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ALTINBAŞ UNIVERSITY

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Electrical and Computer Engineering

**MONITORING VITAL SIGNS AND AFFECTING
ENVIRONMENTAL FACTORS BASED ON THE
INTERNET OF THINGS USING PARTICLE
PHOTON AND BLYNK IOT**

Anas Mohammed Younus ALFARHA

Master's Thesis

Supervisor

Prof. Dr. Galip CANSEVER

Istanbul, 2023

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The thesis titled “MONITORING VITAL SIGNS AND AFFECTING ENVIRONMENTAL FACTORS BASED ON THE INTERNET OF THINGS USING PARTICLE PHOTON AND BLYNK IOT” has been prepared and presented by ANAS MOHAMMED YOUNUS ALFARHA and submitted on 2/7/2023 has been accepted unanimously for the degree of Master in Electrical and Computer Engineering.

Prof. Dr. Galip CANSEVER

Supervisor

Thesis Defense Jury Members:

Prof.Dr. GALİP CANSEVER

School of Engineering and
Architecture, Altinbas
University

Assoc. Prof.Dr. Üyesi SEFER
KURNAZ.

School of Engineering and
Architecture, Altinbas
University,

Asst. Prof.Dr. YÜKSEL BAL

School of Engineering
Istanbul Topkapi University

I certify that this thesis satisfies all the requirements as a thesis for the degree of Master of Science.

Approval Date of Institute of Graduate Studies: ____/____/____

Name1 SURNAME1

I hereby declare that all information/data presented in this graduation project has been obtained in full accordance with academic rules and ethical conduct. I also declare all unoriginal materials and conclusions have been cited in the text and all references mentioned in the Reference List have been cited in the text, and vice versa as required by the abovementioned rules and conduct.

Anas Mohammed Younus ALFARHA

Signature

DEDICATION

I sincerely thank my great supervisor Professor Dr. Galip CANSEVER for helping me conduct the research and prepare the thesis. This thesis is wholeheartedly dedicated to my beloved family, who has been my source of inspiration he is the reason for my progress and success. I am very grateful to my mother,father, wife in particular, brothers and in particular my brother Ibrahim, My friend Bilal and beautiful family for their support, encouragement, and patience with me throughout my studies.



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ABSTRACT

MONITORING VITAL SIGNS AND AFFECTING ENVIRONMENTAL FACTORS BASED ON THE INTERNET OF THINGS USING PARTICLE PHOTON AND BLYNK IOT

ALFARH, Anas Mohammed Younus

M.Sc., Electrical and Computer Engineering, Altınbaş University

Supervisor: Prof. Dr. Galip CANSEVER

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Vital signs are indicator for recognizing a person's health. The increasing in body temperature, Saturation of Peripheral Oxygen (Spo2) or heart rate denote the presence of a pathological condition. The Internet of Things (IoT) role in the healthcare field has become an important role. This thesis aims to produce a healthcare system based on IoT using special sensors and Particle Photon, to monitoring the patient. In comparison with traditional measurement devices, the total average accuracy rates of body temperature, Spo2 and the heart rate sensors used were approximately 99.99%, 99.99% and 99.99% respectively for 25 cases. Then the same 25 cases with increasing in the temperature and humidity values of environment, the total average accuracy rates of body temperature, Spo2 and the heart rate sensors used were approximately 99.99%, 100% and 99.99%. In addition, two set of readings recorded from 7 cases, the first set recorded under the normal air quality while the second set recorded inside a room that polluted with cigarette smoke, the percentage of pollution in the air increases.

Keywords: Internet Of Things (Iot), Cloud, Sensors, Vital Signs, Particle Photon, Platform, Healthcare System.

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ABBREVIATIONS

BME	:	Biomedical Engineering
CBR	:	Case-Based Reasoning
IoT	:	Internet of Things
IDE Spo2	:	Integrated Development Environment Saturation of Peripheral Oxygen
RH	:	Relative Humidity
bpm	:	Beats Per Minute
AQI	:	Air Quality Index
PC	:	Personal Computer
ECG	:	ELECTROCARDIOGRAM
Blood Pressure	:	BP
LCD	:	Liquid Crystal Display
DC	:	Direct Current
LED	:	Light-Emitting Diode
PPM	:	Parts Per Million
TTL	:	Transistor–Transistor Logic
PCB	:	Printed Circuit Board
GUI	:	Graphical User Interface
SDA	:	Serial Data
SCL	:	Serial Clock
FO	:	Finger Oximeters

LIST OF SYMBOLS

$^{\circ}\text{C}$: Celsius Temperature Unit

$\%$: Percent

Δ : Delta

\approx : Approximately Equal

$||$: Absolute Value



1. INTRODUCTION

1.1 BACKGROUND

Day by day, the number of people is increasing and they need for repeated surveillance of their healthiness for healthy life. On the other hand, this leads to increase in cost and risks to ensuring care of general mass. In growing countries with less healthcare facilities and medical practitioners compared to popularity cannot cope up with this situation. For that reason, people are heading to low-cost, reliable, and without difficulty accessible health monitoring systems. This golden years of electronics with its quick development opened enormous chances in this field. Measuring instruments are also getting more compact and user friendly [1].

In latest years, the requirement for deployment of wireless telemetry systems in treatment greater than before significantly because of need for early identification of diseases and endless checking of physiological parameters. Microwave antennas and sensors are main components of these telemetry systems since they offer the communication sandwiched between the patient and base station. Metamaterials can have their electromagnetic properties changed to something beyond what can found in nature. Therefore, metamaterials were involved great notice between microwave engineers and physicists [2].

Because of the quick development of this field, in these years the Biomedical Engineering BME is being useful in the healthcare system, consisting of the diagnostic, cure, recovery and development of different healthcare devices. Electrical Engineering is an advanced field, and BME focus on the progress of technology that recovers human health and healthcare at all stages [3]. One of the most important scopes of BME is the observation of a patient's vital signs, Which used to analyze biomedical signals in real time.in addition, it may be can used to detect risky signs heart disease [4].

Vital signs are a measurement of the simplest functions of the body to distinguish clinical signs. This is suitable for detecting diseases and determining the suitable treatment proposal. There are four main physiological parameters used by Nurses and medical personnel to decide Patient's health status in hospitals. These parameters are body temperature, heart rate, respiratory rate and blood pressure [5].

Furthermore, patients must regularly go to the healthcare center to check their vital signs. In various cases, this manner needs a high cost and time to carrying the patients from home to the health center and needs long queue, for the reason that medical team need check vital signs manually and make sure that the patient is in normal state [5].

So that the solution of this problem is entering to the internet without the need for human mediation, which is the IoT. The Internet of Things (IoT) is a technology that enables physical things/objects to link with each other or to link larger-scale systems and exchange data to deliver well services to users and make their lives more accessible [6].

Smart healthcare systems, which IoT-based, are combined with a number of protocol types and heterogeneous networks via different technologies. The important purpose of creation this system is to monitor a patient distantly via assembling as much up-to-date body condition data as possible via electronic components named the sensors [6].

The IoT based healthcare summarizes several chronic illness tracking [7]. The proposed system uses the Particle Photon as an IoT platform and particle cloud simplifies the storing of historical data that required for an analysis of chronic Diseases.

Particle Photon is a microcontroller with a Broadcom Wi-Fi chip. It is programmed using Integrated Development Environment (IDE) software [8]. Comes together with its ownership, development and cloud management software [9].

1.2 PROBLEM STATEMENT AND CHALLENGES

Several problems can highlighted in the literature related to the healthcare system monitoring of patient vital signs can highlighted as follows:

- a. Technical respects get up from the detail that IoT is still not portion of daily life. The fifth-generation wireless technology (5G) and later IoT services are not exist in most countries. Not only the patients on the other hand also most healthcare practitioners and researchers are not well familiar with what IoT includes and what it do in daily life let away from healthcare [10]. Therefore, this hold back the implementation of the healthcare system.
- b. The systems, which IoT healthcare-based systems, should support the patient's mobility from any place to another place. For illustration, in some zones, a wired network is not available, so the patient should communicate to a wireless network or a mobile network.

On the other hand, if not any of the services is available, he should be linked through the mobile ad-hoc network [11].

- c. The increasing of the electronic components (sensors) require electric energy to process, in addition, it rises the power leakage and energy consumption. An optimization algorithm can be used to decrease the usage of energy [12]. Besides the loss of energy in places where the equipped power source is not available, which delays the work of the sensors, nonetheless with the setting up of replacements such as batteries or solar cells, it will service in the sustainability of the work of these devices.

1.3 MOTIVATION

The problems of the unavailability of fifth-generation wireless network services and the lack of knowledge of healthcare workers about IoT components, the loss of Internet in some places and the problems of energy leakage (when increasing the sensors) are obstacles that will increase the impact on any healthcare system that depends on the IoT. In addition, the disconnection of the network internet may lead to the failure to send the results of the vital signs of the patient, which leads to the inability of the doctor to communicate with the patient.

All these obstacles and challenges prompted us to create a health care system that relies on a portable modem to supply an internet network for this system without any disconnection problem. In this created system, the particle photon, which is considered as the main device representing the brain of this healthcare system, will contribute to being the transit gate for results, which are obtained from sensors, for ready-to-upload data to the cloud then transmit to the doctor. In addition, in order to reduce the leakage of energy or the loss of its sources then the power banks or solar cells are used.

1.4 OBJECTIVES OF RESEARCH STUDY

The research objectives can be summarized as follows:

- a. Design smart healthcare system based on IoT for monitoring the vital signs of the patient.
- b. Monitoring of factors that effect on vital signs such as humidity, temperature and air quality.
- c. Follow-up from the doctor on the status patient by - reading the results transmitted to the cloud after completing uploading from a particle photon.

- d. Support this system by solar cell panels, which considered environmentally friendly source.

1.5 CONTRIBUTIONS OF RESEARCH STUDY

The thesis contributions can summarized as follows:

- a. Low cost of the system will help People with limited income buy such systems in measuring vital signs for patients without to go the hospital.
- b. Easy work of on the system designed without return to the doctor or nurse.
- c. Will worked the system developed to assist patients who reside in villages without hospitals or health centers measures their vital signs for the body.
- d. The developed system model will be small and lightweight.

1.6 RESEARCH SCOPE

This study focused on the healthcare system based on IoT in order to highlights who needs to monitor their vital signals and the factors that affect it. In addition, this study highlights the problems and challenges that may hinder the study in terms of providing the Internet service continuously and obtaining accuracy in the results that read from sensors.

In this thesis, the particle photon used in the work of the health care system for patients who need to know their biomarker consistently, oxygenation, heart rate sensor, infrared body temperature sensor, and sensors for influential factors such as air temperature, humidity sensor and air quality sensor.

1.7 THESIS OUTLINE

This thesis has five chapters, as follows:

Chapter One: provides a background for the research and highlights the important challenges and problems of the study. It also highlights the motivation for this work and discusses the study's objectives, contribution to knowledge, scope, and outline.

Chapter Two: presents a theoretical background for the vital signs and the environment factors that effect on these signs. In addition, it presents detailed review on the relevant works in healthcare systems of surveillance vital signs for patients in-house or another place as well as discuss the previous works related to the factors that effects on vital signs.

Chapter Three: presents the conceptual framework of the design and implementation of the suggested healthcare system in follow up for patients with non-stability vital signs. In addition, it presents the used components of this system, the design of the practical implementation of the used sensors and how connect with the particle photon.

Chapter Four: presents the results of the vital signs of patients and the influencing factors obtained from a reading of sensors installed on particle photon then transmit these results to the person caring for the patient via mobile phone using the Blynk IOT application.

Chapter Five: includes the discussion of the obtained results and the conclusions of this research as well as it highlights the limitations of the study and considers potential directions for future work to overcome errors that may occur in a system while giving more room for researchers to develop their potential.

2. THEORETICAL BACKGROUND AND LITERATURE REVIEW

2.1 THEORETICAL BACKGROUND

Vital signs are the standard for a person's health status and it contains four primary important signs, which are body temperature, heart rate, respiratory rate, and blood pressure. A fifth secondary sign is the level of oxygen in the blood, which called Saturation of Peripheral Oxygen (SpO₂). This chapter focus on the study of temperature and heart rate, as well as the level of oxygen in the blood. In addition, humidity, temperature, and air quality are indicators of the environment that effect on the readings of vital signs.

- a. **Temperature:** One of the most important known testing methods is the measurement of body temperature.it is an important measure of health in both daily life and medical care. The assessment of body temperature has a significant impact on decisions about nursing care, medical diagnosis, and treatment in clinical practice. Where a person whose temperature exceeds 38 infected with a fever, when the normal temperature of a human is 37, it cannot said that this degree represent the truth because measurement errors, the influence of environmental factors, gender, aging, and the location of measurement may affect temperatures degree [13].
- b. **Heart rate:** It represents the health status of the patient's heart by counting the number of heartbeats, which is one of the simplest types of vital signs. The traditional method of measuring the heart rate makes it possible to know the heart rate without any device or sensor by placing a finger on the radial artery near the wrist and counting the pulses for a period one minute, when all requirements of this method are the finger and the watch [14]. In order to find out the acceptable standards (normal standards) for the patient's heart health, it is necessary to know the normal values for the age groups of the heart rate, which measured in beats per minute (bpm). The results of the heart rate showed percentage for people between the ages of 18 and 45 is less than or equal 110bpm, and those in the range their ages are between 45 and 60 is less than or equal 100bpm and less than or equal 95bpm for people over the age of 60 [15].
- c. **Saturation of Peripheral Oxygen:** The blood oxygen level, which called Peripheral oxygen saturation (SpO₂) or Oxygen Saturation Rate, is defined as the amount of oxygen-concentrated hemoglobin that relates to the total hemoglobin (concentrated and non-concentrated) in the blood. The person's body requires a very proportionate and peculiar

balance of oxygen in the blood. In addition, the normal percentage of oxygen in the blood ranges between 95 and 100 percent, and when the percentage is less than 90 percent, a state of hypoxia occurs in the blood, which is associated with a decrease in heart rate and difficulty breathing (Respiratory problems)[16].

- d. Humidity: is a measure of the amount of water vapor present in a gas. It consists of two factors used in calculating humidity. The first factor is an absolute humidity, which is the process of measuring the mass of water vapor per unit volume. The second factor is a Relative Humidity (RH), which is the relationship between the ratio of existing water vapor pressure and the ratio of water vapor pressure needed at a given temperature [17]. Where studies have shown how to reduce health effects by reducing relative humidity and maintaining levels between 40% and 60% according to the seasons of the year, in the winter the percentage should not exceed 40% because this increase will cause problems in the respiratory system and increase the severity of allergies and asthma. In the summer, the percentage can be above 60% in air-conditioned places [18].
- e. Ambient temperature: is the air temperature of any item or environment where kit is stored. This rate also referred to as the ordinary temperature or the baseline temperature. It is important for system design and thermal analysis. Ambient temperature is a major environmental health risk factor that considered a major public health concern. The International Board on Weather Change predicts that global weather change will result in an increased risk of temperature-related mortality worldwide. Therefore, an improved understanding of the association between temperature and human health may provide important insights to address the health hazards caused by weather change in addition. Where studies prepared in a Beijing city about the rise of temperatures and their impact on human health, showed when the average temperature increased from 30.2° C to 36.9°C within 6 days, results to an increase in cases of cardiovascular disease. In other places, the effect of the rise in degrees observed heat is an increase in respiratory deaths, and people over the age of 65 are at risk from the rise in temperature [19].
- f. Air quality: Clean air is the standard air got from dry atmospheric air located in rural areas or over the ocean, away from places that cause pollution. Therefore, it is a measure of clean air pollution degree. In general, whenever the concentration of airborne pollutants decreased, the air become better. The quality airborne pollutants defined as any substance in the air that can cause harm to the health of living organisms besides cause deterioration

in the environmental field [20]. There is an indicator for evaluation air quality called the Air Quality Index (AQI) is a classification system for air quality used to communicate hazards. It provides information to the public on the air quality level in their environment and, therefore, the associated potential health hazards, particularly for People with weak structures, such as children, older people, and people with cardiovascular or respiratory diseases. In addition, this index used to decide outdoor activities in general [21]. As shown in table 2.1.

Table 2.1: AQI Index Value and Their Associated Health Impacts [21].

AQI	Associated Health Impacts
Good (0–50)	Minimal Impact
Satisfactory (51–100)	May cause minor breathing discomfort to sensitive people
Moderately polluted (101–200)	May cause breathing discomfort to people with lung disease such as asthma, and discomfort to people with heart disease, children and older adults.
Poor (201–300)	May cause breathing discomfort to people on prolonged exposure, and discomfort to people with heart disease
Very Poor (301–400)	May cause respiratory illness to the people on prolonged exposure. The effect may be more pronounced in people with lung and heart diseases
Severe (401– 500)	May cause respiratory impact even on healthy people, and serious health impacts on people with lung/heart disease. The health impacts may be experienced even during light physical activity.

2.2 LITERATURE REVIEW

This section will touch on the theoretical and the practical concepts of all vital signs and environmental factors in the design of health care systems based on the IoT in recent years. in addition, this section will focus on the contains of IoT system such as the type of microcontroller, vital signs, sensors that read those signs, environmental parameters and focus on the method of uploading the results to the cloud in order to analysis and comparison with supported devices or systems. As well as, this section reviews previous studies focusing on the implementation and design of healthcare systems.

Vikas Vippalapalli, Snigdha Ananthula [22]. This paper presented a tele-monitoring application, which allows the doctor to view the vital parameters of patient distantly and dynamically in a Web page in real time and does not require to have any special requirements on the Personal Computer (PC) except an Internet access. For the patient side, this system required the LabVIEW application that installed in home PC.

Mobyen Uddin Ahmed [23]. This study presented an integrated health system to monitor the health conditions of elderly people within the indoor environment of their homes and to detect the early stages of the deterioration of their health. Then taking the important notes and recording measurements within a classification prepared by the researcher and called Case-Based Reasoning CBR. The researcher in this system obtained a percentage of 93 % of the rating where the chart was 96 %.

Ali Abdul-Jabbar Mohammed, et al [24]. This paper proposed an integrate IoT devices that work on the applications of health care systems with mobile devices, because these smart systems are complex in nature, which requires the establishment of a common unit between these devices. In addition, this paper presented the framework architecture according to the layered construct of the IoT.

Sami Alshmrany, Arshad Ali [25]. Presented a system consisting of multi sensors, which are electrocardiogram (ECG), blood pressure (BP), Temperature and Heartbeat, to monitor the vital signs of the patient. In addition, the reading of results from sensors transmitted to units whose work based on the IOT in order to analyze the results and send them to the authorities concerned with following up on the patient.

Tamanna Shaown, et al [26]. This study prepared to implement system of monitoring an electrocardiogram (ECG) signal, which depends on IOT, and then send the results to the cloud for the purpose of analysis. This study applied on a device that contains three electrode positions for patient examination compared to hospital devices that contain twelve electrode positions the results of the study showed that it conducted on ten patients, the efficiency and accuracy of the system increased by 80%, compared to the devices that mentioned.

Hafedh Ben Hassen, et al [27]. This study prepared in the development of a high-level healthcare system in terms of patient follow-up, especially in the period of the spread of the Covid-19 epidemic. Then follow the vital signs of elderly and the people who suffer from chronic diseases and it is difficult for them to go to the hospital. The results of the examinations send to specialized doctors via the cloud In order to diagnose their condition

and give them treatment while they are inside their homes. The unit of monitoring vital signs that includes (ECG, blood pressure, and Oxygen saturation level) and the unit of monitoring environmental factors that includes (smoke detection, detection of gas leaks, humidity, and temperature) established as part of the study. These units connected to the Atmega 328 (Arduino UNO) microcontroller for monitoring vital signs and the NodeMCU V3 board connected parts for environmental factors unit.

Ezzaldeen Edwan, et al [28]. This study prepared in the development of a blood pressure measurement system for patients to reduce the cost of blood pressure measurement and to reduce the difficulties of going to health centers or hospitals. In this study, Arduino Uno used to operate a blood pressure measurement system with pressure sensor SIMST PSG010 to read results on the screen or mobile in case of mobile connection with the Bluetooth unit. Where the results of the five people on whom the tests conducted appeared, and the error percentage compared to the other devices was 6.17%, which is the highest percentage of error compared to the remaining four people.

Kusvihawan Muhammad Shihab et al [29]. This study prepared to design an IoT-based device for measuring blood pressure by integrating pressure-measuring devices. Arduino used to analyze data from the MPX5050DP pressure sensor also, NodeMCU used to connect the processed results to the Internet (Wi-Fi or hotspot) and provide them to Firebase, which showed the results no significant difference between the MPX5050DP and the Omron digital blood pressure monitor results. After the comparison, the error rate shown in the case of systole 3.83% and 2% in the case of extraversion while the average transmitting data delay is 13.94 seconds.

Mohammad Monirujjaman Khan et al [30]. This paper presented the design of a health care system that based on IoT to follow up on patients suffering from asthma, pulmonary obstruction and diabetes.

Arduino uno used for receiving private sensors readings (temperature measurement, spo2 and heart rate). After that, treating and converting these readings from analog to digital then send it via the Bluetooth to the mobile to seen by the patient. as well as these results presented to the Liquid Crystal Display (LCD), which helps the patient to know his health and informing the specialist doctor to help with great help in the event of a deterioration of the patient's condition. Where the results, which were conducted on three people in (measurement of temperature, heart rate, and the percentage of oxygen in the blood),

showed, record and good results that were close to the standard values. This paper applied 95% confidence interval and 5% maximum relative error to all measurements related to determining the health parameters of the patients.



3. MATERIALS AND METHODS

3.1 INTRODUCTION

This chapter will introduce the structure and units of the suggested system and provides a detailed description of the particle techniques for the reading process of the vital signs heart rate, Body temperature and the environmental factors. In addition, the next pages of this chapter will present how the particle photon tacks the values from the sensors and how the energy sources provide the electric power to the particle photon and sensors by using clean energy (Solar cell panels). Finally, this chapter illustrates the uploading process of the obtained result to the particle photon to process it using equations and conditions that achieve the proposed system within a special platform called Blynk IoT.

3.2 METHODOLOGY OF THE SYSTEM

The methodology of the system describes the input / output components and the connection of these components with the processing components. The structure of the proposed system contains three basic units according to components' work in each unit.

The first unit represent the input unit of the system that contains the power supplies sources, the electronic components, which called the sensors, and the Internet service provider.

The second unit represent the process unit of the system that contains two particle photon, the first one connected to the sensors that read the vital signs of the human (heart rate, body temperature, and blood oxygenation rate) while the second one connected to the sensors that read the environmental factors (Humidity factor, Temperature factor and Air quality factor).

The third unit represent the output unit of the system that contains electronic components of the system alarms, Blynk IoT platform and PuTTY serial window.

The figure 3.1 represent the block diagram of the proposed system that illustrates the units, which mentioned in above.

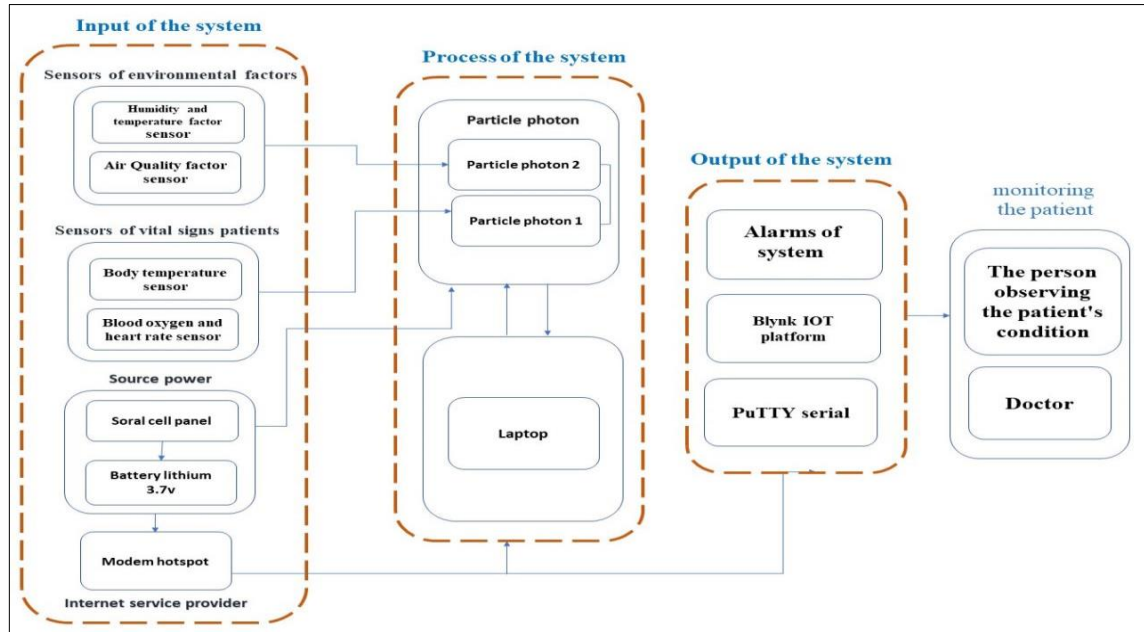


Figure 3.1: The Block Diagram, the Proposed System.

3.2.1 Input Unit of the System

The main purpose of this unit is to provide the system with two types of the signals electric and signals as well as Internet service. This unit contains three types; the first one is the electric sources that supply 5v electrical energy to the system. The second one is the system's Internet Service Provider ISP to enable the particle photon to communicate with cloud and digital platforms. The third one is the sensors that responsible for providing the system with readings of vital signs and environmental factors.

- a. **Power supply resources:** Electrically energy obtained by generate Direct Current (DC) from three main sources solar cell panel, rechargeable batteries and external sources.
- b. **Solar cell panel:** The sources of electrical energy depend on solar cells are one of the best commonly used sources, as well as being considered clean energy and help in protecting the natural environment from pollution as shown in figure 3.2. Figure 3.1 the block diagram, the proposed system



Figure 3.2: Solar Cell Panel 6v & 3.5 w.

3.2.2 Input Unit of the System

The reasons that made the use of this energy in the proposed system are:

- a. Reducing natural environmental pollution.
- b. Ease of preparing the system when the patient is outside the home or in villages far from energy sources.
 - a. Rechargeable batteries: These batteries generate DC volts; they can be recharged via one of the energy sources solar cells or external sources. This system used two lithium batteries, which have a voltage of 3.7 volts and a current strength of 2000 mA, with a charging card that consists of a Type C input port and a USB output port, through which the system parts are equipped with electric power as shown in the figure 3.3.

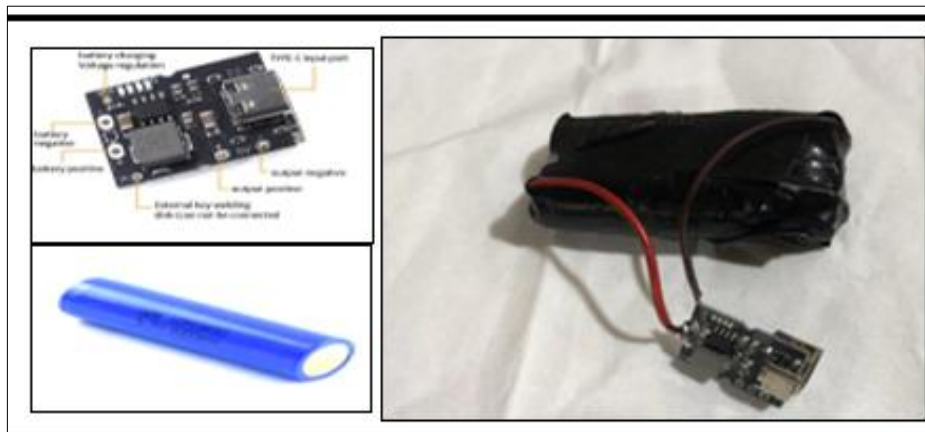


Figure 3.3 :Rechargeable Batteries Lithium 3.7volt 2000mAh.

- b. External sources: External sources of electrical power represent any device has a USB port such as mobile charger, laptop, power bank, or USB plug point.
 - a. Internet service provider: The particle photon must be equipped with the internet service, and this done by using any wireless modem device.

b. Input sensor: It consists of two groups, the first group is the sensors for measuring vital signs, while the second group is the sensors for monitoring environmental factors.

Group1: This group consists of two sensors the first one to measure body temperature and the second one to measure the heart rate and the level of oxygen saturation in the blood and this group connecting to the particle photon1.

Body temperature sensor: DS18B20 probe temperature sensor used for body measurement Temperature. It has 64-bit string stored in ROM, and its electric power source is 3.0v to 5.5v, [31]. Its measures temperatures from -55°C to $+125^{\circ}\text{C}$ and Fahrenheit equivalent from -67°F to $+257^{\circ}\text{F}$. The sensor terminals number of is three VCC, GND and DATA. The goal of using this sensor is to facilitate measuring temperatures for sick children who have a fever as shown in figure 3.4.



Figure 3.4 : DS18B20 Probe Temperature Sensor.

Blood oxygen and heart rate sensor: It has two red Light-Emitting Diode LED and infrared LED. The two red LED lamps emit light then the infrared LED detects this light, through which the reflected light collected and processed to obtain the results related to vital signs and heart rate, SpO2 as mentioned in [32]. This sensor has a low-noise analog signal-processing unit responsible for processing the signals that are connected to the Microcontroller Unit MCU via the Inter Integrated Circuit I2C interface, which its Bus has a two-wire bidirectional serial bus that offers a simple and effective technique of data transmission above a short distance between digital integrated circuits (chips) [33]. It has five pins VCC, GND, SDA, SCL, and INT and it uses 3.3v power supply as shown in figure 3.5.

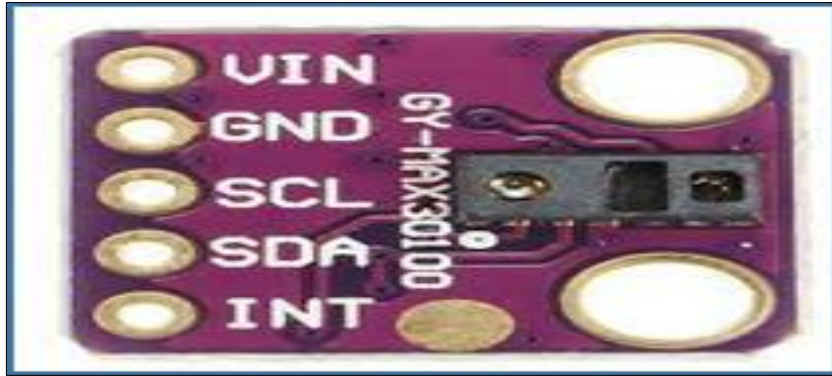


Figure 3.5: GY- MAX30100 Oxygen and Heart Rate Sensor.

Group2: This group consists of two sensors the first one to measure both humidity and temperature and the second sensor to measure air quality, and this group connecting to the particle photon2.

Humidity and temperature sensor: DH-11 Module which measured temperature from 0°C to 50°C with a $\pm 2.0^\circ\text{C}$ accuracy, and humidity from 20 to 80% with a 5% accuracy. It has three pins VCC, GND and OUT as shown in figure 3.6.in the environment with increased humidity and high temperatures, it will result in a decline in evaporation of sweating and stress in both the heart and blood vessels (heart rate) with a temperature rise [34].

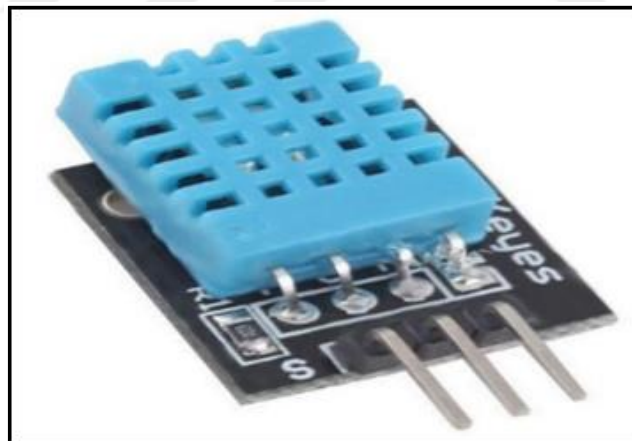


Figure 3.6: DHT11–Temperature and Humidity Sensor.

Air Quality Sensor: The MQ135 module is a low cost carbon dioxide gas sensor CO₂ used to monitor air pollution. As the percentage of pollution in the atmosphere increases, the quality of clean air decreases, representing Parts Per Million (PPM) [35]. In addition, MQ-135 gas sensors used for the measurement and detection of Ammonia NH₃, Nicotine, Benzene, Smoke and CO₂. MQ-135 is with the help of a digital pin; this sensor can function

without a microprocessor and is useful for identifying specific gases. The analog pins are used to determine the gases in PPM. The analog pin may be utilized with the majority of contemporary microcontrollers because it is powered by Transistor–Transistor Logic TTL and works on 5V [36]. It has four pins VCC, GND, Analog OUT and Digital OUT as shown in figure 3.7.

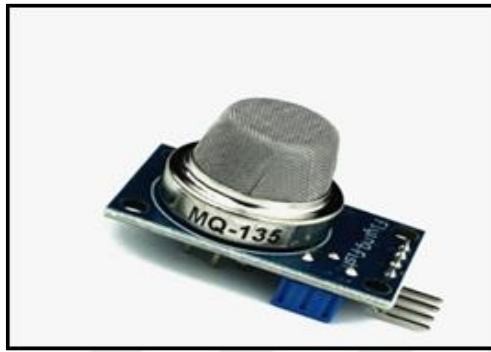


Figure 3.7: MQ135 – Air Quality Sensor.

3.2.3 Process Unit of the System

The particle photon represented as the brain of the proposed system that is responsible for controlling on the readings coming from the sensors of vital signs and environmental factors and then produced the results to the system's outputs.

Particle photon is an open source IoT production platform that has built-in 32-bit ARM Cortex M3 microprocessor and Wi-Fi. It is a complete IoT device development kit and provides every requirements to build this system. It operates with regulated power supplies between 3.6v and 5.5v. With an operating frequency of 120MHz, the size of flash / program memory is 1MB. Particle Build, a web-based integrated development environment, is a Photon Theme. A photon is a component of a sensor node, which collects information from sensors and prepares them for cloud transmission. The key feature of particle photon is remote code programming [7]. It may be programmed locally via Particle's cloud Integrated Development Environment IDE as soon as connected to a Wi-Fi network or any ARM development environment. Cloud IDE as well permits the applications to be kept and compiled in the cloud [37].

The Photon arises in two physical customs: the first one comes with headers pins and the second one without headers pins. It is easy with headers pins as it sets directly into standard breadboards, and may also be fixed with 0.1 pitch female headers pins on a Printed Circuit

Board PCB. In the direction of decrease space required, the Photon form factor without headers pins has castellated edges. These create it possible to mount the Photon directly upon PCB [38].

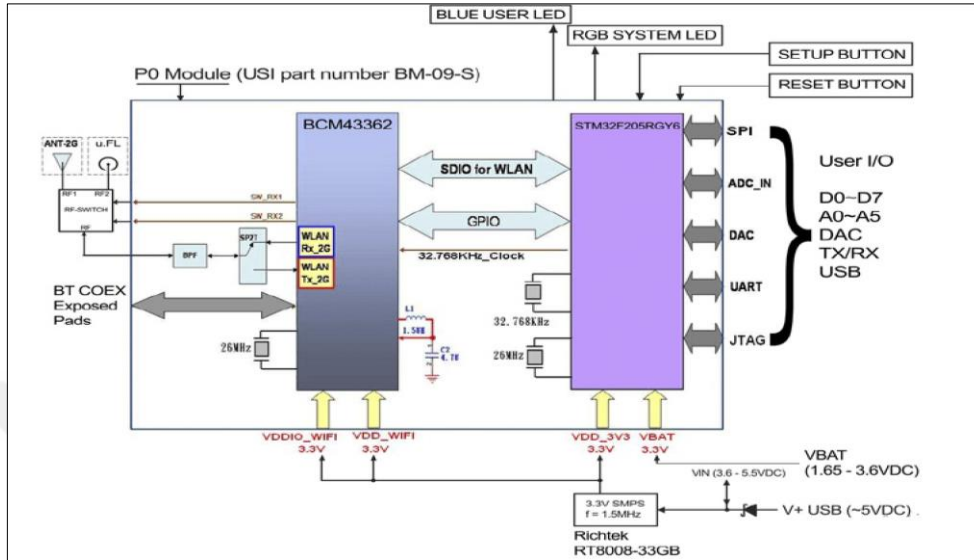


Figure 3.8 : Block Diagram of Particle Photon Interfaces [38].

The particle photon has six analog inputs (A0-A5) and six digital outputs (D0-D5). Additionally, it includes an RGB LED a set of colors, each of which displays the particle photon's current configuration. This RGB LED serves as an essential part of photon settings for programming it to operate in the needed manner as shown in figure 3.9.

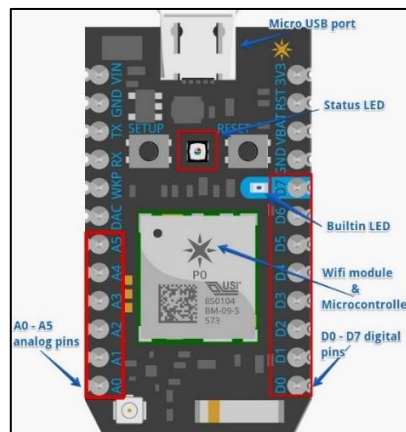


Figure 3.9 : Particle Photon [38].

3.2.3.1 Configuration of the particle photon

Particle web IDE, which represented as an IDE, used in order to programing the particle photon. The programming languages C# and C/C++ used to programming the codes and the libraries of sensors and particle photons [39]. It is a gateway for communication between IoT devices and digital platforms to processing and analyzing the data then display or upload it to the cloud. There are many platforms in the world of the IoT, which including Think Speak, BLYNK IOT and UBIDOTS.

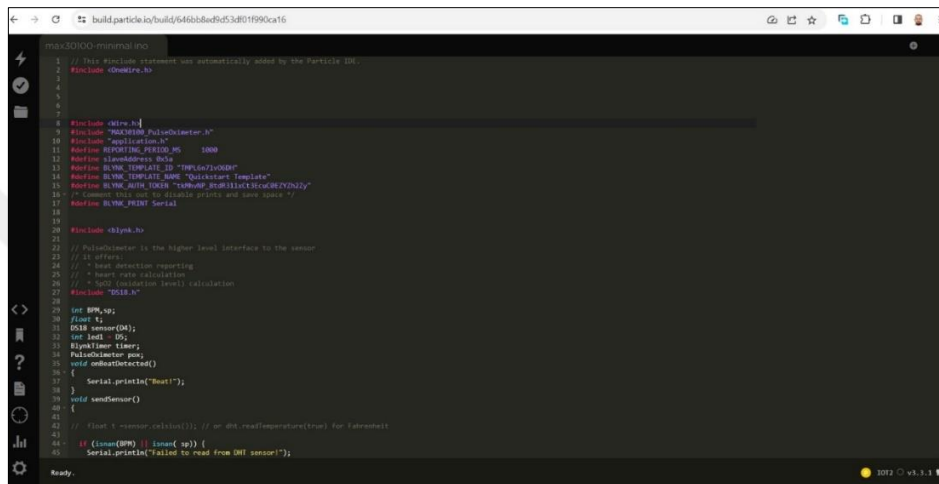


Figure 3.10: Particle Web IDE.

There are two types of configurations on Wi-Fi network:

- a. Graphical User Interface (GUI): The website page of particle photon includes a page of settings for the purpose of identify the Wi-Fi network by using smart mobile or laptop and this is done according to the following steps:
 - a. Create an account on the official website of the Particle Photon.
 - b. Initialize the particle photon to listen mode (flashing blue) to configure it (the particle photon modes described on the help page of particle photon).
 - c. Follow the Particle Photon instructions by going to the setup page on the official website.
 - d. After completing the settings, select the page for selecting a Wi-Fi network to configure the particle photon.
- b. Serial com: The particle photon is prepared to identify the Wi-Fi network via Serial Com using the PuTTY program, as described in the following steps.
 - a. Initialize the particle photon to listen mode (flashing blue) to configure it (the particle photon modes described on the help page of particle photon).

- b. Select the number of Ports (COM & LPT) of the particle photon
- c. Open PuTTY and then select radio button Serial, COM number and Speed 9600.
- d. Press the "w" key on the keyboard - this will initiate the Wi-Fi setup process (Enter your SSID, select you're Security Type, Enter your password).

3.2.3.2 Implementation procedures

The implementation procedures of the system used two particle photons, the first particle photon used for monitor vital signs, and the second particle photon used to monitor environmental factors. There are several reasons for using two particle photons, as follows:

- a. Preventing interference in wires by connecting more than one sensor and a set of other elements such as resistance, LED and buzzer when connected to single particle photon.
- b. Reduced delay time when all sensors connected to a single particle photon.
- c. Ease of developing the system in the future by adding a group of sensors such as a blood pressure sensor or an atmospheric pressure sensor that work on Serial Data SDA and Serial Clock SCL pins when using two particle photon.

The connection between particle photon1 and particle photon2: In the proposed system, the particle photon1 shares with the particle photon2 energy sources through lithium batteries, which charged by the solar cell panel, as shown in the following steps:

- a. The two pins VCC and GND of the rechargeable battery connected with the pins VCC and GND of the breadboard lines, and these lines consist of a group of points that feed the photon, sensors, and other components.
- b. The two pins VCC and GND of the breadboard lines connected with the pins VCC and GND of the both particle photon1 and particle photon 2.

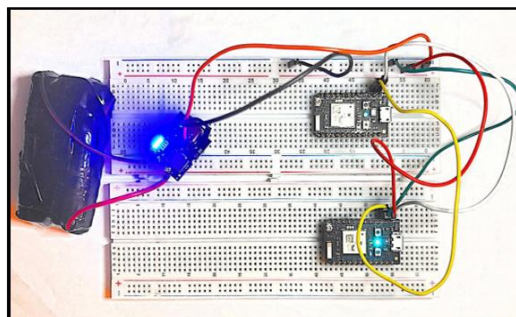
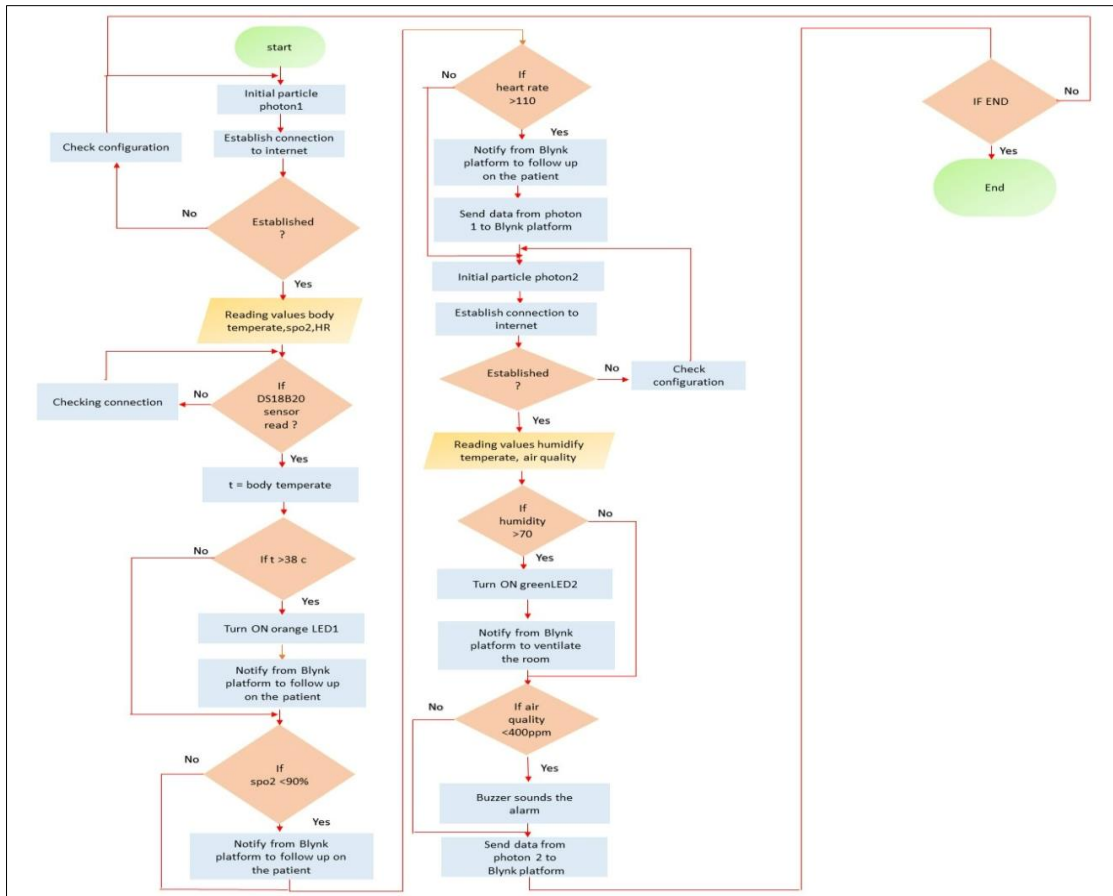


Figure 3.11: Connection Between Particle Photon1 and Particle Photon2.

The proposed algorithm for the process unit of the system that implemented by two particle photon shown in following flowchart 3.1.



Flowchart 3.1: Algorithm for the Process Unit of the Proposed System.

Particle photon1 with temperature body sensor: The D4 pin of particle photon1 connected to the data pin of DS18B20 probe sensor, as well as 4.7kohm resistance connected between both VCC pin and data pin of this sensor. In addition, the Orange LED, which connected between the D5 pin and GND pin of the particle photon1, turned on when the patient has a temperature above 38 degrees to alert the person in charge of monitoring the patient. This sensor programmed by using the particle web IDE code as follows:

a. Libraries calls:

```
#include <OneWire.h>
```

```
#include "DS18.h"
```

b. The variables that used to store the temperature and read it from the output unit of the proposed system should be determined as follow command:

```
int led1 = D5, t;
```

- c. Initialize serial com - baud rate and *led1* in void setup () :

```
Serial.begin(115200);
```

```
pin Mode (led1, OUTPUT);
```

- d. Adding a condition in case of obtaining a reading from the sensor to execute a temperature value and print it with storing its value in the variable "t" as shown in the following instruction:

```
if (sensor.read(){
```

```
t=sensor.celsius();
```

```
}
```

- e. Adding a condition to check the temperature body degree if rises above 38 turn on led1(Orange LED) as shown in the following instructions in void loop() section :

```
digitalWrite(led1, LOW);
```

```
if( t > 38 ){
```

```
digitalWrite(led1, HIGH);
```

```
}
```

Particle photon1 with Blood oxygen and heart rate sensor: The D0 and D1 pins of the particle photon1 connected to SDA and SCL pins of GY-MAX30100 sensor, Infrared radiation is one of the radiations emitted by the sun, and this sensor emits this radiation. To prevent interference in the sensor's signals when sunlight exposure, which prevents the sensor from reading the findings accurately, a plastic shield must cover this sensor to effectively blocks sunlight. The basic condition is if a pulse detected on this sensor, then the serial com will show the value of the heart and continue the next step test. Otherwise, there is error in connection of the sensor. This sensor programmed by using the particle web IDE code as follows:

- f. Libraries calls:

```
#include "MAX30100_PulseOximeter.h"
```

```
#include "application.h"
```

- g. Initialize serial com - baud rate:

```
Serial.begin(115200);
```

- h. The variables that used to store the Spo2 and heart rate values should be defined as a following command:

int BPM, sp;

The connection between the particle photon1 and vital signs sensors shown in figure 3.12.

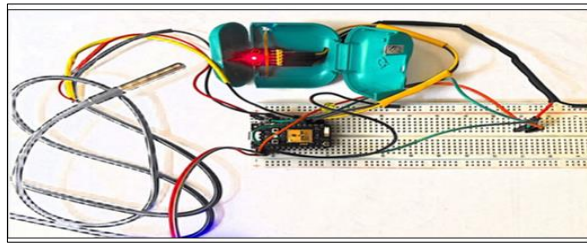


Figure 3.12: Connection of the Particle Photon1 and Vital Signs Sensors.

Particle photon2 with Humidity and temperature room sensor: The D2 pin of the particle photon2 connected to data pin of DH11 sensor. the Green LED, which connected between D3 pin and GND pin of particle photon2, turned on when the humidity rises above 70% to alert the person in charge of monitoring the patient to turn on the air conditioners or ventilate the room. The temperature degree of the room will uploading directly to Blynk IoT platform and PuTTY serial window. This sensor programmed by using the particle web IDE code as follows:

i. Libraries calls:

```
#include <DHT.h>
```

j. The variables that used to store the humidity values should be defined as a following command:

```
#define DHTPIN 2
```

```
#define DHTTYPE DHT11
```

```
int led2 = D3, h;
```

k. Initialize serial com - baud rate and led2 in void setup ():

```
Serial.begin(115200);
```

```
pin Mode(led2, OUTPUT);
```

l. Adding a condition to check the humidity percentage if rises above 70% turn on led2(Green LED) as shown in the following instructions in void loop() section :

```
digitalWrite(led2, LOW);
```

```
h = dht.readHumidity();
```

```
if(h >70) {
```

```
digitalWrite(led2, HIGH);
```

```
}
```

Particle photon2 with Air Quality sensor: The A0 pin of the particle photon2 connected to A0 pin of MQ135 sensor. In addition, Buzzer electronic component, which connected between the GND and D4 pins of particle photon2, turned on when the air quality index rises above 350 to alert the person in charge of monitoring the patient to follow up on the source of pollution (gas leak, fire smoke, or another element). In addition, the source of pollution make the room unhealthy especially for patients suffering from shortness of breath or patients with COVID-19. Where studies have shown that the highest incidence of the unhealthy category of people with allergies was in the summer and autumn seasons, according to AQI [40]. This sensor programmed by using the particle web IDE code as follows:

m. Libraries calls:

```
#include <MQ135.h>
```

n. The variables that used to store the air quality degree and read it from the output unit of the proposed system should be determined as following commands:

```
int Buzzer = D4;
```

```
int ppm = gasSensor.getPPM();
```

```
int led2 = D3,h;
```

o. Initialize serial com - baud rate and Buzzer in void setup() :

```
Serial.begin(115200)
```

```
pinMode(Buzzer,OUTPUT);
```

p. if the air quality index rises above 350 turn on Buzzer as shown in the following instructions in void loop() section :

```
int co2_ppm = gasSensor.getPPM();
```

```
int ppm = co2_ppm / 4;
```

```
digitalWrite(Buzzer, LOW);
```

```
if(ppm>400){
```

```
digitalWrite(Buzzer, HIGH); }
```

The connection between the particle photon2 and environmental factors sensors shown in the figure 3.13.

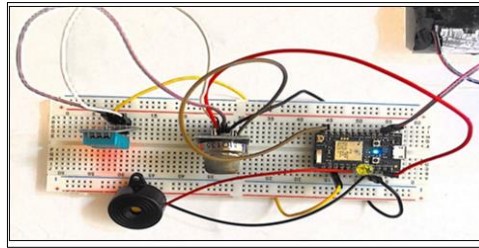


Figure 3.13: Connection of the Particle Photon2 and Environmental Factors Sensors.

In order to summarizing, the connection between the two particle photon pins and other electronic components pins the next tables 3.1 and 3.2 showing this summarize.

Table 3.1: Electronic Components Associated with Particle Photon1.

Sensors and components	Input pins of particle the photon1
DS18b20	D4,VCC 3.3v , GND
Resistance 4.7k Ohm	D4,VCC 3.3v
orange LED	D5,GND
GY-MAX30100	D0,D1,VCC 3.3v,GND
Power from Rechargeable batteries lithium 3.7	VCC 5v,GND

Table 3.2: Electronic Components Associated with Particle Photon2.

Sensors and components	Input pins of particle the photon2
DH11	D2,VCC 3.3v , GND
green LED	D3,GND
MQ135	A0,VCC 3.3v, GND
Buzzer	D4, ,GND
Power from Rechargeable batteries lithium 3.7	VCC 5v,GND

3.2.4 Output Unit of the System

The output unit of the proposed system consists of three types the electronic components that called Alarming system, the serial com (PuTTY) and the Blynk IoT platform. The function of these types is to display sensor readings, but the difference is in the mechanism of displaying these results.

- a. Alarming system: The mechanism is to send signals warns the person responsible for following up the patient about the presence of a rise in one of the vital signs or environmental factors in order to taking the necessary steps. These signals consist of three components as shown in table 3.3.

Table 3.3: Signals of Alarming System.

Signal Type	Name of warn	Output Type	Device Name	Pin No.
Orange LED1	increase in body temperature degree	Digital	Particle photon1	D5
Green LED2	increase in humidity percentage	Digital	Particle photon2	D3
Buzzer	increase in Air quality PPM	Digital	Particle photon2	D4

- b. Serial com (PuTTY): It is the most command computer software that is an open-source terminal simulator. It is free software available online, which has basic options to select Serial line, baud rate of the serial COM and Connection type (SSH, Telnet, Serial and other) [41]. The results obtained using a serial monitor by selecting the COM number from the particle photon associated with the USB Stone Port and the speed installed in the photon-related sensor code, as shown in figure 3.14.

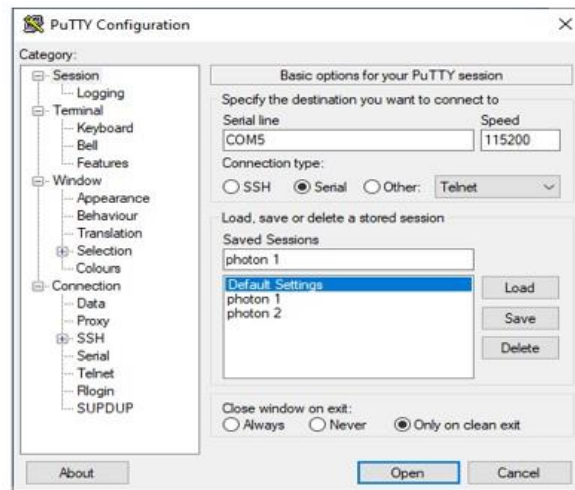


Figure 3.14: PuTTY Configuration Window.

The method of displaying the results in a PuTTY program is through the Serial Monitor window, by means of a set of directives in the code in Particle Web IDE, and according to the following:

- q. Particle photon1 with DSB1820 and GY- MAX 30100 sensors:

```

Serial.println("Temperature %.2f C ", sensor. Celsius ());
Serial.print("Heart rate:");
Serial.print(BPM);
Serial.print("bpm / SpO2:");
Serial.print(sp);
Serial.println("% ");

```

r. Particle photon2 with DH11 and MQ135 sensor :

```

Serial.println("Humidity %.2f ", dht.readHumidity() );
Serial.println("Temperature %.2f C ", dht.readTemperature());
Serial. Print(ppm);
Serial.println("ppm");

```

After executing the above instructions, the results will displayed on the serial monitor window, as shown in the figure 3.15.

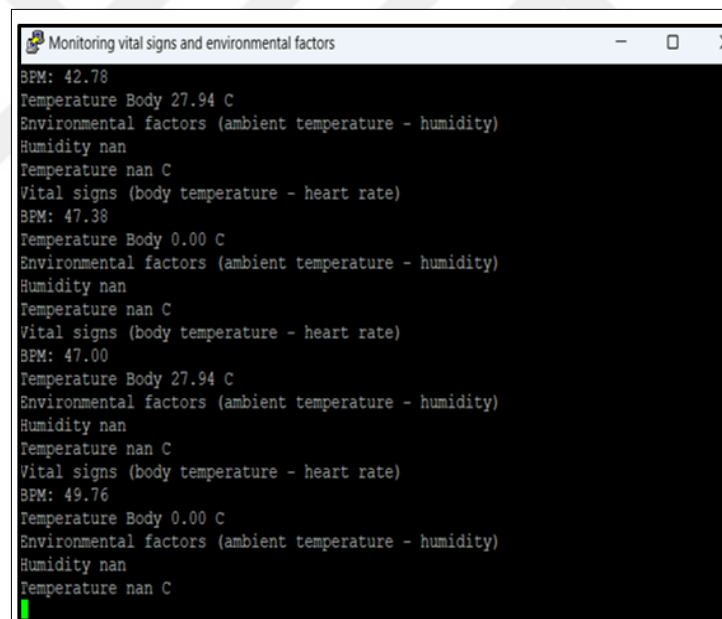


Figure 3.15 : Window of Serial Monitor – PuTTY.

c. Blynk IoT platform: A platform connects IoT devices to the cloud. One of the features of this platform is data analysis and remote management of systems that rely on the IoT. The uses of this platform are in many areas including the medical field, the environmental field, smart homes as well as interfacing with other platforms and controlling many devices such as Arduino, ESP32, ESP8266, particle photon and

Raspberry Pi using mobile applications. [42]. this platform will display the results and warnings of the proposed system on the smartphone or laptop of the person in charge of monitoring the patient or the doctor. It has five components as shown in the block diagram, figure 3.16.

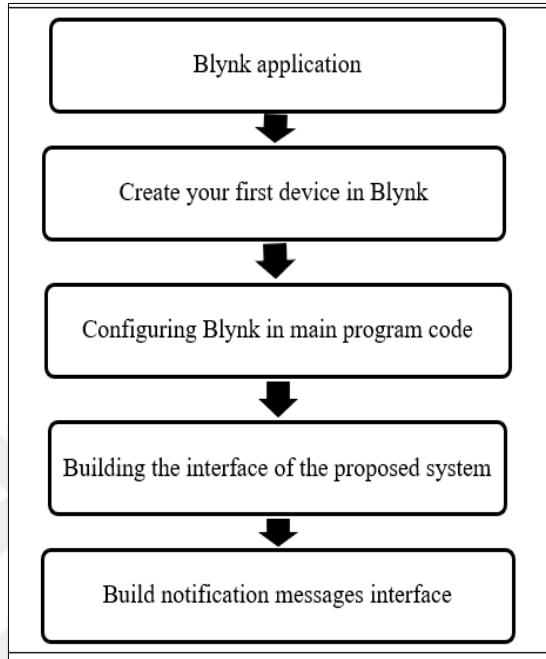


Figure 3.16: Block Diagram of the Blynk Platform Components.

- d. Blynk application: Downloading and installing this application on smartphones running Android and iOS operating systems is the first step in making Blynk. In addition, it is possible to create the Blynk platform on a laptop by entering the official website and creating a new account. The downloading and installing processes shown in the figure 3.1

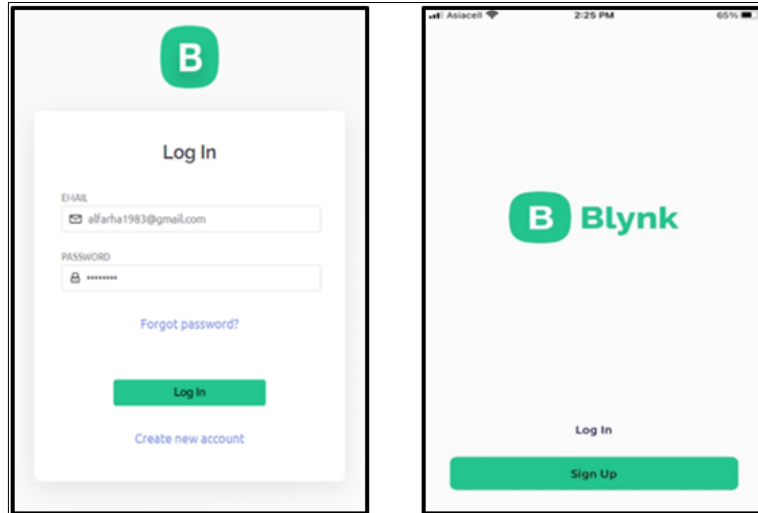


Figure 3.17: Screen Shot of Blynk Application on Laptop and Smart Phone.

e. Create your first device in Blynk :

To add and initialize the particle photon in the Blynk cloud, the following procedures must followed:

- a. Connect the particle photon to the laptop via USB.
- b. Download the code for the device and add the Blynk library inside the code.
- c. Enter the name and password of the Wi-Fi network.
- d. Injecting the code on the particle photon into the Particle Web IDE

All the steps needed to add and initialize the particle photon in the the Blynk cloud shown in the following figure 3.18.



Figure 3.18: Screen Shot of Adding the Particle Photon in Blynk Cloud.

f. Configuration of Blynk in the main program code :

To display the results of the sensor readings on the Blynk platform, some configurations must be made within the code for each particle photon and this is done by means of the following instructions:

a. Particle photon1: In the variable code identification section of the particle web IDE, called the Blynk Library, the particle photon information taken from the Blynk Device Info in the Blynk platform. This information consists of template ID, template name and the Authentication Token, as shown in the following instructions:

```
#define BLYNK_TEMPLATE_ID "TMPL6n7lvO6DH"  
#define BLYNK_TEMPLATE_NAME "Quickstart Template"  
#define BLYNK_AUTH_TOKEN "tkMhvNP_8tdR311xCt3EcuC0EZYZh2Zy"  
#define BLYNK_PRINT Serial  
#include <blynk.h>  
BlynkTimer timer;
```

In the void setup section of the code in the particle web IDE, the particle photon Authentication Token is called as shown in the following interaction:

```
Blynk.begin(BLYNK_AUTH_TOKEN);
```

In void loop section of the code in the particle web IDE, the values of the sensor readings defined with variables in the Blynk platform for selecting these values in the DataStream to be ready for displaying on the application interface as shown in the following interactions:

```
Blynk.virtualWrite(V6,sensor.celsius());  
Blynk.virtualWrite(V3, BPM );  
Blynk.virtualWrite(V4, sp );  
Blynk.run();  
timer.run();
```

b. Particle photon2: In the variable code identification section of the particle web IDE, called the Blynk Library, the particle photon information taken from the Blynk Device Info in the Blynk platform. This information consists of template ID, template name and the Authentication Token, as shown in the following instructions:

```
#include <blynk.h>  
#define BLYNK_TEMPLATE_ID "TMPL6n7lvO6DH"  
#define BLYNK_TEMPLATE_NAME "Quickstart Template"
```

```
#define BLYNK_AUTH_TOKEN "OxLkZI3RCRTkrxA9b8XJrbNdWeurZIGs"  
#define BLYNK_PRINT Serial
```

In the void setup section of the code in the particle web IDE, the particle photon Authentication Token is calling as shown in the following interaction:

```
Blynk.begin(BLYNK_AUTH_TOKEN);
```

In void loop section of the code in the particle web IDE, the values of the sensor readings defined with variables in the Blink platform for selecting these values in the DataStream to be ready for displaying on the application interface as shown in the following interaction:

```
Blynk.virtualWrite(V5, h);
```

```
Blynk.virtualWrite(V0, dht.readTemperature());
```

```
Blynk.virtualWrite(V7, ppm);
```

```
Blynk.virtualWrite(3, led2);
```

```
Blynk.virtualWrite(4, Buzzer);
```

```
Blynk.run();
```

```
timer.run();
```

- g. Building the Blynk Interface of the Proposed System: The device template is a set of interfaces for creating the interface displaying of the results for the particle photon with vital sings sensors. The most important of these interfaces are DataStream, Web Dashboard and Mobile Dashboard.
 - a. DataStream: It is the process of organizing the data entering and leaving the particle photon and the data of the sensor readings. This data consists of four types Digital, Analog, Virtual PIN and Enumerable.
 - b. Web Dashboard: It is an interface for displaying the results of the readings from the sensors on the laptop, and through this interface, adding the required tools for the proposed system, such as temperature, humidity and air quality.
 - c. Mobil Dashboard: It is an interface for displaying the results of the readings from the sensors on the smart phone through the application. Adding the tools required for the proposed system, such as temperature, humidity, and air quality. In addition, the process of monitoring these factors done remotely, as shown in Figure 3.19.



Figure 3.19: Screen Shot of Blynk Interface of the System.

- h. Build notification messages interface: The Blink platform has a wide notification interface with multiple conditions, through which work can be scheduled by setting a specific time to monitor the patient's condition by sending a notification on the smartphone or e-mail. In addition, when any effect occurs in the vital signs, such as rising of the patient's temperature or decreasing of the oxygen level in the blood, a message will arrive to reporting the doctor or the person responsible for monitoring. The building of these warnings is done through the Automation interface on the laptop or smartphone, as shown in the figure 3.20.

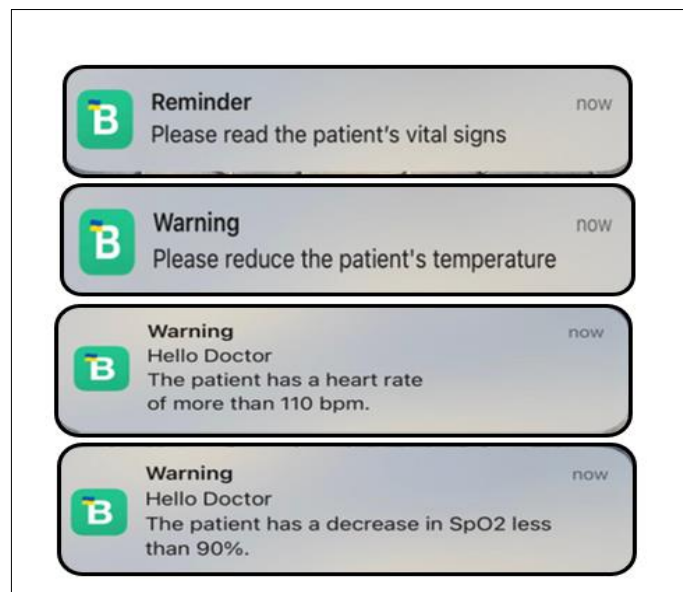


Figure 3.20: Warning Messages of the System

4. EXPERIMENTAL RESULTS AND DISCUSSION

4.1 CHAPTER OVERVIEW

There are a number of tests conducted to evaluate the efficiency of the proposed IoT-based system. These tests have two main axes; the first axis is to compare the proposed system results with the traditional devices results in order to calculate the accuracy and the error rate of the proposed system. The second axis is to compare the results of the proposed system according to two different readings of environmental factors for a group of cases in order to detect the effect of environmental factors on vital signs. These tests include all age groups of children, young people and the elderly with observations for cases with chronic diseases, such as high blood pressure and respiratory distress.

4.2 MEASUREMENT USING SENSORS AND TRADITIONAL DEVICES

The vital signs examination applied on twenty-five cases, ten females and fifteen males, for two different readings under different environmental factors, which are humidity and ambient temperature. The first reading used the sensors, while the second reading used the traditional devices such as Finger Oximeters (FO) [43] and electronic thermometers. The examination repeated for the same cases when the humidity and ambient temperature increased, as shown in table 4.1 and table 4.2.

Table 4.1: When the Humidity =36% and the Temperature Rom=30.°

Age year	Gender	Traditional devices			Sensors			Pathological case
		Temp. body °c	Spo2 %	Heart rate bpm	Temp. body °c	Spo2 %	Heart rate bpm	
74	F	35.8	97	82	35.2	94	80	shortness of breath
73	M	35.1	97	60	35	95	60	high blood pressure
73	M	36.4	99	82	36.3	98	81	normal
69	F	36.5	98	77	36.4	98	76	normal
59	M	36.4	97	75	36	97	73	normal
57	F	35.5	98	76	35.5	98	75	normal
48	M	36.3	95	62	36	95	62	normal
43	F	35.8	95	96	35	94	95	normal
42	M	36	95	108	36	94	104	normal
40	M	36	98	69	35	97	68	high blood pressure

Table 4.1: When the Humidity =36% and the Temperature Rom=30 “Table Continued”.

38	M	36.6	97	96	36	97	95	normal
36	F	36.6	98	91	35.5	95	89	normal
35	M	36.6	94	75	35.5	95	75	normal
33	M	36.1	94	70	36	94	70	normal
30	M	35.9	97	91	36	96	90	normal
29	F	36.6	98	91	36	95	89	pregnant
24	F	36	99	98	35	98	95	normal
8	F	36.5	99	128	36	98	125	normal
6	F	36	98	114	36	95	113	normal
6	F	36	98	114	36	95	113	normal
5	M	35.4	98	117	35	96	115	normal
4	M	36	99	122	35.5	98	121	normal
3	M	35.2	98	127	35	97	125	normal
2	F	35	99	117	35	98	115	normal
1	M	35.9	99	129	35.5	99	128	normal

Table 4.2: When Humidity =79% and Temperature Rom=35.°

Age year	Gender	Traditional devices			Sensors			Pathological case
		Temp. body °C	Spo2 %	Herat rate bpm	Temp. body °C	Spo2 %	Herat rate bpm	
74	F	36.3	94	83	36	94	82	shortness of breath
73	M	36.9	95	78	36.5	95	77	high blood pressure
73	M	37	99	85	37	98	84	normal
69	F	37	98	80	36.7	97	79	normal
59	M	36.7	97	79	36	97	75	normal
57	F	36	97	77	35.5	97	76	normal
48	M	36.5	95	68	36	94	67	normal
43	F	36	95	97	36	95	96	normal
42	M	36.2	95	110	36	95	110	normal
40	M	36.4	98	75	36.2	98	74	high blood pressure
38	M	36.2	96	89	36	96	88	normal
36	F	37	96	92	36.5	95	91	normal
35	M	36	95	76	36	95	76	normal
33	M	36.7	95	78	36.5	95	75	normal
30	M	36	97	95	36	96	94	normal
29	F	37	97	96	37	96	95	pregnant
24	F	36.5	99	99	36	98	97	normal
8	F	36.3	98	130	36	98	129	normal
6	F	36.5	95	118	36.5	96	117	normal

Table 4.2: When Humidity =79% and Temperature Rom=35° “Table Continued”.

6	F	36.2	96	122	36	96	120	normal
5	M	37	99	128	36.5	98	127	normal
4	M	36	97	129	35.3	97	128	normal
3	M	36	98	122	35	98	120	normal
2	F	37.2	99	130	36.8	99	129	normal
1	M	37.4	97	134	36	97	131	normal

The heart rate and the level of oxidation in the blood measured in seven cases over the age of 40 years, two of whom had high blood pressure. Two different readings recorded under the same environmental factor, which is the air quality factor, the first reading used sensors while the second reading used conventional devices such as a Fingertip Oximeter (FO). The examination repeated for the same cases. After they were put inside a room that polluted with cigarette smoke, the percentage of pollution in the air increases, as shown in Tables 4.3 and 4.4.

Table 4.3: When Air Quality =75ppm.

Age	Gender	Traditional devices		Sensors		Pathological case
		Spo2	Heart rate	Spo2	Heart rate	
Year		%	bpm	%	bpm	
74	F	97	85	96	84	normal
73	M	99	65	98	63	high blood pressure
73	M	98	82	98	80	normal
69	F	98	77	97	77	normal
59	M	97	79	96	79	normal
57	F	98	76	96	76	normal
40	M	96	63	95	62	high blood pressure

Table 4.4: When Air Quality =170ppm.

Age	Gender	Traditional devices		Sensors		Pathological case
		Spo2	Heart rate	Spo2	Heart rate	
Year		%	bpm	%	bpm	
74	F	97	87	96	85	normal
73	M	98	69	98	68	high blood pressure
73	M	95	88	94	87	normal
69	F	97	88	96	86	normal
59	M	95	79	95	78	normal
57	F	95	78	94	77	normal
40	M	94	68	94	67	high blood pressure

4.2 DISCUSSION

From the comparison between the readings of traditional devices and the readings of used sensors in tables 4.1 and 4.2 that mentioned in previous pages, the change between the readings in each case calculated by applying the following mathematical equations 1, 2 and

$$\Delta \text{Body temperature} = (\text{Body temperature from device} - \text{Body temperature from sensor}) \quad (4.1)$$

$$\Delta \text{Spo2} = (\text{Spo2 from device} - \text{spo2 from sensor}) \quad (4.2)$$

$$\Delta \text{Heart rate} = (\text{Heart rate from device} - \text{Heart rate from sensor}) \quad (4.3)$$

After applied the previous equations on both tables 4.1 and 4.2, the change between the two readings calculated for each case in as shown table 4.5 and 4.6:

Table 4.5: The Change Values between the Readings of Traditional Devices and the Readings of Used Sensors when the Humidity =36% and the Temperature Rom=30°.

case no.	Traditional devices			Sensors			Δ Temp. body	Δ Spo2	Δ Heart rate
	Temp. body	Spo2	Heart rate	Temp. body	Spo2	Heart rate			
	°c	%	bpm	°c	%	bpm			
1	35.8	97	82	35.2	94	80	0.6	3	2
2	35.1	97	60	35	95	60	0.1	2	0
3	36.4	99	82	36.3	98	81	0.1	1	1
4	36.5	98	77	36.4	98	76	0.1	0	1
5	36.4	97	75	36	97	73	0.4	0	2
6	35.5	98	76	35.5	98	75	0	0	1
7	36.3	95	62	36	95	62	0.3	0	0
8	35.8	95	96	35	94	95	0.8	1	1
9	36	95	108	36	94	104	0	1	4
10	36	98	69	35	97	68	1	1	1
11	36.6	97	96	36	97	95	0.6	0	1
12	36.6	98	91	35.5	95	89	1.1	3	2
13	36.6	94	75	35.5	95	75	1.1	-1	0
14	36.1	94	70	36	94	70	0.1	0	0
15	35.9	97	91	36	96	90	-0.1	1	1
16	36.6	98	91	36	95	89	0.6	3	2
17	36	99	98	35	98	95	1	1	3
18	36.5	99	128	36	98	125	0.5	1	3
19	36	98	114	36	95	113	0	3	1
20	36	98	114	36	95	113	0	3	1
21	35.4	98	117	35	96	115	0.4	2	2
22	36	99	122	35.5	98	121	0.5	1	1
23	35.2	98	127	35	97	125	0.2	1	2

Table 4.5: The Change Values between the Readings of Traditional Devices and the Readings of Used Sensors when the Humidity =36% and the Temperature Rom=30⁰ “Table Continued”.

24	35	99	117	35	98	115	0	1	2
25	35.9	99	129	35.5	99	128	0.4	0	1

Table 4.6: The Change Values between the Readings of Traditional Devices and the Readings of Used Sensors when Humidity =79% and Temperature Rom=35⁰.

case no.	Traditional devices			Sensors			Δ Temp. body	Δ Spo2	Δ Heart rate
	Temp. body	Spo2	Heart rate	Temp. body	Spo2	Heart rate			
	$^{\circ}$ C	%	bpm	$^{\circ}$ C	%	bpm			
1	36.3	94	83	36	94	82	0.3	0	1
2	36.9	95	78	36.5	95	77	0.4	0	1
3	37	99	85	37	98	84	0	1	1
4	37	98	80	36.7	97	79	0.3	1	1
5	36.7	97	79	36	97	75	0.7	0	4
6	36	97	77	35.5	97	76	0.5	0	1
7	36.5	95	68	36	94	67	0.5	1	1
8	36	95	97	36	95	96	0	0	1
9	36.2	95	110	36	95	110	0.2	0	0
10	36.4	98	75	36.2	98	74	0.2	0	1
11	36.2	96	89	36	96	88	0.2	0	1
12	37	96	92	36.5	95	91	0.5	1	1
13	36	95	76	36	95	76	0	0	0
14	36.7	95	78	36.5	95	75	0.2	0	3
15	36	97	95	36	96	94	0	1	1
16	37	97	96	37	96	95	0	1	1
17	36.5	99	99	36	98	97	0.5	1	2
18	36.3	98	130	36	98	129	0.3	0	1
19	36.5	95	118	36.5	96	117	0	-1	1
20	36.2	96	122	36	96	120	0.2	0	2
21	37	99	128	36.5	98	127	0.5	1	1
22	36	97	129	35.3	97	128	0.7	0	1
23	36	98	122	35	98	120	1	0	2
24	37.2	99	130	36.8	99	129	0.4	0	1
25	37.4	97	134	36	97	131	1.4	0	3

The small changes between the readings of traditional devices and the readings of the used sensors in both tables 4.5 and 4.6 can be used to evaluate this system by calculate the

accuracy rate of this system according to equations 4, 5 and 6. In addition, to calculate the average accuracy rate for each sensor, the equation 4-7 used.

% Body Temp. accuracy rate

$$= 100 \times \left(\frac{|\Delta \text{Body Temperature}|}{\text{manual devices Body Temp.}} \times 100\% \right) \quad (4,4)$$

% Spo2 accuracy rate

$$= 100 \times \left(\frac{|\Delta \text{Spo2}|}{\text{manual devices Spo2}} \times 100\% \right) \quad (4,5)$$

% heart rate accuracy rate

$$= 100 \times \left(\frac{|\Delta \text{Heart rate}|}{\text{manual devices Heart rate}} \times 100\% \right) \quad (4,6)$$

Average of sensor accuracy rate

$$= \frac{\text{sum of all accuracy rate for 25 cases}}{25} \quad (4,7)$$

Table 4.7:The Accuracy Rates when the Humidity =36% and the Temperature Rom=30.°

Case no.	Accuracy rate of Temp. body	Accuracy rate of Spo2	Accuracy rate of Heart rate
1	99.98	99.97	99.98
2	100.00	99.98	100.00
3	100.00	99.99	99.99
4	100.00	100.00	99.99
5	99.99	100.00	99.97
6	100.00	100.00	99.99
7	99.99	100.00	100.00
8	99.98	99.99	99.99
9	100.00	99.99	99.96
10	99.97	99.99	99.99
11	99.98	100.00	99.99
12	99.97	99.97	99.98
13	99.97	99.99	100.00
14	100.00	100.00	100.00
15	100.00	99.99	99.99
16	99.98	99.97	99.98
17	99.97	99.99	99.97
18	99.99	99.99	99.98

Table 4.7:The Accuracy Rates when the Humidity =36% and the Temperature Rom=30° “Table Continued”.

19	100.00	99.97	99.99
20	100.00	99.97	99.99
21	99.99	99.98	99.98
22	99.99	99.99	99.99
23	99.99	99.99	99.98
24	100.00	99.99	99.98
25	99.99	100.00	99.99
Total average of accuracy rate	≈ 99.99	≈ 99.99	≈ 99.99

Table 4.8: The Accuracy Rates when Humidity =79% and Temperature Rom=35.°

Case no.	Accuracy rate of Temp. body	Accuracy rate of Spo2	Accuracy rate of Heart rate
1	99.99	100.00	99.99
2	99.99	100.00	99.99
3	100.00	99.99	99.99
4	99.99	99.99	99.99
5	99.98	100.00	99.95
6	99.99	100.00	99.99
7	99.99	99.99	99.99
8	100.00	100.00	99.99
9	99.99	100.00	100.00
10	99.99	100.00	99.99
11	99.99	100.00	99.99
12	99.99	99.99	99.99
13	100.00	100.00	100.00
14	99.99	100.00	99.96
15	100.00	99.99	99.99
16	100.00	99.99	99.99
17	99.99	99.99	99.98
18	99.99	100.00	99.99
19	100.00	99.99	99.99
20	99.99	100.00	99.98
21	99.99	99.99	99.99
22	99.98	100.00	99.99
23	99.97	100.00	99.98
24	99.99	100.00	99.99
25	99.96	100.00	99.98
Total average of accuracy rate	≈ 99.99	≈ 100.00	≈ 99.99

When the humidity equal to 36% and the temperature rom equal to 30°, then the total average accuracy rates of body temperature, Spo2 and the heart rate were approximately 99.99%, 99.99% and 99.99% respectively.

When the humidity equal to 79% and the temperature rom equal to 35o, then the total average accuracy rates of body temperature, Spo2 and the heart rate were approximately 99.99%, 100% and 99.99% respectively.

From the comparison between the results of both tabel 4.1 and 4.2, there are noticed changes in body temperature, spo2 and heart rate values because of the increasing in the humidity and the temperature of environment around the patient.

In addition, from the comparison between the results of both tabel 4.3 and 4.4, there are noticed changes in Spo2 and heart rate values when the air qulity incresed because of the patient placed inside inside a room that polluted with cigarette smoke.

5. CONCLUSION AND FUTURE WORK

5.1 CONCLUSION

This scheme is a proposed prototype that has been implemented at the lowest cost and time to monitor and detect the healthcare of the patient remotely without needs going to the healthcare center by using IoT technology.

In this thesis, the different sensors of vital signs and environment factors are used to detect the healthcare of a patient then uploading the readings of these sensors to the cloud by using modern microcontroller called a particle photon, which is the processor of this system.

The system architecture was designed by using three mainly units that are worked as a cooperated platform. The first unit, called input unit, worked as a main provider service to other units, it feeds the system with cleaning energy by using modern electrically recourse called Solar panel cells, also it feeds the system with Internet using modem hotspot as well as the sensors that feeds the particle photon with readings. The second unit, which called processing unit, used the particle photon as a central processing unit of the system and process all received all readings from the sensors then uploaded it to the third unit. The third unit, which called output unit, worked as a monitor of the results to send it to the person in charge of monitoring the patient by using Blynk IoT Platform, which is GUI application in smartphone or laptop devices.

Numerous readings have been taken from twenty-five cases of people to emulate this system and make the comparison between the traditional measurement devices and the used sensors of the proposed system, and then the accuracy rates of the proposed system calculated and they were very close to the real values with percentage of 99.99.

5.2 FUTURE WORKS

Future work suggestions for the present research are as follows:

- a. The percentage of oxygen in the blood may decrease in the highlands due to the decreasing in the atmospheric pressure factor, so it is possible to add a BME280 sensor to know the value of the atmospheric pressure and altitude.
- b. A sensor for measuring blood pressure MPS20N0040D-D (Sphygmomanometer) can be added in developing the proposed system by measuring the patient's blood pressure, as the human blood pressure is one of the vital signs that can be monitored.

- c. The Twilio platform can be used with the particle photon to develop the proposed system when requiring an increase in the number of people monitoring the patient's condition by sending SMS or MMS messages.
- d. If requiring the application of the proposed system in more than one country and to solve the problem of redefining the particle photon on the new Wi-Fi network, so it is possible to use a modem that accepts any SIM card in the world.
- e. The NEO-6M GPS Receiver Module can be used with the particle photon when the patient needs to send his location to the doctor or health center for the purpose of first aid when sudden changes in vital signs occur.
- f. The AD8232 ECG sensor can be used with the particle photon to monitor the electrical performance of the heart by means of a graph and send it to the doctor to evaluate the heart's condition.
- g. The SparkFun Photon Micro OLED Shield can be used with the particle photon to display the results as an alternative to a mobile or display screen for people who cannot handle a mobile.

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