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Enhanced Health Monitoring System Using Wireless Sensor Networks: A Case Study of Hypertensive Patients

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ABSTRACT
This study presents the design and implementation of a Wireless Sensor Networks (WSN) based health monitoring system for hypertensive patients. The system comprises four (4) basic units namely; the sensing unit, control unit, display unit and monitoring unit. The sensing unit utilizes a DS18B20 temperature sensor and MAX30102 heartbeat sensor to measure the blood pressure and temperature level of patients. The measured parameters are then forwarded to the control unit which further comprises two (2) microcontrollers namely; Arduino Nano and ESP8266. The Arduino Nano processes the received data from the sensing unit and forwards it to the display unit and ESP8266 microcontroller for real-time monitoring. In addition, the ESP8266 microcontroller sends the processed data to the cloud. Finally, a Blynk application was used to access the measured parameters from the cloud and thus, allowing the user to monitor the temperature and heartbeat levels of the patient. Tests were carried out on five random cases in order to determine the performance of the proposed system. The experimental results obtained showed that the system efficiently measures as well as remotely monitors the temperature and heartbeat levels of patients.

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I. INTRODUCTION

In the past decades, one of the most prominent problems facing Nigeria is the inadequate and efficient healthcare system (Abdullahi et al., 2023). This leads to high mortality rate especially in the case of hypertensive patients (Haripriya et al., 2016). These patients require regular medical checkups as well as attention. However, the present healthcare systems in the country have a limited manpower to provide the required services. To address this, there is need for technologies to be developed that will help the medical personnel in carrying out their duties efficiently. This can be achieved through the utilization of an efficient Health Monitoring System.

A Health Monitoring System (HMS) is a systematic device employed to help the healthcare personnel to track vitals, as well as monitor the patients' health condition. In addition, the HMS acts as an early warning system that helps in diagnosing the disease at its earliest stages so that any serious damage or health problems can be prevented. Besides predicting the disease due to the variation in cell energy levels, it can also detect any anomalies, and will also provide useful diagnostic support (Haripriya et al., 2016). Furthermore, it monitors the patients' heart rate, body temperature, blood oxygen saturation, blood pressure, glucose levels, respiration rate, and other essential parameters (Shruthi & Resmi, 2019). All these information is important in preventing numerous diseases, especially dangerous ones like heart attacks (hypertension).

Several works have been carried out in the area of health monitoring system in order to reduce the mortality rate of patients especially those suffering from hypertension. This is due to the fact that these hypertensive patients require monitoring at all times. However, some of these existing techniques do not provide a platform that will aid the healthcare personnel to regularly monitor the state or condition of the patients in real-time. Hence, necessitates the need for a system that will remotely monitor the patients at all times. Therefore, this study presents the Wireless Sensor Network (WSN) based health monitoring system for hypertensive patients.

In this study, a WSN was employed to collect and exchange data via the internet that can be stored, analyzed, measured, and referenced by the healthcare personnel (Yahya et al., 2023). Thus, providing a platform that will enable the healthcare personnel to remotely monitor and control the condition of the patient. In addition, the proposed system comprises a hypertension meter, ESP8266 microcontroller, and a GSM module (SIM900). The GSM module was utilized to provide an alternative communication medium that will instantly alert the healthcare personnel in case they are offline.

II. RELATED WORKS

This section presents the review of related works that have been carried out in the area of HMS. In this regard, an IoT based heart attack detection, as well as heart rate and temperature monitor was presented in (Vijayalakshmi et al., 2018). In this study, the heart rate was measured using pulse and temperature sensor (DS18B20) which wirelessly send the data to a database. The database then stores the data of the patient pulse rate over a period of time which helps in diagnostics. These heart beat sensor device and temperature sensor were attached to the patient's body which detects information from the patient, gathers readings and interfaced to the Arduino and then transmitted to the sensor and the produced voltage shifts directly with change in temperature. This model clearly specifies the pulse rating beats for minute and body temperature in Celsius. However, the system can be further improved by incorporating it with a wrist bands in order to improve the speed. Another automatic healthcare monitoring system using sensors like pulse, ECG to check the health status of the patient was presented in (Patil & Sanjay, 2018). The authors used a temperature sensor (DS18B20) to monitor the patient's room temperature. The patient's details were acquired by the sensor and processed using Arduino Uno and Octabrix boards. For real time monitoring, the patient's status and parameters were sent to the cloud using Thing Speak Server.

A heart rate measuring system using Bluetooth module was presented in (Izneid et al., 2012). The authors utilized a pulse sensor; Arduino Uno and Bluetooth module to measure the heart rate. The pulse sensor measures the heart rate and sends it via Bluetooth to the android mobile application. Furthermore, the sensor uses Photo plethysmography which is a low cost technique that is optically able to detect volumetric changes in blood flowing through capillaries from the surface of skin. Experimental results show that the proposed system detects and displays the reading efficiently. However, due to the Bluetooth used the system has limited distance coverage.

III. METHODOLOGY

This section presents the design and construction of the entire system. The overall methodology comprises two basic units; the hardware development unit and the software development unit. The hardware development involves the construction of the system circuitry modules, whereas the software development unit involves the design and development of a web-based application to remotely monitor and control the temperature and heartbeat rate. An explanation of each block is presented herewith.

3.1 Hardware Development

This section presents the step by step procedure followed for the hardware development of the proposed system. In the construction of any electronic circuits, some factors have to be considered such as: cost effectiveness, minimum circuit complexity, and minimum temperature rate and sugar level. All components selected for the construction were chosen in order to meet the requirement mentioned. The overall hardware development is summarized in the block diagram presented in Figure 1.

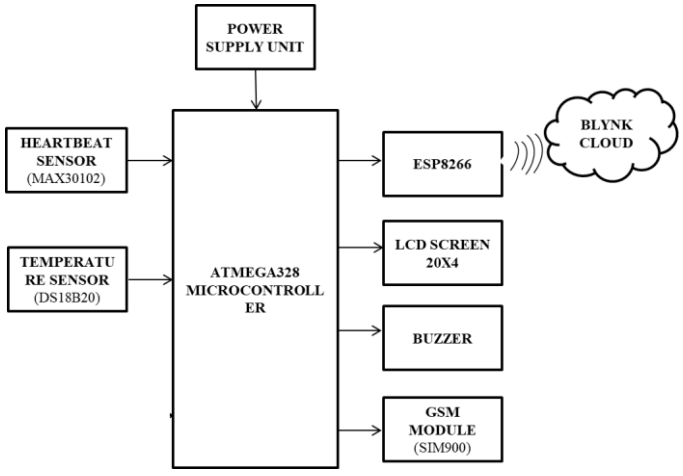

Figure 1: Block Diagram of the Proposed System

3.1.1 Control Unit

The unit comprises of two microcontrollers, Arduino Nano and the ESP8266. The ESP8266 was interfaced with Arduino Nano because the ESP has a single analog pin (A0) and the designed system requires two analog input pins. Given this, an Arduino Nano which has 8 analog pins was interfaced with the ESP8266

so as to ensure that the system works efficiently. The control unit serves as the central controller of the entire system. The mode of operation is in such a way that when the sensing unit senses the data, it sends it to the Arduino to process it and the Arduino sends the data to the ESP8266 through a process called serial communication. The ESP8266 sends the measured data to the display unit and the web application through the cloud. The ESP8266 and Arduino interface is shown in Figure 2.

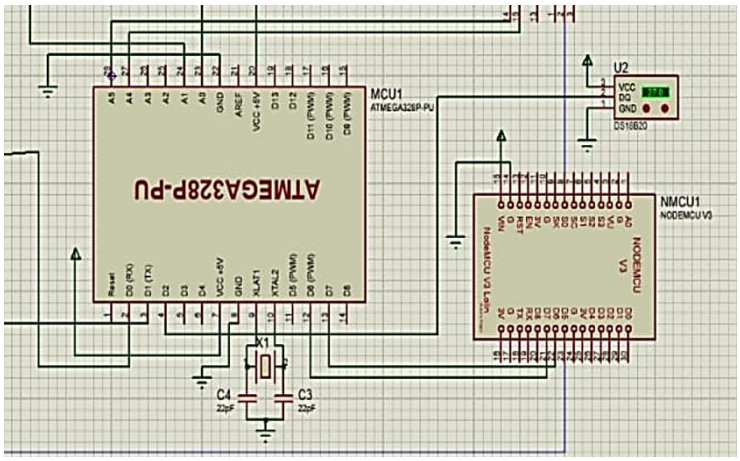

Figure 2: ESP8266 and Arduino Interface

3.1.2 Heart Beat Sensor (MAX30102)

Heart beat sensor as shown in Figure 3 was designed to give digital output of heart beat when a finger is placed inside it. It works on the principle of light modulation by blood flow through finger each pulse. It was connected to the analog pin A0. It uses a pair of LED, and LDR. Light is passed using LED from one side of the finger and intensity of light is measured on the other side using an LDR. As the heart rate increases intensity decreases. As a result, there will be a change in resistance value of LDR. The output voltage is amplified and detected using microcontroller.

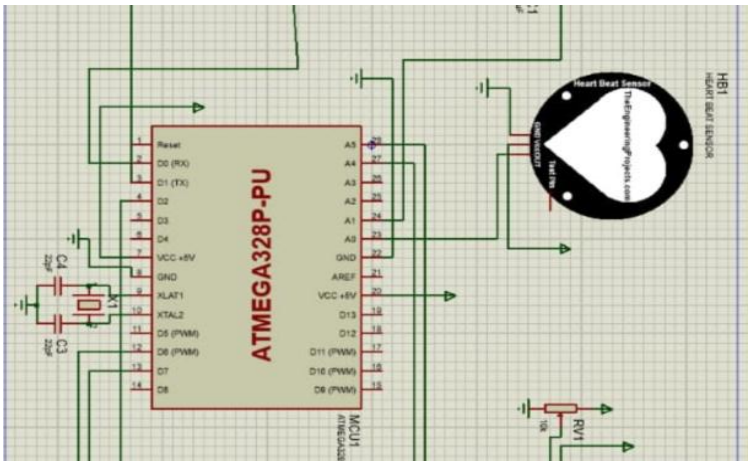

Figure 3: Heart Beat Sensor (MAX30102)

3.1.3 Temperature Sensor (DS18B20)

Temperature sensor (DS18B20) is a device used for measuring body temperature of patient and it gives values in digital form. In this study, MLX90614ESF which is an infrared Temperature sensor (DS18B20) that detects an object's temperature without any contact at all and also senses the ambient temperature of the surroundings was used. Figure 4 shows the implementation of the Temperature sensor (DS18B20).

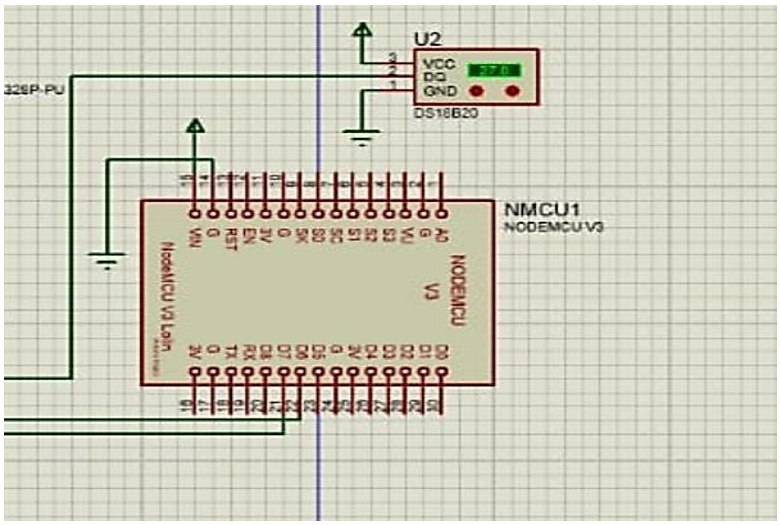

Figure 4: Implementation of the Temperature Sensor (DS18B20)

3.1.4 Display Unit

The display unit shows the measured parameters. In this system, a 20x4 LCD display was used. When the sensor measures and senses the voltage and current the load is consuming and sends it to the control unit, the control unit sends those measured parameter to the display unit for monitoring. The GND pin of the LCD was connected to the ground of the Arduino, the Vcc which is the power supply for LCD was connected to the 5 volts pin of the Arduino and D0-D7 (Data bus) pins are connected to digital output pins of the Arduino. Figure 5 shows the connection of the LCD.

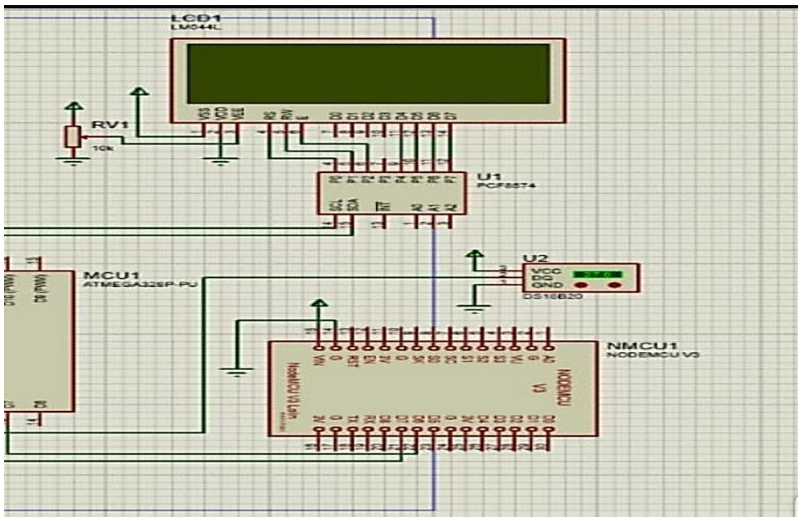

Figure 5: Connection of the LCD

3.2 Software Development

The software development unit involves the design and development of a web-based application to remotely monitor and control the temperature, heartbeat rate and sugar level the web based application was designed using Blynk application. Figure 6 presents the flowchart of the developed system.

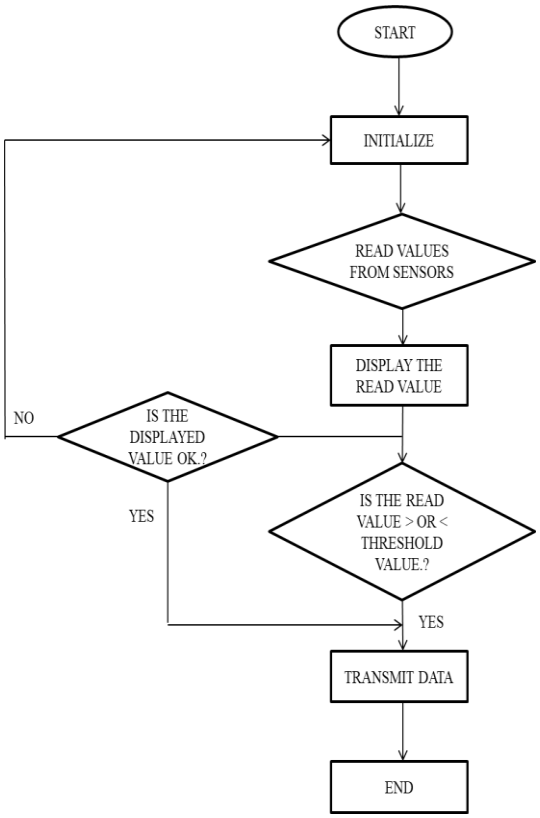

Figure 6: Flowchart of the Proposed System

IV. EXPERIMENTAL RESULTS

This section present the results obtained after the successful realization of the proposed system. Various tests were conducted, and the performance of the system was observed. Tables 1 and 2 shows the result obtained for temperature and heartbeat level measurements of five (5) random cases.

Table 1: Heartbeat Measurement of Patients

Standard Level (BMP)	Cases	Heart Beat Measured (BMP)	Level	Remark	Alert
90 – 120/60 90 – 120/70 90 – 120/80 (Ideal) 140 – 190/90 – 100 (High) 70 – 90/40 – 60 (Low)	1	135	High	Critical	Yes
	2	89	Low	Critical	Yes
	3	119	Ideal	No Message	No
	4	74	Low	Critical	Yes
	5	160	High	Critical	Yes

Based on the result obtained in Table 1, it was discovered that for case 2 the hypertension level of the patient was normal (89 BMP) and as such there was no message sent and there was no alert received. For case 3, the hypertension level of the patient approached high (119 BMP) which is unsafe for the patient, therefore a message was received saying the patient needs attention and the buzzer gave an alert.

For case 4, the hypertension level of the patient approached low (74 BMP) which is unsafe for the patient, a message was received saying the patient needs attention and the buzzer gave an alert. However, for case 1, the hypertension level of the patient became critical (135 BMP) which is very dangerous, a message was received saying the patient's hypertension level was critical and there was an alert from the buzzer.

Table 2: Temperature Measurement of Patients

Standard Level (°C)	Cases	Temperature Measured (°C)	Level	Remark	Alert
35°C – 36°C (Ideal)	1	48.88	High	Critical	Yes
	2	35.62	Normal	No Message	No
	3	39.19	High	Critical	Yes
	4	31.00	Low	Critical	Yes
	5	36.00	Normal	No Message	No

Based on the result obtained in Table 2, it was discovered that for case 2 the temperature level of the patient was normal (35.62°C) and as such there was no message sent and there was no alert received. For case 3, the temperature level of the patient approached high (39.19°C) which is unsafe for the patient, therefore a message was received saying the patient needs attention and the buzzer gave an alert. For case 4, the temperature level of the patient approached low (31.00°C) which is unsafe for the patient, a message was received saying the patient needs attention and the buzzer gave an alert. However, for case 1, the temperature level of the patient became critical (48.88°C) which is very dangerous, a message was received saying the patient's temperature level was critical and there was an alert from the buzzer.

V. CONCLUSION

This study proposed the design and implementation a real-time IoT based health monitoring system for hypertensive patients using heartbeat sensor (MAX30102) and temperature sensor (DS18B20). The system was used to measure the temperature and heart beat level of a patient over a period of time; the measured parameters were displayed on an LCD screen after which it was transmitted to the cloud using Blynk application. Whenever the measured parameters goes above or below a predefined value, the buzzer gives out an alarm while at the same time a short message is sent to a remote user through the GSM module (SIM900). Thus, provides the health personnel with an automated system capable of attending to patients in critical needs with less human interventions.

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