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ODUSAMI, Modupe, MISRA, Sanjay, ABAYOMI-ALLI, Olusola, SHOBAYO, Olamilekan <http://orcid.org/0000-0001-5889-7082> and MOSES, Chukwuemeka

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An Enhanced IoT Based Array of Sensors for Monitoring Patients Health

Modupe Odusami [1], Sanjay Misra[1], Olusola Abayomi-Alli[2], Shobayo Olamilekan[1] , Chukwuebuka Moses[1]

[1]Department of Electrical and Information Engineering, Covenant University, Ota, Nigeria.
[2] Department of Software Engineering, Kaunas University of Technology, Lithuania

{modupe.odusami, sanjay.misra, olamilekan.shobayo}@covenantuniversity.edu.ng, olusola.abayomi-all@ktu.edu, ebuka516@gmail.com

Abstract. The advancement of information technology is demonstrated by the emergence of the Internet of Things, which impacts many areas, such as health care and health services. Internet of Things has grown its branches in nearly all areas due to its enormous characteristics. Due to the current pandemic that has created a gap between doctors and their patients, an intelligent health monitoring system for exact and precise tracking of a patient's health is crucial. Various health monitoring systems are being developed on the button of current growths in the Internet of Things. However, there exist some shortcomings in the likes of range of connectivity, cost, and portability. This study aims to develop an enhanced Internet of Things-based patients' health monitoring system consisting of four vital sensors: temperature sensor, heartbeat sensor, pulse sensor, and a UV sensor. These sensory units are attached to the Arduino nano board, and the data gotten from these sensors are stored in a ThingSpeak cloud with the ESP8266-01 wi-fi Access Module communicating. The proposed solution is fully tested on 25 live patients, and the overall results with respect to the output of the sensors with given live temperature, Heartbeat, pulse rate, and UV readings showed an automated response of sensors and significant improvements to the availability of patients vitals in real-time with a least average response time of 7seconds. In conclusion, our experimental results showed an advancement in existing studies regarding numbers of measured parameters, deployment environment, and response time.

Keywords: Arduino nano, Health monitoring system, Health security, Heartbeat sensor, Internet of Things (IoT), Pulse sensor, Thingspeak, UV sensor

1 Introduction

Health monitoring systems are becoming more critical, and Internet of things (IoT) technology offers an effective approach to handle real-time service in health care. (Zafar et al., 2018, Verma and Sood, 2018). Automatic and mobile-based health monitoring devices are gaining momentum nowadays (Omoregbe et al., 2020, Adeloye et al., 2017, Osebore et al., 2017, Santos et al.,2020, Ajayi et al., 2018). This is partly due to the shortage of the numbers of available doctors in the rural areas as compared to their urban counterparts. In these rural areas, medical equipment is also hard to come by, and when available, most of this equipment is already in bad condition in poorly funded government hospitals in developing countries. Hypertension has pride itself to be the root cause of cardiac/stroke mortality among many other chronic illnesses affecting humankind (Prasadand Paudel, 2020). The advent of the Internet of Things (IoT) has led to the seamless integration of computing devices that can connect to the Internet to be able to provide the health details of a patient to a remote doctor in real-time. These devices are known as IoT devices, and they can be categorized as physical assets such as Sensors, Machines, Gateways, and the Network. They can connect people to things (people to objects) and things to things (objects to objects).

Typically, an IoT network can grow radically in an uncontrolled manner. This can lead to an increase in the variety of data that it processes, computational speed of the data, and an increase in the size of the data as well (Rathee et al.,2019). This increase in the speed and size of data that IoT devices processes on a daily basis can lead to money-making opportunities and value expansion. The only shortcoming from this large chunk of data is the availability of sophisticated tools to analyze them and be able to conclude them in real-time (Marques and Pitarma, 2019).

The sophisticated and complex nature of the IoT technology coupled with the frenzy created by the Internet, Mobile Technology, and an ever-present IT environment has created a sort of urgency to build powerful analytical tools (Gil et al., 2019). To make the industry a very viable option requires the ability to use these data for real-time predictions. In contrast to the pre-IoT era, where for instance, a typical supply chain challenge takes about 2–3 days to be resolved, cases nowadays take a very short time to be handled in these days of IoT. Time periods such as 30 minutes for the rectification of electrical faults to 30seconds reaction times to information from devices to even a 5 milliseconds reaction to breaches in security (Park and Lee, 2019).

This data explosion and high expectations experienced in the IoT environment can lead to loss of value of data due to the short life span. Hence, there is a need to act on this data in real-time. The importance of timeliness of IoT data can be experienced in a wide range of applications and use cases. These applications can be grouped into 3 parts, namely: long term growth and innovation on new products and services can increase revenue and raise the value of a business, the second being operations and fulfillment are in the right place to provide efficiency gains and applications that are focused on sales and marketing will increase customers satisfaction (Najar, 2019).

Some other specific use cases such as demand/supply optimization, predictive maintenance, and predictive one-to-one marking and outage management are also available within the application. To be able to address the time for actions to be taken on these application use cases requires an advanced and sophisticated analytic solution that will combine real-time streaming, predictive, historical and prescriptive analytics as well as provides top-notch analysis and smarter resolutions (Hoque et al., 2018, Yassine et al., 2019, Habibzadeh et al., 2019).

The Bluetooth technology thrives on its low battery consumption, but it also lacks in its range of connectivity (Zubair et al., 2019). The Zigbee module's downside is having a limited bandwidth of 250 kbps, which takes up to four times more time to transmit a fixed amount of data compared to other technologies. Bluetooth technology which allows the implementation of a single sensor has shown to be a promising technology in the health care system (Petrakis et al., 2018). However, this technology can be improved via the implementation of simultaneous transmission of ECG data via ADC. This speeds up the ECG sampling process and, in effect, generates complete and accurate ECG data. Also, various vital sign devices are standalone, and even those equipped with multiple sensors are either two or three. Some of the IoT-enabled health monitoring systems focused on a single parameter. One important point to consider here is how to integrate several sensors together into a single device for the health monitoring system. The main contribution of this paper is

- The design of an automatic health monitoring system using an Arduino device and a wi-fi module relays the information to thingspeak cloud-based web servers.
- To integrate different sensors such as temperature sensor, UV sensor, pulse sensor, heartbeat sensor, and it is IoT enabled.
- To develop an easy-to-use, cost-effective smart system that will enable patients or individuals to monitor their vital signs and enable doctors to remotely monitor patients' health via the Internet easily using IoT.

The rest of the paper is organized as follows: Section II covers the background of IoT – sensors in health monitoring systems. Section III discusses in detail the related works with highlights on the limitations of existing approaches. Section IV presents the method used with a detailed description of the sensing units., controlling unit and the display unit. Section V describes the results achieved in the proposed system. The paper concludes in Section VI with future research and recommendations.

2 Background and Related Work

The Internet and its applications have become an integral part of the human lifestyle today. In every aspect, it's become an essential tool. IoT technology has completely changed the narratives of society by giving us the ability to track and manage important phenomena in our environment through devices that can sense, store and transfer information wirelessly to remote storage, such as cloud for analysis and presentation in a human-readable form (Nagy et al., 2018).

Researchers went beyond just connecting computers to the web because of the tremendous demand and necessity. These researches led to a groundbreaking gizmo, the IoT, being developed. The IoT technologies were suggested years ago, but it is still in the initial phase of commercial implementation (Khanna and Kaur, 2019). The increased use of mobile technologies and smart devices in the healthcare sector has a major impact on the world. The eradication of diseases and illnesses requires careful monitoring of one's health. Health experts are gradually taking advantage of these innovations, thereby creating a major change in health care. Likewise, several people are provided with the advantages of M-Health (Mobile Health) and E-Health (ICT-supported healthcare) applications to improve, assist and assist their wellbeing. In order to contribute to and expand the overall health care system, various devices and systems can work together in the scope of IoT. End-user healthcare applications need a variety of knowledge about a patient's condition and environment to better understand the health of the patient and the type of treatment required. This data is gathered from a collection of sensors with different applications (Rao et al.,2012). The system facilitates Real-time analysis of various patient vitals such as heart rate, temperature, foot pressure and ECG. Data emanating from the system is transferred to the cloud using an IoT device. The main function of the IoT device is to connect the various sensors to a central platform.

IoT has recently become an area of enormous concern for both risk investors and technology companies, contributing to a multitude of research and business initiatives. Smart grid, clever town, intelligent wearable devices, and intelligent home are some of the applications that have gained great attention. Nearly every IoT device requires some sensors and transducers usually attached to a microcontroller and a wireless link that connects to a remote cloud server or a local repository and has the capacity to turn preprocessed data into useful information. This section discusses the various studies tailored towards IoT patient health monitoring systems.

Related Studies on IoT Patient Health Monitoring System.

Raiz (2018) designed a system monitoring the Heartbeat and blood pressure of a patient with the Arduino serving as a bridge that uploads the data collected from the sensors to the web. Low cost and efficiency were some of the authors' strengths. However, the authors did not consider enough parameters to be measured. Sivasankari et al. (2018) concentrated on temperature, blood pressure measurement, and pulse rate sensor using the Arduino ATmega328P AVR microcontroller. The results gotten from the Arduino were uploaded to the Lab View. Medical Doctors could view their patient chart data in real-time, and the data gotten from the patients are stored in an excel sheet on the cloud for easy access. However, the cost of implementation was very high. Similarly, Vippalapalli and Ananthula (2016) proposed a system to measure patients" vitals with heartbeat sensors, temperature sensors, eyeblink sensor, ECG sensors, and Arduino ATmega328P, the microcontroller transmits the data to a cloud-based website called ThingsSpeak. Akshaya et al. (2019) used the Raspberry Pi was used the connecting point between the input of the sensor and the Virtual Network Computing (VNC) server. Each of the sensors, namely: blood pressure sensor, body temperature sensor, an electrical sensor, pulse/heartbeat sensor, and patient location sensor, are connected to the Raspberry Pi.

Signals of Raspberry pi can be shown on the window, and the importance of these sensors can be shown on the doctor's Local Area Network or wi-fi compatible Raspberry Pi VNC Server Similarly, signals from temperature transducers, heartbeat sensors, and respiration are sent to the Raspberry Pi with the use of signal conditioning and an amplifier circuit according to Uddin et al. (2017). Furthermore, Rahman et al. (2019) proposed a raspberry pi system as a central device that connects the input and output device. The data gotten from the sensors such as ECG and the temperature sensors are sent to the Arduino uno, sending the data to the raspberry pi. One major limitation of the approach is the low signal gain that can lead to data loss.

Kumar and Rajasekaran (2016) proposed a system that monitors health using raspberry Pi and IoT. This system used measurements derived from four physiological parameters: the accelerometer sensor, the respiratory sensor, and the heartbeat sensor. The sensory units' captured signal was also amplified and conditioned before passing through to the Raspberry Pi.

The proposed system was very effective in monitoring patient's health. Future work introduces more parameters and utilizes web applications so that patient's data can be accessed anywhere in the world. Rajkumar et al. (2017) proposed a health monitoring system based on temperature and heart rate. The details of the patients' medications were stored in a local repository made available in the raspberry Pi, and body temperature of the patient and their Heartbeat were monitored by temperature sensor and heartbeat sensor, respectively. These devices were also connected to the Raspberry Pi through the Fitbit.

The temperature value was also extracted the same way. The doctors get notified via SMS, if there is an anomaly in the patients' data. The proposed system reduced health care costs and facilitated a faster way to detect the problem. However, patient's data are not easily accessible at all times. Furthermore, Sunehra and Ramakrishna (2016) proposed Arduino uno and Raspberry Pi's use for monitoring patient's health through the Internet. The physiological component of the human body used includes: blood pressure, body temperature, the oxygen level in the blood and pulse rate. Zigbee was utilized for the transmission of data from Arduino to the raspberry pi. The proposed system is useful in monitoring the health status of older adults. Purnima (2014) upped the ante by designing a patient monitoring system that is more reliable and energy-efficient. They were able to incorporate real-time transmission of patient's parameters, i.e. (location, temperature, Heartbeat, and ECG). The protocol used for transmitting the data is the Zigbee module which is connected to an Arduino uno. Kumar and Pandey (2018) also proposed a similar health monitoring system that was able to track vital health parameters. They included a human skin response sensor and glucose level sensor in addition to the pulse rate, blood pressure, and body temperature sensors, respectively.

Zigbee IEEE 801.15.4 was used for the data transmission to provide a low-cost solution. Nurdin et al. (2016) used only the ECG sensor connected to the ZigBee module. The data sent to the ZigBee module is transmitted to a testing webserver called the web stress tool and apache benchmark. One of the drawbacks was that the ZigBee interface could only allow only 20 users. Deepa and Kumar (2013) designed a smart non-invasive wearable monitoring device using ZigBee developed and designed to measure physiological parameters, such as temperature, heart rate, blood pressure, and patients' movement. The machine contains an electronic gadget worn on a dangerous person's wrist or arm. To detect falling, an impact sensor was used. The results were obtained with the software LabVIEW.Sollu et al. (2018) proposed a heart rate monitoring system and body temperature using Raspberry Pi. The patient's data stored on the raspberry pi can be viewed on a personal computer. The proposed system error rate in detecting heartbeat rate and body temperature was very insignificant. Warsi et al. (2019) presented a model based on IoT for remote patient health observation. Through the use of the sensors, the device was capable of monitoring the essential vital elements of patients at home or remotely such as temperature, blood pressure, Heartbeat, and Electrocardiographic readings. The doctor can monitor the patient's live status from anywhere from a remote location without being restricted due to internet access to receive live patient notifications. The model introduced is highly useful to society and supports the current health monitoring solutions. Akhila et al. (2017) proposed a microcontroller-based Patient health monitoring system using Arduino and Atmega328 microcontroller to obtain readings from a heartbeat, blood pressure, and body temperature transducer. Thingspeak was used to store the transducer readings to the cloud recorded in the Arduino uno via the wi-fi module. From experimental results, the proposed system showed high reliability, great returns, and user-friendliness. The shortcoming of the system is that only three vitals were taken into consideration, and improvements can be suggested, such as adding more parameters like Body Mass Index (BMI) and body glucose level. Singh and Jain (2016) performed an experiment on the performance and evaluation of Bluetooth technology-related blood pressure monitoring systems. Preliminary results obtained indicate the prototype developed can give results with some degree of confidence, and the criteria set by the Advancement of Medical Instruments protocol was duly met. Further recommendations for the work are to include all other parameters to improve the robustness of the system. And also, several other technologies can be incorporated into the analysis of the design.

Tello et al. (2012) proposed a remote health monitoring system that measures the body temperature and Electrocardiogram (ECG). The medium for transmission is the Bluetooth module, and the data collected here is displayed on an LCD screen. The information could later be accessed through a web application platform using internet connectivity. The performance of the proposed model was verified using 13 volunteers and could be effectively used in remote areas; optimal connectivity is not classified as an important parameter. Experimental results also showed that there was a delay in the signals received by the proposed model. Majumder et al. (2018) proposed a health monitoring system that is wearable, user-friendly, and monitors continuously body vitals such as heart rate, blood pressure, and body temperature. An Arduino was implemented for the data acquisition unit. Bluetooth technology was utilized for the means of data transmission in order to achieve a cost-efficiency model. The proposed system was very effective in getting different vital sign readings when the patients or doctors wish to. The implemented device was easily portable and cheaper than other devices and proven to be an appropriate solution for densely populated countries. Future work is the inclusion of ECG sensor and respiratory rate checking unit. Zainal et al. (2016) presented wireless photoplethysmography data acquisition for health monitoring systems using blue tooth technology, and the outcome was able to fulfill the desire of producing a valuable product. Li and Pan (2017) proposed a health monitoring system based on IoT. The physiological parameters monitored are temperature, ECG, and pulse rate, and the measured data were transmitted through Bluetooth to the android platform. The medical doctors were able to get the patients through GPRS that is connected to the mobile platform. Experimental results showed that the proposed model gave a high accuracy. Future work is the utilization of wi-fi technology which is capable of greater connectivity both at indoor and outdoor. Hasan and Ismaeel (2020) proposed an ECG monitoring system based on Arduino Uno, ESP8266 wi-fi module, and IoT Blynk application. The Blynk IoT application is used by physicians to monitor the heart state of their patients. The proposed system is very easy to use by anyone, and it is cost-effective.

Bharadwaj et al. (2018) presented a health monitoring system Using Arduino and ThingSpeak. The parameters measured were ECG and temperature. The acquired data is sent to a web server in real-time for the doctors to be able to view the patients' vital signs anytime. The proposed system is very cost-effective. The authors recommended the utilization of a mobile platform to enable the use of SMS, especially when there is an emergency. Yeri and Shubhangi (2020) proposed a real-time health monitoring system consisting of a web and mobile applications. The major sensors used to capture patients' vital are: temperature sensors, pulse sensors, and SpO2 sensors. The data acquired from the sensor devices is transmitted to the cloud via a wi-fi module that interfaced with Arduino uno. The system allows doctors to monitor their patients' health remotely, and the patients via the system can seek medical care from any specialist all over the world. The system can be upgraded by incorporating another sensor that will allow regular check-ups of the client.

Table 1: Summary of Related Works

Author	Sensors	Methodology	Contribution	Limitation
Yeri and Shubhangi (2020)	temperature sensor, pulse sensor, and SpO2 sensor	Arduino, Wi-fi, web and mobile platform	The intervention time between doctor and patient is reduced in case of emergency	proposed model doesn't include the blood pressure monitoring system.
Hasan and Ismaeel (2020)	ECG	Arduino Uno, ESP8266 wi-fi module, and IoT Blynk application	Low cost	Absence of cloud database and limited parameters
Akshaya et al. (2019)	pulse / heart beat sensor, temperature sensor, electrical sensor, blood pressure sensor and patient position sensor	Raspberry pi and wi-fi module	The proposed system was able to display data in real time	Data loss due to low signal gain
Rahman et al (2019)	ECG	Raspberry pi	The proposed system was able to monitor real time status of the patient irrespective of the presence of	Limited parameter was considered

			doctor.	
Warsi et al (2019)	blood pressure, heartbeat rate and ECG	Arduino and wi-fi module	The proposed system was able to upload the data to a cloud storage.	Just three sensors was used for the analysis.
Majumder et al (2018)	Blood pressure, heartbeat rate, and temperature	Arduino and Bluetooth.	easily portable and cheaper	Need for additional sensory unit
Raiz (2018)	Heart beat	Microcontroller with wi-fi module	Low cost and high response rate.	Limited parameter was considered.
Sollu et al. (2018)	Heartbeat and temperature	Raspberry pi	Low cost.	Distance of transmission is limited with obstruction
Bharadwaj et al. (2018)	ECG and Temperature	Arduino, Wi-fi module and Thingspeak	Low cost	Limited parameter was considered.
Li and Pan (2017)	temperature, ECG, and pulse rate	Bluetooth and GPRS	Portable and did not need extra communication network.	Limited connectivity
Rajkumar et al. (2017)	Temperature, heartbeat rate	Raspberry pi	Low cost	Data's are not easily accessible
Akhila et al (2017)	Temperature and Heartbeat.	Arduino and Wi-fi module	Low cost	Limited parameters
Kumar and Rajasekaran (2016)	temperature sensor, heartbeat sensor, respiration sensor, and accelerometer sensor	Raspberry pi	Effective transmission of patients data.	Limited connectivity
Tello et al. (2012)	Temperature and ECG	Arduino and Bluetooth.	Portability, low cost, connectivity easiness, and scalability	Delay in signals

The summary of some related work in the health monitoring system using different technologies and the number of parameters considered for patient monitoring is presented in Table 1. Some of the limitations affecting research efforts are the absence of a cloud base database, delay in signals, limited connectivity, obstruction of data transmitted, and limited sensory units. However, there is a need for effective and affordable methods that will integrate more sensors in one device for patient's health monitoring system (Majumder et al.,2018).

3. Proposed Approach

The proposed system uses four vitals for the health monitoring system. These vitals use four sensors in return, which are heartbeat sensor, Temperature sensor, UV sensor and the pulse sensor. These sensors are connected to an 8-bit ATmega328P Arduino board. ThingSpeak acts as the remote cloud-based repository that connects the doctor's computer to the Arduino uno through the ESP8266-1 wi-fi module. This system's advantage is that it adds four vitals where other works have used less and integrates all the components on one device. The block diagram of the proposed system is depicted in Figure 1.

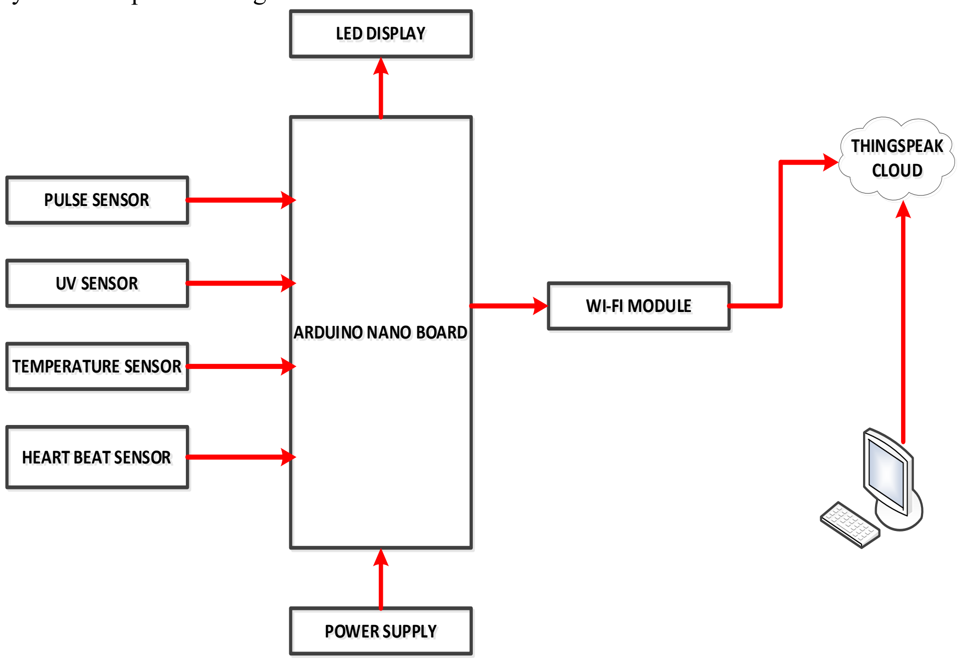

Figure 1: Block Diagram of the Proposed System.

3.1 Pulse Sensor

This study uses a pulse sensor that comprises two parts, the light sensor and the circuitry on the other side. The LED is specifically located on the vein, and it flashes with each pulse. The Technical Specifications are as follow: 5v operating voltage, Green LED as a transmitter, optical receiver

3.2 Heartbeat Sensor

This study uses a phototransistor, and an infrared LED to detect the finger's pulse, whereby a red LED flashes with each pulse. The finger's light side is the LED while on the other side of the finger is the phototransistor. The flux emitted while capturing the blood pressure pulse is obtained via the phototransistor. It is very critical to have a very sensitive phototransistor; therefore, we use a very high resistance resistor. There are variations in the flow of blood in various parts of the veins, and luminosity variations are noticeable. The sensor can precisely calculate these variations, and the measured values are printed on the display unit. Technical Specifications are as follows: Resistance can be selected by experiment to get the best results; the stray shield light must be kept into the phototransistor.

3.3 Dallas Temperature Sensor DS18B20

The DS18B20 digital thermometer can measure up to 12-bit temperature measurement in Celsius. It is also incorporated with an alarm function that has a trigger point that is programmable by the user to hard-code its upper and lower trigger points. It transmits data to and from the central microprocessor via 1 data line, which also acts as a ground. This same data line is also used to power the thermometer with a technology known as "parasite power," thereby reducing the circuitry of an external power source. Each DS18B20 has a unique 64-bit serial code, which allows multiple DS18B20s to function on the same 1-Wire bus. This makes it easy to use a single microprocessor to control many DS18B20s scattered around a large area. The temperature sensor's technical specification is as follows: Unique 1-wire interface; it measures temperature from −55 to +125 °C, Power supply range: 3.0V to 5.5V, 9 to 12-bit selectable resolution.

3.4 Ultraviolet (UV) Detection Sensor

The Ultraviolet Sensor is commonly known as the UV Sensor, is used to sense the magnitude of an incident UV radiation. Its electromagnetic radiation with a shorter wavelength than visible light. The UV Sensor is based on the sensor GUVA-S12D, which has a wide spectral range of 200nm-400nm. The module generates an electrical pulse based on the intensity of the incident UV light.

3.5 Liquid Crystal Display (LCD)

This study utilizes a 16x2 LCD display, and it is basically used in DIYs and circuits. The 16x2 translates on display 16 characters per line in 2 of such lines. In this LCD, each character is displayed in a 5×7-pixel matrix. This is the visual output where all the commands made and decisions taken by the 'brain', the microcontroller unit (MCU) are displayed. It has 16 special pins that are mapped out for special functions. The data character is shown on the LCD.

3.6 ESP8266-1 wi-fi Module.

The ESP8266-1 (ESP-01) is a wi-fi module that can allow a microcontroller (MCU) to have access to a wi-fi network. The module comes with a SOC (System on a Chip), which means that it doesn't necessarily need a microcontroller to manipulate inputs and outputs pins. This gave the ESP-01 properties to act like a small computer. The ESP-01 has 9 GPIOs (General Purpose Input Output). With the ESP-01 module acting as a module as it is connected to the MCU in Station (STA) mode, we can have internet access once we are connected to the wi-fi network. The ESP8266 wi-fi Module is a module that can connect to the Internet. The Technical Specifications are as follows: 802.11b/g/n; wi-fi Direct, 1 MB flash memory, SDIO 1.1/2.0, SPI, UART.

3.7 Microcontroller unit.

Arduino microcontroller ATmega328P – 8-bit will be used to control the circuit and get the desired output. The code for the microcontroller was written in C using the Arduino IDE to read ECG, temperature, heartbeat rate, and pulse rate. The code was first tested and reviewed for bugs via the IDE and transferred to the microcontroller via the IDE. Data is processed and transmitted to transmit serially to the ESP8266 wi-fi module. The integration test and the logical error test of the code were performed during the hardware device simulation. The technical specification according to the datasheet is described in the table below.

Table 2: Technical Specification for the Arduino Nano

Description	Specification
Microcontroller	ATmega328P – 8-bit AVR family microcontroller
Operating Voltage	5V
Recommended Input Voltage for Vin pin	7-12V
Analog Input Pins	6 (A0 – A5)
Digital I/O Pins	14 (Out of which 6 provide PWM output)
DC Current on I/O Pins	40 mA
DC Current on 3.3V Pin	50 mA
Flash Memory	32 KB (2 KB is used for Bootloader)
SRAM	2 KB
EEPROM	1 KB
Frequency (Clock Speed)	16 MHz
Communication	IIC, SPI, USART

3.8 Proposed System Circuit Design

The LCD connection was made using 4-bit data connection. The register selects (RS) connection is connected to digital pin 13. The wiper of the potentiometer is connected to Vo. The Enable (E) pin is connect to digital pin 12 on the Uno board. The 4-bit data pins (D4 through D7) are connected to digital pin 9 through 6. The read/write (RW) is grounded. The buck converter module was used to shift the voltage level from 5V to 3.3V for the ESp-01 module. The ESP-01 module won't work on 5V and usually gets hot and would burn out on long usage when powered by 5V. All ground pins are connected to the ground.
The sensors are connected to the analog IOs of the Microcontroller board. At the same time, the UV sensor is connected to the SPI pins, which are the analog pin 4 and 5. The circuit layout comprised of four sensors and was developed using the circuit design program called Fritzing; the components were connected to the Arduino via jumper cables. Arduino is interfacing with various modules such as LCD, wi-fi, Temperature sensor, heartbeat sensor, ECG sensor, and pulse sensor. Communication between the sensors and the Arduino was transmitted to the thingspeak cloud through the ESP8266-1 wi-fi module. The wi-fi module will keep giving detailed information of the person's Heartbeat at the exact time. Figure 2 shows how the sensors are interfacing with the Arduino nano; it also shows the ESP8266-01 wi-fi Access Module's role in communicating with the Arduino.

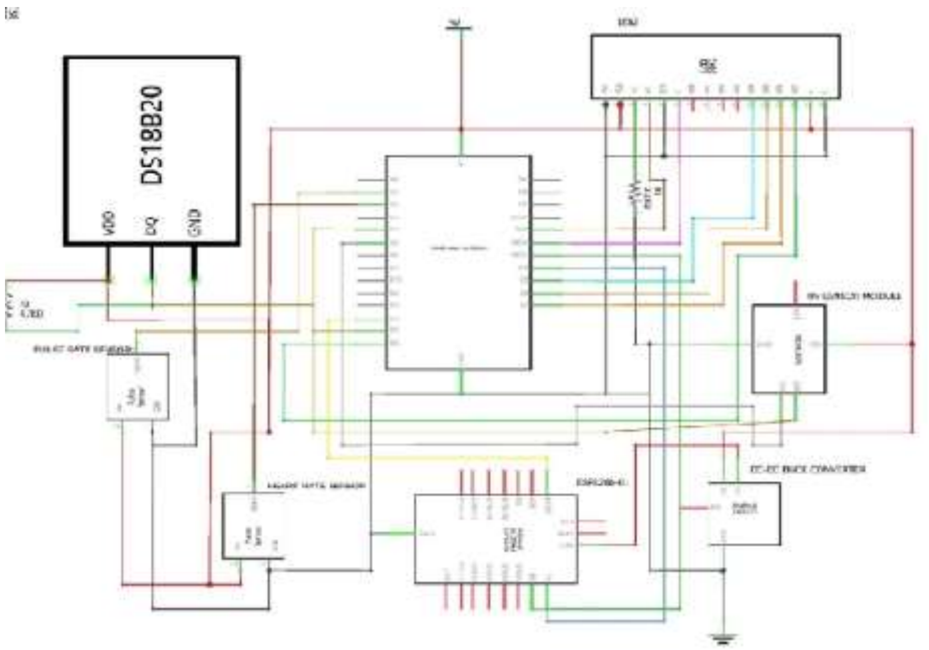

Figure 2: Proposed System Schematic Diagram

3.9 Web Application

ThingSpeak is a very popular GUI-based analytical software tool for IoT applications. It can help the user analyze and have visuals of live streams of data as received in real-time. Once connected, the monitoring of data happens instantly. Most times the ThingSpeak application can be interfaced with different microprocessor technologies such as Raspberry Pi, Arduino and any other hardware devices. If there is any application that requires the logging of data from a sensor device, ThingSpeak will make that data come alive (Bharadwaj et al., 2018). Figure 3 shows the layout of the ThingSpeak web application for the proposed system.

Figure 3: Thingspeak web application for the proposed system

In order to effectively send data to thingspeak using an Arduino, the thingspeak needs a user account and a channel. The basic steps to follow while using thinkspeak.com are:

Step 1: Collect the data in the new channel.
Step 2: Analyze your data.
Step 3: Act on your data.

The proposed system prototype is shown in Figure 4.

Figure 4 : Proposed System Prototype

Figure 4 shows a working prototype of the proposed health monitoring system. The universal serial bus from the Arduino is connected to a power supply. The default serial communication pins of the Arduino are 0 and 1. Once powered up, the PC's mobile hotspot's name and password have been configured to match the ESP8266-01 wi-fi Access Module configuration. The patient places their finger on each of the different sensors and the readings are displayed on the LCD screen. The ESP8266-01 wi-fi Access Module transmits these readings to the Thingspeak cloud. The communication is made through virtual serial ports created in a computer. On the other hand, the doctor logs into the thingspeak cloud platform and views the different readings of each sensor of the patients

4 Results and Analysis

The output from the sensors were connected to arduino and successfully sent via wi-fi module. The output in Figure 5 to Figure 7 depicted the given live Temperature, live Heartbeat, live Pulse rate, and live UV readings which can be viewed through the cloud (IoT- thingspeak. com). The output reading displayed at the rate of of 7 seconds as depicted in Table 3.

Figure 5: Health Vitals Chart of User 1

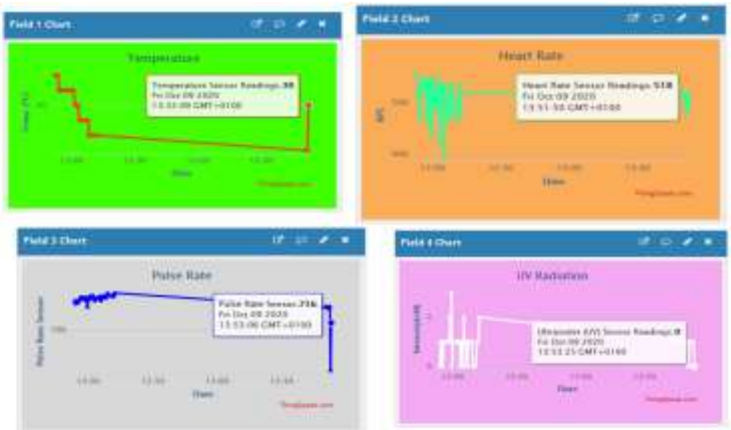

Figure 6: Health Vitals Chart of User 2

Figure 7: Health Vitals Chart of User 3

Table 3 shows the average number of seconds taken for the readings gotten from the sensors to be uploaded to the Thingspeak web cloud.

Table 3: Responses of the Sensors

Sensors	**Trial 1 (Seconds)**	**Trial 2 (Seconds)**	**Trial 3 (Seconds)**	**Average Time (Seconds)**
Temperature	7	7	7	7
Heart beat	7	7	7	7
Pulse Rate	7	7	7	7
UV	7	7	7	7

After each patient takes their readings the doctor logs into the thingspeak web application through www.thingspeak.com to view the health parameters of each patient. The different charts in Figure 5 to Figure7 show the different readings of each sensors for different patients taken in real time. With the readings for each sensor on the Y-axis and date and time on the X-axis the graphs were plotted. Each dot on the chart shows a reading taken by the sensor together with the date and time. The readings gotten from the sensors are automatically uploaded to the thingspeak cloud, and these helps doctors to easily access a patient data from months or years ago. These datas stored on the cloud can easily be downloaded and export to another platform for offline availability of patient's data. The format for the export data is Microsoft excel as depicted in Figure 8.

1	created_at	entry_id	Temperature	Heart Rate	Pulse Rate	UV Sensor
2	2020-09-10 12:05:16 UTC	381	28	493	782	0
3	2020-09-10 12:05:35 UTC	382	28	519	785	0
4	2020-09-10 12:05:59 UTC	383	28	497	779	0
5	2020-09-10 12:06:14 UTC	384	28	480	784	0
6	2020-09-10 12:06:33 UTC	385	28	514	779	0
7	2020-09-10 12:06:52 UTC	386	28	518	782	0
8	2020-09-10 12:07:11 UTC	387	28	508	781	0
9	2020-09-10 12:07:31 UTC	388	28	517	775	1
10	2020-09-10 12:07:50 UTC	389	28	513	781	0
11	2020-09-10 12:08:09 UTC	390	28	519	781	0
12	2020-09-10 12:08:28 UTC	391	28	487	782	0
13	2020-09-10 12:08:47 UTC	392	28	522	781	0
14	2020-09-10 12:09:07 UTC	393	28	518	782	0
15	2020-09-10 12:09:26 UTC	394	28	506	784	0
16	2020-09-10 12:09:45 UTC	395	28	486	780	0
17	2020-09-10 12:10:04 UTC	396	25	514	777	0
18	2020-09-10 12:10:23 UTC	397	34	522	776	0
19	2020-09-10 12:10:42 UTC	398	32.5	442	772	0
20	2020-09-10 12:11:01 UTC	399	31.5	561	785	0
21	2020-09-10 12:11:20 UTC	400	31.5	755	776	0
22	2020-09-10 12:11:39 UTC	401	31	502	771	0
23	2020-09-10 12:11:58 UTC	402	30.5	518	772	0

Figure 8: Patient data Stored on the Thingspeak Cloud for export

Table 4: Comparison with Existing Work

Authors	No of parameters measure	Cloud Platform	Statistical Analysis
Yeri and Shubhangi (2020)	3	Yes	Nil
Hasan and Ismaeel (2020)	1	No	Nil
Rahman et al(2019)	1	No	Nil
Warsi et al (2019)	3	Yes	Nil
Our Work	4	Yes	Response time

4. 1 Comparison with Existing Work.

Table 4 shows the comparison of the proposed prototype with previous work on health monitoring system. Our prototype considered four parameters (temperature, UV, pulse rate, and Heartbeat) whereas the device designed by (Yeri and Shubhangi ,2020) considered three parameters. The device designed by (Hasan and Ismaeel, 2020) focused only on ECG and there is absence of cloud platform. The work carried out by (Rahman et al.,2019) also considered limited parameters and there is no cloud storage. The comparison table shows the various physiological parameters measured. Some of draw backs of the existing methods is the use of limited parameters and also lack of evaluation. One major drawback of our proposed health monitoring system is that it is not portable.

5. Conclusion

The use of remote patient health monitoring system innovation based on IoT that enabled patient observations outside clinical settings cannot be overemphasized. Generally, IoT provides a new approach of health and patient care with remote monitoring. This study is focused on implementing an enhanced health monitoring system that can measure various vital signs (pulse rate, temperature, heartbeat rate, and UV) of patients/ users that can be transmitted in real time over the Internet. This study effectively developed a cheap but efficient system of monitoring the health vitals of people without them needing to go to the hospital for regular check-ups. In order to achieve this, the system is built on Arduino ATmega328P – 8-bit. The 16x2 LCD displays the readings from the integrated sensory units that measure the vital signs of patients.

The proposed system is IoT enabled so that the patients reading is seamlessly relayed to a cloud environment (thingspeak.com) via a ESP8266-1 wi-fi module that allow microcontroller to have access to a wi-fi network. The doctors are able to login to the IoT platform to monitor the vital signs of patients and view the readings from each of the sensors. Experimental results show that the health monitoring system effectively and efficiently monitors patients' vital signs with a response time (i.e the time it takes to display on the LCD). of 7 seconds consecutively for each of the 3 trials for all of the sensory units (temperature sensor, pulse rate sensor, heartbeat sensor, and UV sensor). The acquired readings are further automatically loaded and uploaded to the thingspeak cloud.

Hence, the proposed system is a low-cost system that eliminates the need of constantly going to the hospital for check-ups and doctors are able to monitor their patient health in real time by focusing on their temperature, pulse rate, Heartbeat, and UV. From the evaluation and the results of analysis, the system is very efficient. However, there is room for improvement, in the future the system can be extended by adding few parameters (ECG, Body Mass Index, and glucose levels can be added to the proposed systems for a concise vital signs of the patients. The working prototype can also be developed into a wearable device to allow for efficient portability. A mobile application can also be created so that doctors can be get alert via SMS in the event of emergency and critical cases.

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