail in Figure-1.

| *Error Source* | *Effects on* $SpO_2$ | *Response* |
|---|---|---|
| Hypotension | Possible loss of signal | Correct underlying problem (eg, give fluid challenge, lighten anesthesia), vasopressors |
| Vasoconstriction (Reduction of blood flow to arterial bed) | Possible loss of signal, reduction of $SpO_2$ | Change to more central site |
| Hypothermia (Reduction of blood flow; seen in Pts. w/Raynaud's disease) | Possible loss of signal, reduction of $SpO_2$ | Keep patient and extremities warm |
| Shivering/muscle twitching | Changes in pulse size, possible loss of signal | Warm and/or sedate patient |
| Carboxyhemoglobinemia | Falsely high $SpO_2$ reading | Increase ventilation, eliminate rebreathing |
| Methemoglobinemia | Falsely low readings approaching 85% | Administer methylene blue |
| Venous pulsations | Falsely low $SpO_2$ readings | Change site |
| Blood pressure cuff on monitored arm | Loss of signal decreases $SpO_2$ | Change site |
| Arterial lines on monitored arm | Loss of signal decreases $SpO_2$ | Avoid use of arteries in monitored arm |
| Intense bright light (eg, fiberoptic fluorescent lights) | Lower $SpO_2$ readings | Avoid exposure of photodiode to light |

Figure -1 Different Types of Errors [2]

Sensors now form the basis of healthcare. It is used in every field. Of course, these can be used thanks to IoT. Without IoT, the presence of sensors will only benefit the person, maybe not even that benefit. Therefore, these sensors need to be developed in collaboration with IoT. The most basic data output by oximeter sensors is SpO2. The partial pressure of oxygen dissolved in arterial blood is termed PaO2. The percent saturation of oxygen bound to hemoglobin in arterial blood is termed SaO2. When measured by a pulse oximeter sensor, this value is called SpO2.

$$SpO_2 = \frac{(HbO_2)}{(Hb)+(HbO_2)} \times 100\%$$

Used correctly, the oximeter sensor is a potentially life-saving tool. Healthcare providers need to be aware of oximeter sensor results, benefits, and drawbacks. More importantly, clinicians must be able to interpret the information provided by the oximeter sensor. With proper education and training, clinicians will find the oximeter sensor an invaluable monitoring tool.

In short, oximeter sensors play a very important role in diseases such as lung and chest diseases, pneumonia, asthma, chronic respiratory failure, COPD, and cancer. It first appeared in the 1970s. Its working principle is based on detecting the oxygen ratio in the blood, thanks to the wavelength of the light passing through the skin surface. There are sensors consisting of light sources on the devices (including an oximeter sensor). You can examine the oximeter sensor in Figure-2. The measurement is achieved by placing limbs such as fingers or earlobes between the sensors. Its basic output is also SpO2. You can see different sensor examples in Figure-3. The foundations on which sensors are based is everything that is done thanks to IoT platforms. Also, IoT design ideas are used. Therefore, it is necessary to make a brief introduction to IoT.

While the oximeter sensor is generally safe, there are some risks when using it. If the light-emitting diode overheats, the sensor may burn or swell. If the probes attached to the patient are placed too tightly, it may cause some complications. Corneal abrasion can develop if the patient scrapes the cornea after awakening from anesthesia and touches their eyes with the probe on their finger. Long-term use of a pulse oximetry probe can leave injuries such as finger stiffness in intensive care patients. Although these results have been reported, they are unlikely to occur.

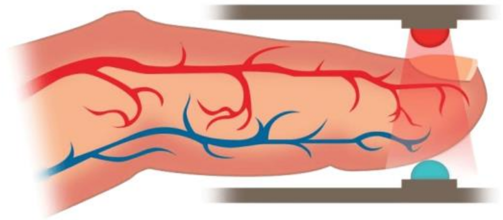

Figure – 2 How to Use the Oximeter Sensor

| Sensor | Communication Method |
|---|---|
| LM35, Pulse Rate Sensor, Grove-gas sensor | ESP8266/WiFi |
| Pulse Sensor, LM35 | Bluetooth |
| PPG Sensor, OLED SPO2 | Bluetooth |
| Pulse sensor, MLX90614 temperature sensor, MPU6050 accelerometer sensor | ESP8266/WiFi |
| PPG sensor | Bluetooth |
| ECG, accelerometer | Xbee RF |
| ECG sensor, LIS331DLH accelerometer sensor | Bluetooth and Wifi |
| LM35 temperature sensor, TSL257 PPG Sensor | nRF24L01 |

Figure – 3 Different Types of Sensors [3]

### 1.1 Internet of Things

The Internet of Things (IoT) is a network and technology platform that uses electronic devices such as sensors and cameras, without focusing on people.

It is a system that provides data exchange and flows thanks to cloud servers and also facilitates these operations. IoT systems, which are constantly developing, find themselves in every field. Every day, there are new methods that make human life easier. One of them is oxygen sensors. These systems, which focus on human health, can communicate with each other over the internet. When a problem occurs in the oxygen level in the blood, it can save human life by contacting the hospital or similar institutions. In other words, it can provide early diagnosis instantly.

The IoT consists of users and sensors that communicate and monitor each other simultaneously over the network via the user interface. Some recent technological advances are allowing the emergence of IoT such as nanotechnology, wireless sensor networks, mobile communications, and ubiquitous computing. There are some difficulties such as [4] sensors, communication methods, protocols, etc.

In communication methods, the speed of the data delivery process is most important. If data is transmitted quickly, transactions will also be made quickly. When we do not apply this to our sensors, any delay in sending information or misdirection has the potential to both increase the density of the system and result in the death of the person. Thus, we have clarified how important a criterion is.

Oximeter sensors focus on older people. Elderly people, heart ailments, etc. diseases are more common. Therefore, while developing these sensors, it is necessary to take action by considering the body conditions of elderly people (to prevent the errors that occur as we mentioned above). That is, it is possible to adopt the Internet of Things (IoT) and use sensors in these areas to improve living conditions, especially for the elderly.

Health monitoring systems using IoT can utilize a variety of sensors, microcontrollers, and user interface devices, as well as provide secure, efficient, and intelligent services to applications. Thanks to these, the efficiency and security of the system can be ensured. So why are they important? I'd like to focus on efficiency first. The higher the efficiency, the better. Because, when any complication occurs, criteria such as the rapid response of the systems and the accuracy rate become important. Any deficiency in these could result in a person's life.

As a result, the doctor can analyze the patient's condition using sensor readings. In the next step, it can be used as RFID technology or in the clinic as the patient's card, so that it is easier to know the identity of the patient while recording, while the patient's record is found. Transactions become faster due to this.

## 2. Wearable Sensors

Wearable sensors are gaining importance because the application and usage areas of their sensors are people, and even their purpose is to make people's lives easier. IoT methods that we mentioned above are also used in these. The main purpose is to collect data instantly with these sensors and forward them to the necessary authorities over the internet. There are not many oximeter sensors as direct wearable sensors. It is often similar to the sensors used by diabetics.

Some studies have developed devices to obtain personal health information instantly with low-cost sensors [5]. These devices are a basic solution to expensive inspection fees. Heart rate sensors and oximeter sensors are examples of these devices. Another study uses a smartwatch as a health monitoring device to monitor vital conditions such as temperature, heart rate, blood oxygen, stress level, and blood pressure [6]. Also, via Bluetooth, the data is sent to the mobile phone connected to the database, which is the cloud server. This is an example of a data transfer scheme. You can see this in Figure-4 and Figure-5.


Figure- 4 Wearable Sensor Diagram

To talk about the rest of the article, in the Literature Review, we will examine the sensors that have been made and developed in this area. We'll also go into the details of what they focus on, apart from how they were developed. In the Findings section, we will examine the sensor structure that we have constructed. It won't go into too much detail, usually, the general framework will be created to form an idea. In the Conclusions and Recommendations section, the sensors mentioned in the article will be discussed in a general way, and their benefits to the people and organizations will be mentioned.

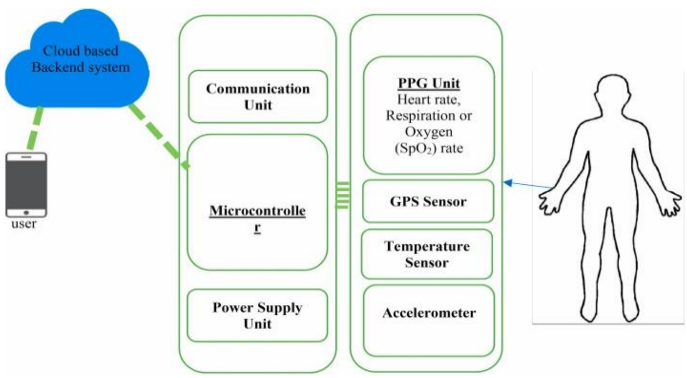


Figure-5 Example of IoT Platforms

## 3. Purpose of Paper

The main purpose of what is mentioned in this article is to explain oximeter sensors and similar ones to people in a simple way, which can help reduce the clutter in the health sector to some extent. Thus, a result can be achieved that everyone can benefit from. We can show both how important IoT methods are and how highly applicable they are. The main purpose in these areas is always to facilitate and improve human life.

## 4. Literature Review

First, I want to start with the methods used in others articles. In this article [7], they tried to detect the changes in the amount of oxygen in the blood by covid-19 using oxygen sensors. A 3-layer structure is considered: Wearable IoT layer, Cloud layer, Web frontend layer. Instant data from the Wearable IoT layer is delivered to the required places with the Cloud layer. Experts can see this data with the web frontend layer. This is how the system is set up. The SpO2 level in a normal person ranges from 95% to 100%. If the sensor is 94% and below, it shows that the person has covid-19. The basic principle we talked about is used. Using IoT systems, the presence or absence of covid-19 is found with the instant data obtained. By sharing this information with experts, it is ensured that the necessary treatment is applied quickly. To achieve this, the Spark Fun pulse oximeter sensor is used in this article. It is a wearable device and is said to be more efficient and cheaper than other products. The chip used for this sensor is the MAX30101. MAX30101 senses the LED to know the light absorbed from the arteries and photo detect the sensor confidence from the finger detection data as the dimensions of the chip are small enough as 25.4 mm × 12.7 mm. [8] It works with a very small margin of error of 3%. This article says that real-time monitoring of SpO2 can do covid-19 detection with a high success rate, also to experience health conditions during sleep apnea. Apart from the focus of our subject, more than one sensor (Basic physiological sensors, Body temperature, etc.) has been used in the detection of covid-19 in this article. This shows how functional IoT is.

Another article focused on the wearable sensor working with microservices [9]. It is aimed to obtain the basic parameters of the person. Wireless Body Sensor Networks were mainly used in covid-19 detection. Each sensor in it is connected to the other in the form of nodes on the IoT cloud (where data is analyzed and visualized). The analyzes obtained thanks to this framework are shared with people. The sensors in the framework can be listed as follows: Temperature Sensor, GPU sensor, PPG Unit (Heart rate, Oxygen Rate (SpO2)). These sensors are both interconnected and located in the wearable device in the person. Thanks to microcontrollers, the necessary data is delivered to the user. In this way, similar to the first article, covid-19 detection can be made quickly, and solutions can be offered accordingly.

This designed framework is designed to be used in different places. In this way, it can be used to obtain different information.

In another article on changes in oxygen content in covid-19 patients, a different design was used [10]. I should point out that they all have IoT processes and sensors at their core. The aim here is to explore the oxygen exchange in the blood using the different wavelengths we mentioned at the beginning. In this way, it helps the discovery of diseases such as asthma, anemia, pneumonia, lung cancer, COPD (Chronic Obstructive Pulmonary Disease), and CHF (Congestive Heart Failure) that cause oxygen exchange in the blood. A small oximetry sensor is attached to the patient's finger while the embedded system reads oxygen saturation and pulse. There is no contact. Thus, the PPG (data association mentioned in the previous article) signal captured by the sensor is converted into a digital signal by the presented system. This signal is also converted into necessary digital data by the platform microprocessor. This data is transferred to an online database, which will then provide visualization. (Similar to Hadoop) Specialists such as a doctor can access this data to examine the patient's condition and can be visualized to make it easier to understand. The main advantage of this system is that the doctor does not have any physical contact with the patient that could become infected. Also, if the patient's health is deteriorating rapidly, specialists can quickly contact the emergency services teams for the patient's treatment. As a result of this article, here are some of the benefits that the oximeter sensor provides:

- Monitoring oxygen exchange over time
- Warning of dangerously low oxygen levels
- Evaluation of supplemental oxygen need
- Indicates dangerous side effects in people taking medications that affect breathing or oxygen exchange.

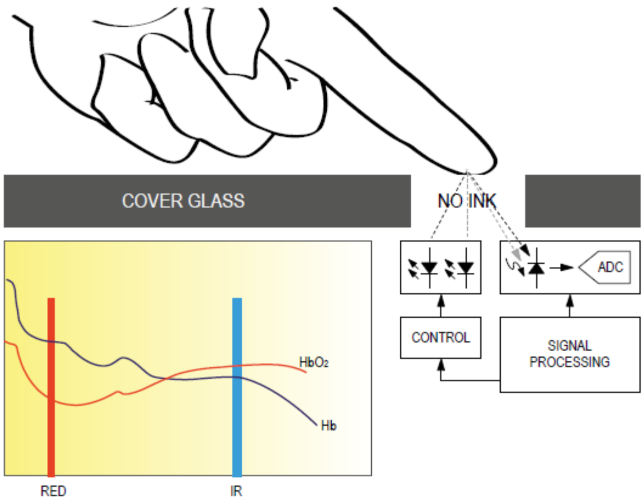


Figure- 6 Oximeter Sensor Usage Method

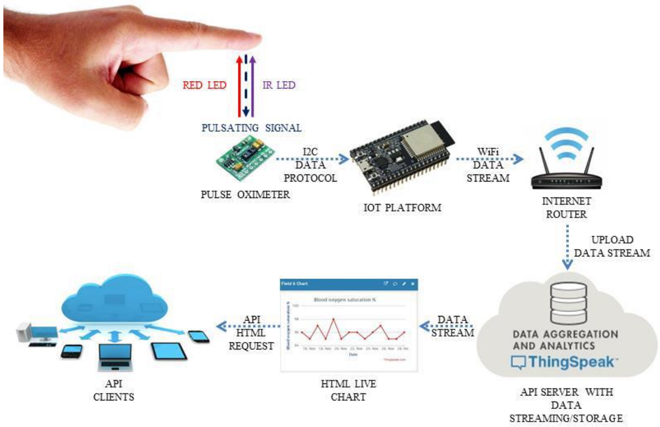


Figure- 7 IoT Methods and Sensors Used in Article

Recent articles about the oximeter sensor are usually about the changes caused by covid-19. Therefore, in this article, they developed a system using information from covid-19 patients. The results of this research can be summarized as follows [11]:

1. Based on IoT, Vehicle Pulse Oximetry Kit uses an Oximeter BLE Sensor to measure dissolved O2 levels in the blood, and then the data is processed by ESPDUINO-32 and sent to the database by NodeMCU.

2. Determining the minimum limit of dissolved O2 levels in the blood during the research and trial phase,

conclusions can be drawn from this study. No matter how different designs and kits are used in each article, the result has always been the same. IoT is the basis for making such applications.

The other article [12], includes the reduction of health systems to mobile. In this paper, we used the Wi-Fi protocol IEEE 802.11, standard IPv4 address, beside a 3G cellular network to send data from sensors to the mobile application “Blynk”. Moreover, NodeMCU and Arduino UNO microcontrollers are applied. For their implementation, the Blynk mobile program, an IoT platform, was used. It receives, stores visualizes data, and provides hardware control remotely. This article focuses not only on the change of SpO2 value but also on parameters such as ECG signal and heart rate. It is aimed to develop useful equipment for people with chronic cardiovascular problems and those who have had a heart attack.

The SpO2 (Saturation of Peripheral Oxygen) parameter indicates the ratio of oxygenated hemoglobin amount to the whole hemoglobin amount. It is a very important parameter for cells to do their job properly. To summarize, this study proposes an experimental model to develop a wearable, real-time remote bio-signal monitoring system based on IoT technology.

Validation is accomplished by comparing project findings with medical devices used by doctors and healthcare professionals. Additionally, these bio-signals were performed with the Blynk mobile app. This allows health practitioners to monitor and diagnose several health parameters simultaneously. The circuit design used in this study is given in Figure-8.

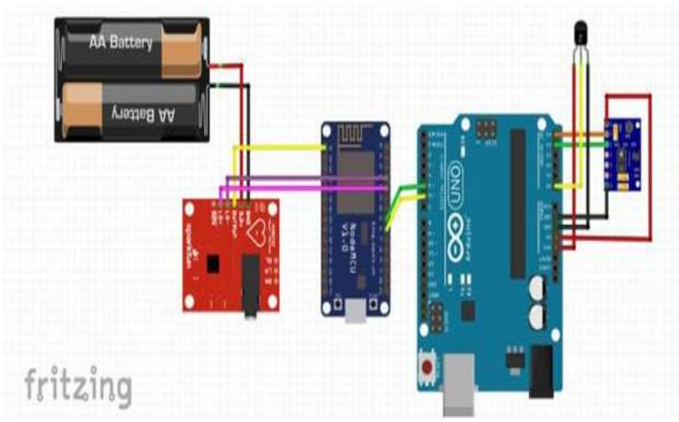


Figure- 8 Circuit Design Used in Article

In our last article [13], the authors used different sensor network technology such as LoRa in their designs. MySignals and LoRa are used in conjunction with an electrocardiogram (ECG) sensor, temperature sensor, pulse rate sensor, and oxygen saturation sensor. This research has tried to evaluate the performance and effectiveness of different sensors and different wireless platform devices with data analysis methods. MySignals enables the sensors focused above (Oxygen saturation and oximeter sensors are important to us) to collect physical data. It carries out data transfer with LoRa using a wireless system so that the expert can examine the information from MySignals. According to the results, MySignals has been successfully used with ECG, temperature, oxygen saturation, and pulse rate sensors.

In this article, they built an IoT-based healthcare system on the MySignals platform based on the data obtained from the sensors. It also has a different structure than other short-range sensor network technologies such as LoRa, Bluetooth, ZigBee, Wi-Fi, and the like, and offers a unique set of capabilities such as Bu This wide-area connectivity for low power and low data rate devices. Lora has been developed as a solution to the current IoT-based health problems in 3G/4G systems, such as costly communication lines, data privacy problems, and lack of information on monitored health metrics, which are now a cause for concern in society. Because LoRa's medical sensors are the solution to these problems, it combines the cloud and gateways.

Figure- 9 Different Parameters Mentioned in [13]

| Human Body Characteristics | Normal Data | Sensor Data (Proposed System) | Issues |
|---|---|---|---|
| Body Temperature | 36.5–37.5 °C | 35.10–35.40 °C | Air condition environment |
| Pulse Rate | 60–100 bpm | 55–62 bpm | No |
| Oxygen Saturation (%) | 96–99 | 96–100 | No |
| ECG Values (Heart Rate) | 60–100 bpm | 60–100 bpm | No |
| ECG Values (Time Interval (s)) | 0.1–0.2 | 0.1 | No |

Figure-10 Different Network Technology Mentioned in [13]

| Network Technology | Data Rate | Transmission Range | Power Consumption | Battery Life |
|---|---|---|---|---|
| BLE | 1–2 Mb/s | 10 m | 40 mA TX, Standby 0.2 mA | 1 Year |
| ZigBee | 0.02–0.25 Mb/s | 100 m | 30 mA TX, Standby 1 µA | Week |
| Wi-Fi | 11 Mb/s–10 Gb/s | <1 km | 400 mA TX, Standby 20 mA | Hours |
| LoRa | 290 bps–50 Kbps | 15 km | 28–44 mA TX, Standby 1.4 mA | 10 Years |

## 5. Findings

The application that we designed collects the heart rate and O2 saturation using oximeter sensors application will return the data via MQTT messaging protocol [14]. MQTT will transfer the data to the data receiver is a microservice that we implement. Also, this microservice transfers data as raw data to a database. After transportation ended we process data with machine learning algorithms and finally we store the final version of data in the database.

MQTT is a publish/subscribe message transport protocol for clients and servers. It's light, open, and basic, and it's supposed to be simple to use. These qualities make it excellent for application in a variety of circumstances, including confined environments where a minimal code footprint is required and/or network bandwidth is limited, such as communication in Machine to Machine (M2M) and Internet of Things (IoT) contexts. The publish/subscribe pattern is a client-server architecture alternative. A client communicates directly with an endpoint in the client-server model.

The pub/sub model separates the client who transmits the message (the publisher) from the client or clients who receive the message (the subscriber) (the subscribers). Publishers and subscribers never communicate directly with one another. They are completely unaware of the existence of the other. A third component manages the link between them (the broker). The broker's responsibility is to filter all incoming messages and properly distribute them to subscribers. In this design, clients (publishers and subscribers) establish a link through a broker and communicate with one another.

After we collect data that we need from the smartwatch we process it again with Hadoop machine learning and after this process, we have two operations. In the first operation, all data from Hadoop will go to a server pc to classify which data is in danger classification. After classification sends a notification to an emergency. Also in the background pc will send data to the emergency database. Also, the emergency database will insert the information into the general database in the special table. Information that we explained above pc sends a notification to the emergency.

Notification will include phone, current address that was taken from GPS, name, surname, and reason to call. If emergency can't reach to person. The watch will send a notification if have an emergency case please press the yes button else please press the no button. If the owner of the watch press no button operation will stop. But the owner presses yes or there is no response came from the watch within the time limit. They will send an ambulance. The second operation is information that came from Hadoop directly stored in our general database. All information is based on the below diagram. You can Show in Figure-11 and Figure-12.

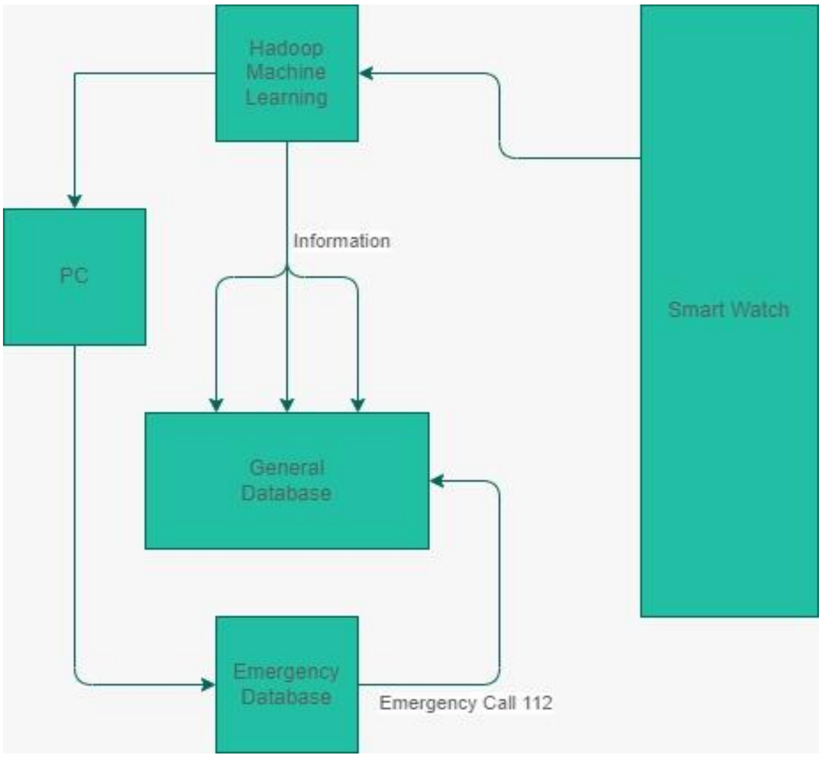


Figure- 11 Communication of the Sensors

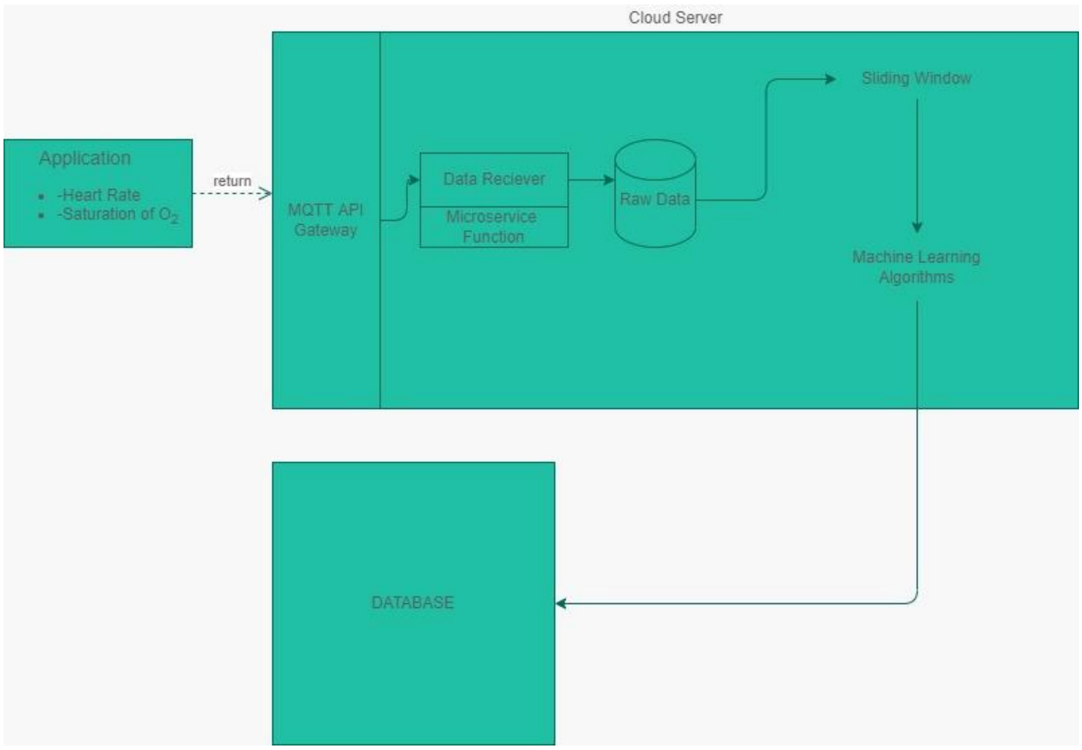


Figure-12 Design of Smart Watch

## 6. Comparison with Other Works

Unlike the methods used in other articles, the MQTT protocol was used. In others, cloud-based programs are generally used. Also, instead of using ready-made ML, our programs are applied on top of the data. In other parts, it is generally similar. According to the data results, experts are informed simultaneously, and it is tried to prevent people from experiencing any health problems. Apart from this, heart rate and Saturation of O2 parameters are obtained from the person with wearable devices. The condition of the person is examined according to SpO2 and heart rate, and the necessary method is selected. Everything described throughout the paper is also included in our design. The difference from other studies is the use of MQTT, as we mentioned above.

## 7. Conclusions and Recommendations

The main purpose of this article is to protect body health, which is one of the biggest problems in the World. Based on this, the use of IoT applications has now become a necessity. Wearable devices, which are the technology of the future, are also low-cost things that add functionality to the IoT. Because it can catch small changes that can be missed by people and can apply the desired treatment with high accuracy. Thus, both the weight on the health systems is reduced and the processes are accelerated. Articles generally use PPG sensors, not Oximeter sensors directly, because of the small device and utilized for several functions such as heart rate readings, blood pressure, and oxygen in the blood.

New systems and IoT frameworks can be developed by private companies using the sensors mentioned in the article. In this way, both the literature is developed and the recognition of IoT is increased. However, although these are the main effects, the main effect is of course the effect on people. The purpose of all these improvements is to make human life easier and to increase the average life expectancy. This lies at its core. Using the IoT, this goal can be easily achieved.

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