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IMPLEMENTATION OF A VITAL SIGNS MONITORING SYSTEM WITH BLOCKCHAIN STORAGE

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ABSTRACT

The advent of wearable devices has placed people at the centre of the healthcare delivery process, empowering them to take control of their health and simplifying interactions with healthcare professionals. However, these wearable devices face data loss, theft, unavailability, or misuse by health information managers. In this article, blockchain technology is employed to store patients' medical data in a decentralised blockchain made available to the patient or the Doctor upon request. The patient's medical data is secured by a passphrase that the user keeps securely. To achieve real-time patient health monitoring with cloud storage, this study implemented a wearable device that monitors the temperature and pulse of the patient using the Arduino nano microcontroller, Air 208 GSM Module, MAX30102 Pulse sensor, DS18B20 Temperature sensor, Li-ion

Introduction:

Wearable technology refers to electronic gadgets that patients wear purposely to acquire medical data about their health status (Dias and Cunha 2018). Doctors or other healthcare professionals could utilize these gadgets to retrieve the user's wellness information in real-time. This makes it simpler and more comfortable for doctors and other caregivers to monitor patients and for personal health records. The primary driving force behind this system is to provide a secure and dependable way to store the vast amount of data generated by the rapidly growing wearable

batteries, and a 1.7-inch TFT LCD. The medical data collected is sent at intervals to the blockchain via an HTTP request. The system reached 99.4% accuracy for temperature readings when measured against clinical values, and 93.4% accuracy for pulse, and the data collected is stored securely in a decentralised manner on the Ethereum Blockchain.

Keywords: Blockchain, Cloud Storage, Health Data Security, IoT in Healthcare, Wearable Health Monitoring.

health devices market by employing distributed blockchain storage. The user or the doctor will be able to readily access the information from the distributed (Blockchain) storage network, where these gadgets send the patient's vital signs.

A general overview of blockchain applications and advantages for secure cloud storage is presented in the work of (Goel, Sharma, and Singh 2024). Another recent research that has utilized blockchain technology to address data storage issues, such as difficulty in data processing and authentication, is also presented in (Gade et al., 2024). In (Zang, Kim, and Kim 2024), a decentralized cloud storage system that uses blockchain technology for improved scalability, data security, and privacy was proposed. To effectively utilize the blockchain technology for cloud storage applications, the work of (Jerbi et al. 2024) also developed a new protocol called BlockStock to enhance intelligent data storage at a reasonable cost, mainly for any blockchain-based application, including healthcare. Based on the numerous focuses on data security capabilities and data sovereignty as presented in (Merlec and In 2024). This paper aims to develop a wearable device that monitors heart rate and body temperature and synchronizes data with blockchain technology as a key contribution. The client application for data retrieval is then implemented on the system to test the operation of the developed system. Another benefit of this system is the presence of a dedicated internet for reading and writing to and from the blockchain cloud. This stored data is retrieved and displayed on a web application interface.

The fundamental architecture of this system consists of four parts;

i. Body Area Network
ii. HTTP API

iii. Blockchain Smart Contract
iv. Data Visualization and Configuration Web Interface

i. Body Area Network

Wireless Body Area Network (BAN), which is sometimes referred to as the Body Sensor Network (BSN) refers to the connectivity of the various sensors in the system (Care 2020) , which provide the functionality of external data collection, which is sent to and processed by the processing unit (Mohammed and Tashev 2017). BSN differs from BAN in that it is used in place of one when a patient (or linked network node) has a sensor installed. Using specific components like sensors, Arduino, memory, and Wireless Local Area Networks (WLAN), Wireless Sensor Networks (WSNs) use a large number of very compact, less expensive, and less energy-efficient sensor nodes (Li et al. 2022). The integration of all sensors offers several benefits, including the ability to centralize data on a server for remote processing and to improve system programming, control, and synchronization so that it can adjust to the user's current surroundings and physical state. Wireless connectivity is a requirement for portable and universal systems and is an essential tool. (Mohammed and Tashev 2017).

ii. HTTP API

The HTTP (Hypertext Transfer Protocol) API (Application Programming Interface) serves as the portal for data between the wearable and the blockchain (Alenoghena et al. 2023). Reading and writing to the Blockchain requires running a node, which is beyond the computing capacity of the processing units used in the wearables; this gives rise to the need for an HTTP API. This API sits on a cloud server and runs a block-chain node, or in this case, contains a link to a third-party block-chain node provider like 'Infura'. The HTTP API exposes endpoints for reading and writing to the blockchain and the wearable makes requests to these endpoints. The data visualization module also relies on the HTTP API for data.

iii. Blockchain Smart Contract

A smart contract is a small program that is built and deployed on the Blockchain network. The efficacy of this technique has been demonstrated in (Jerbi et al. 2024). This particular design features a smart contract that performs Create, Read, Update, and Delete (CRUD) operations on data in the blockchain. Each device creates an instance of such data, and it writes and reads from this throughout its lifetime. The choice of the blockchain technology was based on the privacy and security features demonstrated by other researchers for similar designs, as shown in Table 1.

Table 1: Application of Blockchain in Related e-Health Designs

Reference	Problem addressed	Main Focus	Specific Details
(Nguyen et al. 2019)	Data privacy and network security for e-health designs	*Prototyped Electronic Health Record (EHR) sharing architecture that uses blockchain and decentralized interplanetary file system (IPFS) on a mobile cloud platform.	*The novel architecture uses the Ethereum blockchain network on Amazon cloud computing via a mobile app in a real data sharing scenario. *The proposed architecture is practicable for various e-health designs
(Dias, Sereno Ferreira, and Martins 2020)	Access control in large-scale and distributed systems in e-health scenarios	*Implementation of blockchain architecture using JavaScript to manage access control	*This approach utilises a consortium blockchain to store transactional information about EHR and access control policies
(Hossein, n.d.)	Privacy-preserving of patients' medical data in e-health	*Security analysis of proposed blockchain-based access control architecture for preserving privacy of patients' data in e-health applications * The proposed system enables users to have full access control of the data generated from their wearable sensor network.	*Stores hash of patients' healthcare data instead of the original data *Clustering of miners to minimise data redundancy *By means of assigning a pseudonym to each patient for privacy and security, data storage and processing is done nearest to the location of the patient

To achieve a robust e-health system architecture, the following EHR sharing challenges must be addressed (Nguyen et al. 2019):

Scalability: The e-health system must provide a reliable and robust interconnection for several mobile nodes within the mobile cloud blockchain network.

Latency: Wearable devices generate a high volume of data at a fast rate that could lead to traffic congestion on the cloud server. Also, high network latency as a result of the physical distance of mobile nodes could cause delays in emergency health applications when using conventional cloud-based health services.

Data uploading privacy: There is a need for optimization of medical data uploading for client protection using approaches such as Reinforcement Learning (RL).

QoS: For an effective QoS, parameters such as data availability, flexibility, and usability are necessary by integrating e-health designs with intelligent services on blockchain.

iv. Data Visualization and Configuration Web Interface

Web technologies allow for perfect retrieval of network-based data, and also for writing into network-based storage such as databases, and in this case, the blockchain network. The data is displayed in the form of text, tables, and charts for the provision of insight into collected data. It also provides controls for sorting, filtering, and searching through data, alongside time-based classifications.
Various wearables are deployed for collecting a wide range of vital signs from the users; these various signs are key for the evaluation of the patient's well-being. The various signs and how they have been used in the previous systems are presented.

a. Human Pulse Rate

The definition of pulse rate, a common vital indicator used in both healthcare and fitness activities, is the noticeable, continual dilatation of an artery caused by the contraction and relaxation of the heart, which increases blood flow into it. In beats per minute (Beats/min.), it is the variation in the heart cycle of an organism. (Dias and Cunha 2018) . Table 2 shows a human heartbeat for the appropriate age group.

Table 2: Pulse Rate by Age Range for the Human Heart

AGE CATEGORIES	RANGE OF PULSE IN BEATS/MINUTE
Less than 1 Month	120-160
Between 1 month and 12 months	80-140
Between 12 months and 2 years	80-130
Between 2 years and 6 years	75-120
Between 6 years to 12 years	75-110
More than 12 years	60-100

b. Human Body Temperature

The stability of heat production and heat removal inside the body controls system temperature. In some situations, such as when a protein denatures and loses function at a certain temperature, it is employed to adjust temperature. Body temperature can be divided into two categories: core temperature and skin temperature. Due to the body's ability to regulate core temperature, skin temperature fluctuates across a wider temperature range than core temperature. Heart rate, metabolism, and skin temperature are all influenced by blood flow. Air velocity, ambient temperature, and humidity levels also have an impact on the body's ability to regulate its temperature. (Majumder et al. 2018). Table 3 indicates the normal body temperature of human beings related to age categories.

Table 3: Human Body Temperature Concerning Age

AGE CATEGORIES	AVERAGE BODY TEMPERATURE RANGE
Infants and Children	97.9^{0}F (36.6^{0}C) to 99^{0}F (37.2^{0}C)
Adults	97^{0}F (36.1^{0}C) to 99^{0}F (37.2^{0}C)
Adults over 65 years	Below 98.6^{0}F(37^{0}C)

LITERATURE REVIEW

The Astrophysical Multi-Messenger Observatory Network, also known as AMON, was the first wearable body vital sign monitoring device. It was first released in 2002 and was designed to monitor skin temperature and pulse rate using wireless data transmission modules that sent the data to a central database. More recent iterations of wearables, particularly smartwatches with wireless and broadband connections, have been developed and made commercially available. These devices have a design that is similar to a traditional wristwatch, making them comfortable to wear for an extended amount of time. These gadgets were made to track activities including calories burned, distance traveled, pulse rate, and in more modern models, sleep cycles. They were also developed as activity and wellness monitors. A recently developed bracelet called MOOV is used to track movement, as well as Google Eye lenses and several other things.

A Bluetooth and WLAN real-time monitoring system for bodily vital signs has been developed in (Ahmed et al. 2016). This study suggests a miniature model in which body-worn sensors discreetly track the wearer's physiological health. The sensor nodes gather heart rate, temperature, and other body vital indications, which are then transported over Bluetooth to the mobile device and stored there before being relayed to distant locations. The system's reliability for tracking bodily vital signs and delivery of strong and rapid advancement in telemedicine were both demonstrated by the testing results.

A monitoring system for patient healthcare was designed and constructed, as shown in (Azizulkarim, Abdul Jamil, and Ambar 2017), to monitor the patient's health, the researchers created a device that measures their body temperature and pulse rate. Patients can use a wearable device they can put on their fingertips to measure their body temperature and heart rate as part of the system. The system was able to use an Arduino microcontroller to connect to the central host system and record the measured data. The recorded information can be used as a history file or saved for future research. Yet, the experiment's findings show that both sensors are capable of providing useful information for monitoring vital signs.

Shown in (Janjua et al. 2017) was a wireless chest wearable vital sign monitoring platform for hypertension? The system was created by researchers that measures the signals from the electrocardiogram (ECG), photoplethysmograph (PPG), and ballistocardiogram (BCG) and transmits the information to a mobile device using Bluetooth low energy (BLE). To transfer data to the server, the system employed a 13 Android application built from scratch. The system employed offline analysis based on MATLAB to estimate blood pressure. For patients with hypertensive conditions, the chest provides a natural position for the sensor to adequately capture signals. According to the experimental findings, aortic arterial stiffness provides a more accurate estimate of SBP than DBP. By using the Bland-Altman analysis, the

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researchers concluded that the device algorithm complied with the Grade C British Hypertensive Society guidelines for SBP estimation.

For effective monitoring of smart zones, an IoT-based remote health gadget was presented in (Ngo Manh Khoi et al. 2015). Within the limitations of the current network infrastructure, particularly in rural locations, the study seeks to address the problem of wasteful healthcare data transfer. The system's goal was to quickly transfer medical data to servers. In a healthcare scenario, the Co AP-based IReHMo implementation was used to cut the amount of output data by up to 90% for a single sensor event and the required bandwidth by up to 56%. Also, a scalability study was done to see how well the system worked in northern Sweden. Z-wave sensors were employed in the system's implementation to monitor variables such as room temperature, human presence, the condition of the door and windows, and the presence of smoke. According to the testing findings, the system is capable of integrating various types of IoT devices for healthcare and home automation. The researchers came to the conclusion that adopting the Co AP network communication protocol during the deployment of the IReHMo system allowed for a significant reduction in bandwidth and data volume.

For patients and the elderly, a remote health monitoring system built on the Internet of Things was developed. (Lousado and Antunes 2020). The study created a 14-patient prototype of an IoT-based remote health monitoring system. The system uses three health sensors: a galvanic skin response sensor, a body temperature sensor, and a sensor that measures heart rate. The use of an Arduino Uno and a Raspberry Pi allowed for the integration of all the sensors into a single device. The data gathered from the sensors and kept in a database was transferred using the Raspberry Pi. The database is continuously updated in real-time. Using Android Studio, it was possible to access the database and provide graphical representations of the health parameters. An extensive analysis of the signals in connection to changes in physical and environmental activities was carried out to clarify how the sensors function and comprehend their operation. They discovered that the observed signals and patterns agreed with their basic working theory. The server received the completed output.

A technique for remote health monitoring was created in(Sunil et al. 2014) To find cardiac problems. The three primary parts of the modelled system are a mobile gateway, which was placed on the patient's mobile device and receives 12-lead ECG signals from each ECG sensor, and a remote server component, which has algorithms for precise ECG signal annotation and analysis. And a point-of-care medical device that receives a diagnostic report based on ECG signal analysis from the server. A 12-lead portable ECG sensor that transmits real-time ECG data to a PoCD using a mobile gateway and CDSS server was described in the paper as an end-to-end remote monitoring system. The experimental findings indicate that a sensitivity of 91.8% and a specificity of 91.9% were attained.

The creation of a system for automated healthcare record-keeping is described in (Yahaya et al. 2019). The project's goal was to lower the cost of healthcare delivery, and the system did this by deploying a database management system and sensor over a GSM network. Its shortcoming is that data transmission was extremely slow, but it was nonetheless reasonably priced. In the NICU, the GSM-based patient monitoring system is demonstrated in (Bhargavi 2013). The system integrated a healthcare device onto a smartphone using an Arduino and GSM module on a single chip. The project's goal was to close the communication gap between the patient and the healthcare provider. The device's limitation was that it could only be used in a hospital setting, but it was still reasonably priced and robust.

(Jasemian and Nielsen 2005) Demonstrated the design and development of a health monitoring system using a mobile phone. The device was created by integrating sensors with an Arduino ATmega 32 and then integrating it on a 4G network that was already in place. The goal was to equip healthcare providers with the tools necessary to prevent the transmission of infectious diseases. However, one drawback was that it could not be used in environments without a 4G network, a problem that this current study will attempt to solve.

In (Teng et al. 2008) Wearable medical systems for public health are presented. A limitation of the device was that the transmission unit did not support 4G networks, which will be taken into account in this work. The device integrated multiple health sensors on the Arduino to measure vital signs with the intention of resolving hospital environment queuing problems and enhancing patient self-participation in healthcare monitoring.

The presentation of advanced wearable sensors for health monitoring is found in (Yilmaz, Foster, and Hao 2010). The device was created to address the issue of the danger of accidents for healthcare providers as they move from one area to another to provide care to patients. This device's drawback was that few individuals could afford it, which made it not cost-effective. Finding Vital Indicators with wearable wireless sensors was the goal of the concept to assist the health care provider inside a hospital in remotely sharing multiple patients' health status information. This gadget was created by integrating wireless sensors on a microchip to detect vital signs of the human body. This device's restriction prevented it from being used in locations that were too far from the hospital.

The current state and potential difficulties of smart wearable systems were discussed in (Rezayi, Safaei, and Mohammadzadeh 2021). The device's purpose was to improve independent living and smart communication with medical personnel. It included different sensors (temperature and pulse sensors) and a GSM module on a Raspberry Pi. The one drawback of this device was that it used up more energy and generated a lot of heat, making it impossible to wear for extended periods.

The use of wearable smart sensors for tracking patients' vital signs during epidemics is described in (Rezayi et al. 2021). Wearable sensors and optical sensors were included in the Arduino Uno design. The goal of the project was to develop a method for the early diagnosis of high-risk diseases that are associated with symptoms of abnormal vital sign variables in the COVID-19 period and later. However, this method is limited by the device's high cost and the necessity for advanced training.

MATERIALS AND METHOD

System Design Overview

The entire system is divided into four major units: the sensor network, HTTP API, Blockchain Smart Contract, and A data management and visualization web interface. The sensor unit consists of a temperature and pulse sensor that reads data and sends it to the central processing unit (CPU) of the development board. These signals are amplified and processed by the CPU into digital data. The digital data is displayed on a TFT display screen, and also stored on the microcontroller's memory for analysis, and transferred to the cloud using HTTP via an internet connection that is facilitated by a GSM module.

The HTTP API consists of a Node.js server with specific routes for reading and writing operations. The API parses the data it receives and writes it to the blockchain using web3.js libraries, which write to the Solidity smart contract that was deployed to the Ethereum blockchain. The API also facilitates the hosting of the data visualization and management web app, which is developed with ReactJS. Figure 1 shows the block diagram of the vital sign monitoring device with blockchain storage.

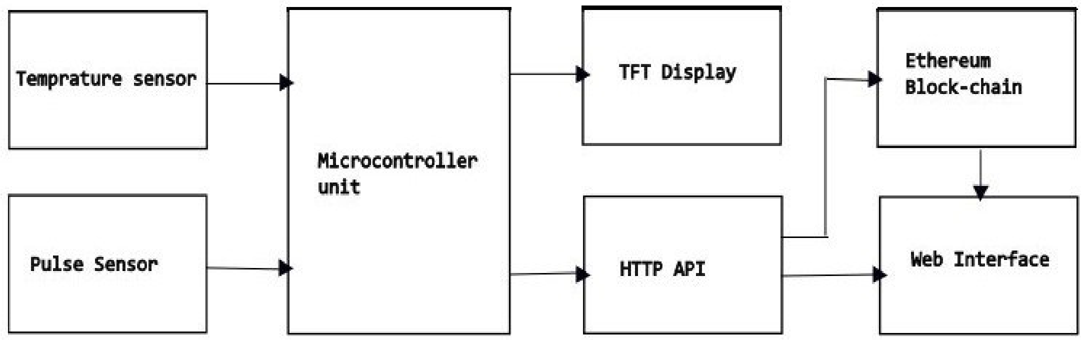

Figure 1: Block diagram of the system

Materials and Components

The major components and materials used for the implementation of this design are listed below:

i. Arduino nano
ii. Pulse sensor (MAX30105)
iii. Temperature sensor
iv. TFT Display
v. Wrist Strap
vi. A cloud server with Node.js
vii. GSM Module
viii. Infura.io account/app

Arduino Nano

In this work, the processing on the device level is done by the Arduino Nano microcontroller. This is one of the members of the Arduino family of development boards. It uses an ATmega328P chip. This chip is compatible with the Arduino IDE and can be programmed from the IDE.

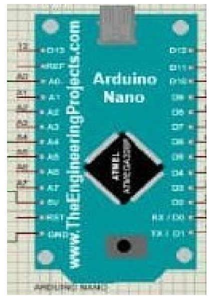

Figure 2: Arduino Nano

Pulse Sensor

A pulse sensor is a well-designed plug-and-play heart-rate sensor for Arduino. the MAX30105 Sensor, which employs the I2C communication protocol, was used. It reads the pulse of the body it is in contact with, in order to get accurate readings, the pressure between the sensor and the skin must be kept constant.

Figure 3: MAX30105 Pulse sensor

Temperature Sensor

A temperature sensor is a type of electronic gadget that gauges the ambient temperature and transforms the input information into electronic data for logging or monitoring. The specific model that was employed in this case was the DS18B20, which may be configured to have a resolution of 9, 10, 11, or 12 bits, which equate to precision increments of 05, 0.25, 0.125, and 0.0625, respectively. Use is made of the 12-bit default resolution.


Figure 4: DS18B20 Temperature sensor

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GSM Module

The Air208 is a quad-band GPRS (General Packet Radio Service) enabled GSM module with a very small form factor. It is employed here to enable the system to send SMSs and make HTTP requests to the HTTP API.

Figure 5: Air208 GSM module

TFT Display

The TFT LCD Display employed is a 1.4-inch I2C-enabled model with a resolution of 130×160, with a full-color display.

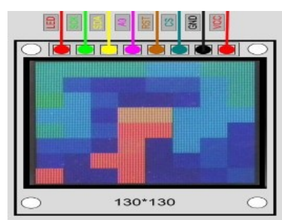

Figure 6: TFT Display

Preliminary Design Method

Using Proteus software, the preliminary design was completed to ensure that each component was used correctly in the circuit and that the circuit itself was functioning properly. Proteus is a comprehensive platform for development that allows designers to work from concept to completion. The Proteus software includes functions like hybrid circuit simulation and precise analysis, single-chip software debugging, circuit simulation, PCB automatic designing and wiring, and others. Figure 7 shows the simulation environment.

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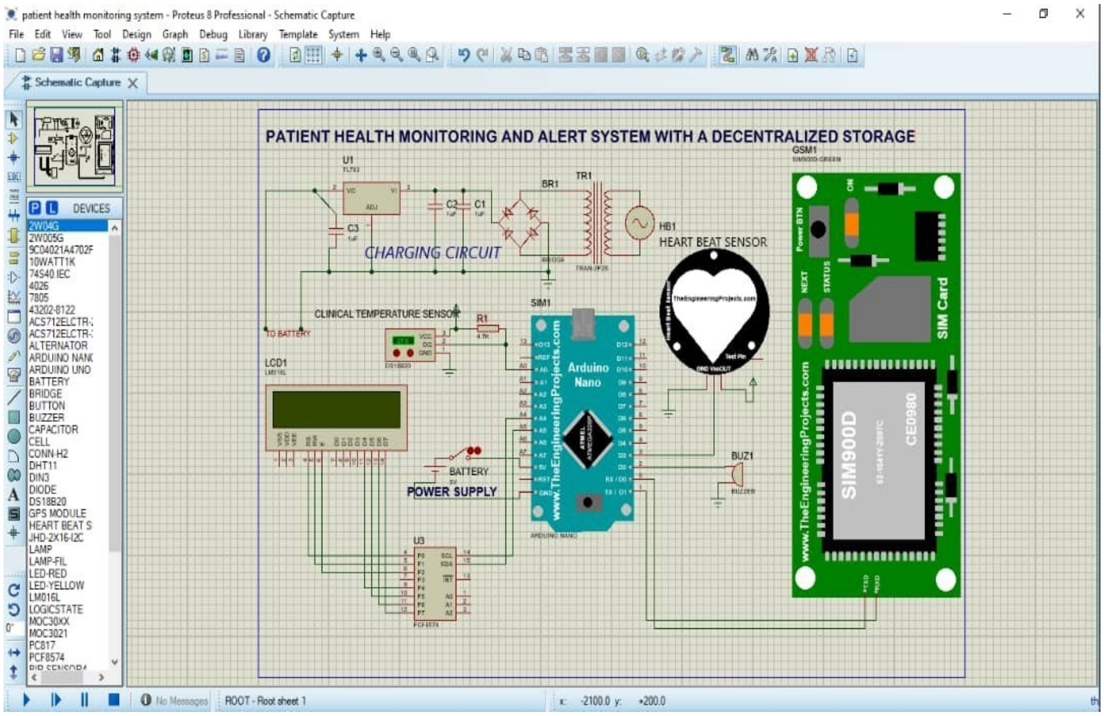

Figure 7: Simulation environment

Hardware Implementation

In implementing this system, the connections were done as described in the circuit diagram of Figure 6 and the final prototype device and the 3D design of the casing are shown in Figure 8 and Figure 9 respectively.

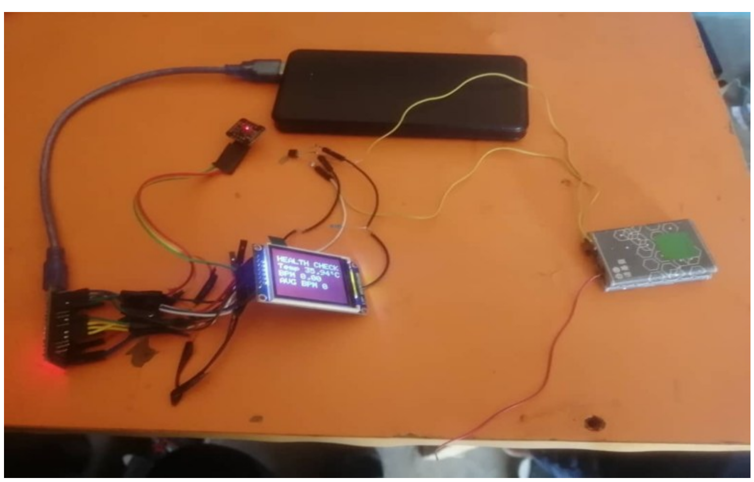
Figure 8: Prototype Device during implementation

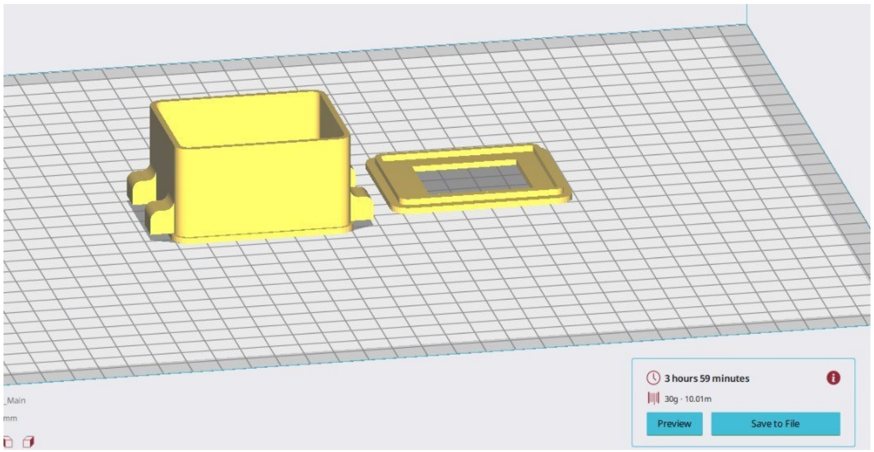

Figure 9: 3D Casing design

RESULTS AND DISCUSSION

The wearable vital signs monitoring device design and development, which included both the hardware and software phases, is in this section. The system performance is also presented.

Simulation Results

Proteus software was used to simulate the System at the beginning to ensure that the design and implementation were functional. The temperature and pulse sensors were able to read readings during the simulation, which are listed in Table 4.

Table 4: Simulation readings for temperature and pulse

Number of beats per minute	Temperature in degrees Celsius
62	33
77	35
80	41
75	34
84	39
Average values: 75.6	36.4

From Table 4, within a specified time, pulse rate and temperature were recorded from the sensors and the average values were taken.

System Hardware Implementation Results

The hardware design was firstly implemented by prototyping using jumper wires as shown in Figure 10, and subsequently, the components of the hardware were permanently connected by soldering, and then fitted into the case, with the sensors placed at the bottom of the case to ensure contact with the user's skin, and the screen at the top to show collected data to the user. The hardware also featured charging capabilities, thus making the whole hardware system a truly portable wearable as shown in Figure 11.

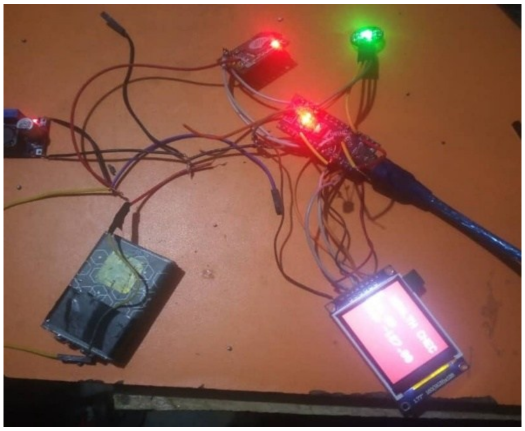

Figure 10: Jumper wire connected to the preliminary implementation

Figure 11: Completed device under testing

Software Implementation

The system's microcontroller programming, which manages other components, was created using the Arduino IDE. The smart contract was created using the VS Code text editor and the Solidity programming language. The web application is built using the React JavaScript framework.

Results

Following the System's implementation and testing, the following outcome was attained. To ensure that accurate values are received from the sensors and transferred to the blockchain, where they can be watched via the web app, the accuracy and efficiency of both sensors were checked.

Temperature Results

The temperature readings from the supposed patient are taken using a DS18B20 temperature sensor and uploaded to the blockchain for web-based access. The finished system, depicted in Figure 11, displays the temperature reading on the TFT panel.

Pulse Rate

The MAX30102 pulse sensor was used to determine the putative patient's pulse rate. As a biosensor module with an integrated pulse and heart rate monitor, it is appropriate for wearable and fitness aids. Hence, appropriate for the Vitals Monitoring device. The finished system displaying pulse rate values on the TFT panel is also shown in Figure 11.

Result Representation

Here, the results from a number of testing situations are compared to the clinical values that were found. Table 5 lists the many values the gadget produced along with relevant clinical values.

Table 5: Vital Signs Results

S/N	Vital Sign Monitor Test values		Clinical Standards	
	Pulse (bpm)	Temperature (°C)	Pulse (bpm)	Temperature (°C)
1	110	33	119	35
2	105	36	107	35
3	109	36	111	35
4	70	37	88	37
5	66	34	68	35
AVERAGE VALUES	92	35.2	98.6	35.4

Storage Performance and Presentation

Storage

The designed device makes HTTP requests to the web API, and the API writes the results to the blockchain. The stored results are equally retrieved by the API and fed to the React web app. The inspected blockchain entries are presented in Figure 12.

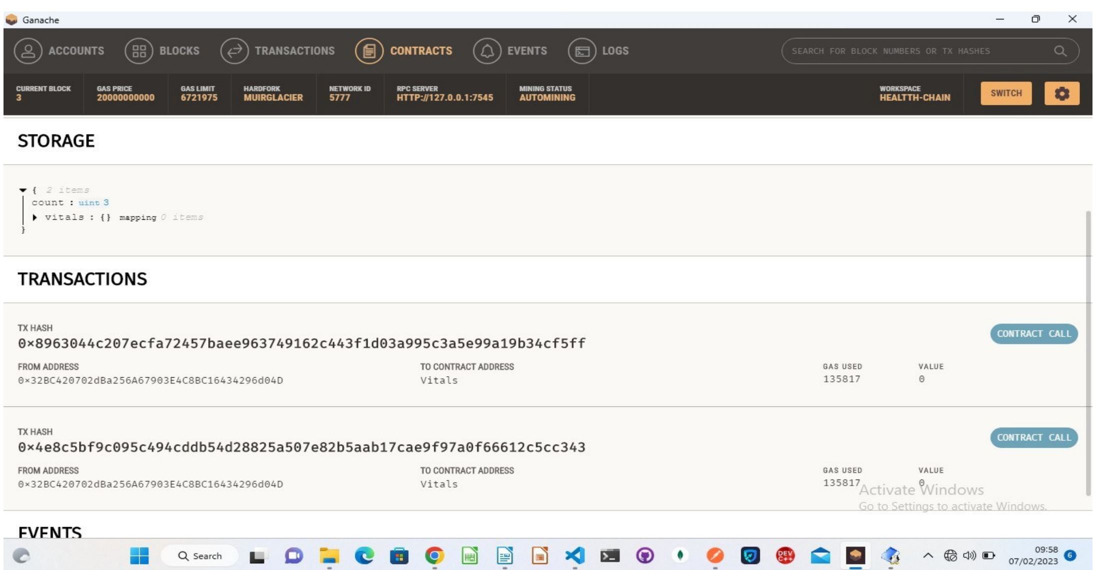

Figure 12: The Contract Entry in the Block-chain

Storage Results Presentation

The Results stored in the blockchain are retrieved and presented in tabular form in the web app. The data for each device can be accessed by logging into the web app with the unique device ID. The login screen is presented in Figure 13, and the data table is presented in Figure 14.

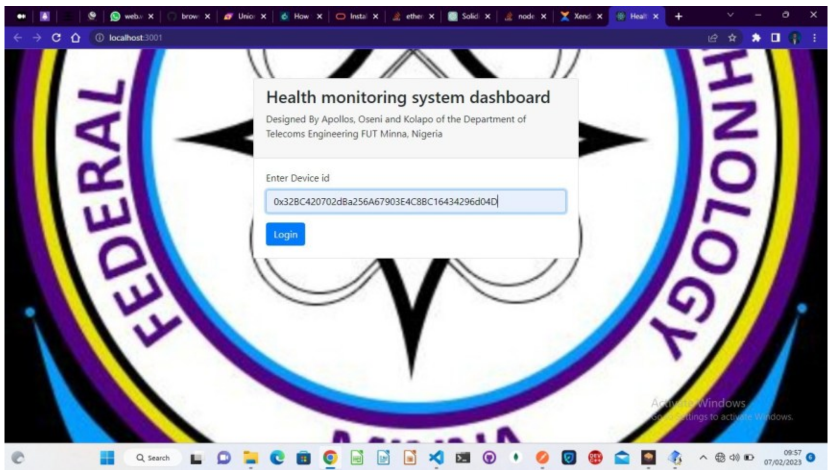

Figure 13: Web-app login page

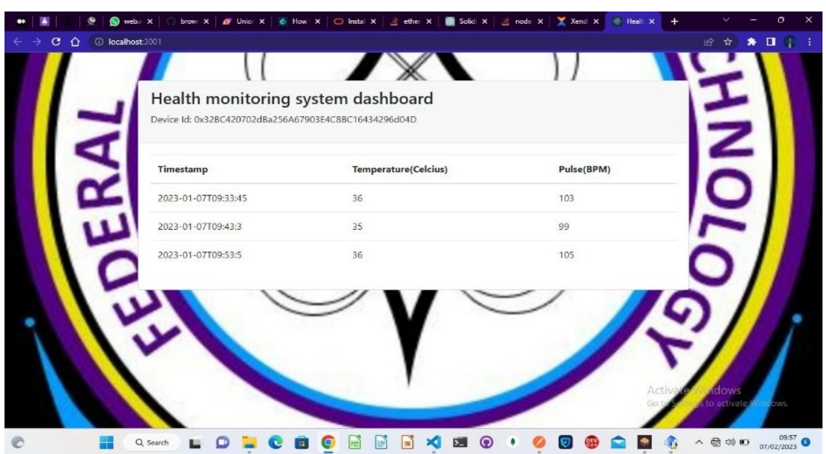

Figure 14: Web-app data-table

Discussion of Results

The system performed according to the objectives of the design, and reached 99.4% accuracy for temperature readings when measured against clinical values, and

93.4% accuracy for pulse. The HTTP functions performed as expected, and the stored data was successfully presented on a web app. Despite the high accuracy recorded for this design, the size and dimensions of the wearable gadget still needs to be minimized by using different approach for PCB implementation for user convenience. While the size of the screen contributes to the dimensioning, reducing it could also affect visualization of the readings leading to trade-off issues between sizing and output. Also, the heartrate values which could be used to determine patient's heart conditions does not translate to blood pressure (BP) readings directly which is normally required to actually confirm normal heart function in some cases. In order to also compensate for reliable energy requirement for the device to function effectively for along period, a wireless charging capability could be integrated in the design. Other limitations of this design include the need to loosen the device before battery replacement during maintenance and the need for external charging capability only while the device is not in use.

CONCLUSION

The wearable device's circuitry was created, simulated, and put into practice. Temperature and pulse rate sensors were combined into a hardware prototype. Also, the system's dependability and performance show that the system operates within the permitted margin of error. The wearable device was made portable, which is significant to make it acceptable for the intended users. The vital sign monitoring device's blockchain storage capabilities, data retrieval and presentation abilities, and security of patient data were successfully achieved. The developed system, which is a wearable wrist device, keeps track of the patient's temperature and heart rate in real-time. The blockchain technology utilized for this design has demonstrated the practical implementation of an IoT-based healthcare system that could be used to monitor patients' health status remotely. This research has produced a real-world wearable device for heart rate and body temperature data acquisition and transmission using blockchain technology.

To achieve comprehensive vital signs monitoring in future systems, more sensors should be included because the current design has only temperature and pulse-rate sensors. Secondly, the system has a limited capacity for battery retention; better battery options should be considered for future systems. Also, a more user-friendly interface for the web app might be added. Additional health monitoring sensors for measuring the BP and blood sugar could be integrated in future designs to enable full-scale monitoring and data acquisition.

REFERENCES

Ahmed, Najeed, M. Ajmal, Marium Hai, Arwa Khuzema, and Mehak Tariq. 2016. "Real Time Monitoring of Human Body Vital Signs Using Bluetooth and WLAN." *International Journal of Advanced Computer Science and Applications* 7(10):210–16. doi:10.14569/ijacsa.2016.071028.

Alenoghena, Caroline Omoanatse, Henry Ohiani Ohize, Achonu Oluwole Adejo, Adeiza James Onumanyi, Emmanuel Esebanme Ohihoin, Aliyu Idris Balarabe, Supreme Ayewoh Okoh, Ezra Kolo, and Benjamin Alenoghena. 2023. "Telemedicine: A Survey of Telecommunication Technologies, Developments, and Challenges." *Journal of Sensor and Actuator Networks* 12(2). doi:10.3390/jsan12020020.

Azizulkarim, Azra Hazwanie, Muhammad Mahadi Abdul Jamil, and Radzi Ambar. 2017. "Design and Development of Patient Monitoring System." *IOP Conference Series: Materials Science and Engineering* 226(1). doi:10.1088/1757-899X/226/1/012094.

Bhargavi Sundara. 2013. "Gsm Based Patient Monitoring System in Nicu." *International Journal of Research in Engineering and Technology* 02(07):120–23. doi:10.15623/ijret.2013.0207014.

Care, Emergency. 2020. "Wireless Body Area Network (WBAN)-Based."

Dias, Duarte, and João Paulo Silva Cunha. 2018. "Wearable Health Devices—Vital Sign Monitoring, Systems and Technologies." *Sensors (Switzerland)* 18(8). doi:10.3390/s18082414.

Dias, João Pedro, Hugo Sereno Ferreira, and Ângelo Martins. 2020. "A Blockchain-Based Scheme for Access Control in e-Health Scenarios." *Advances in Intelligent Systems and Computing* 942:238–47. doi:10.1007/978-3-030-17065-3_24.

gade Sayali kore Vaishnavi mundhe Nikita pawar Author, Rani. 2024. *Decentralized Cloud Storage Using Blockchain*. www.ijnrd.org.

Goel, Mousmi, Nirmesh Sharma, and Gurdip Singh. n.d. *BLOCKCHAIN TECHNOLOGY-A WAY FOR SECURE DATA STORAGE IN DIGITAL CONSULTING PLATFORMS*. https://www.researchgate.net/publication/379697252.

Hossein, Koosha Mohammad. n.d. "Blockchain-Based Privacy-Preserving Healthcare Architecture."

Janjua, G., D. Guldenring, D. Finlay, and J. McLaughlin. 2017. "Wireless Chest Wearable Vital Sign Monitoring Platform for Hypertension." *Proceedings of the Annual International Conference of the IEEE Engineering in Medicine and Biology Society, EMBS* 821–24. doi:10.1109/EMBC.2017.8036950.

Jasemian, Yousef, and Lars Arendt Nielsen. 2005. "Design and Implementation of a Telemedicine System Using Bluetooth Protocol and GSM/GPRS Network, for Real Time Remote Patient Monitoring." *Technology and Health Care* 13(3):199–219. doi:10.3233/thc-2005-13307.

Jerbi, Wassim, Omar Cheikhrouhou, Abderrahmen Guermazi, and Hafedh Trabelsi. 2024. "Blockchain-Based Data Storage for Internet of Things Networks." *International Journal of Business Data Communications and Networking* 19(1). doi:10.4018/IJBDCN.341590.

Li, Limiao, Junyao Long, Wei Zhou, Alireza Jolfaei, and Mohammad Sayad Haghighi. 2022. "Joint Optimization of Energy Consumption and Data Transmission in Smart Body Area Networks." 1–25.

Lousado, José Paulo, and Sandra Antunes. 2020. "Monitoring and Support for Elderly People Using Lora Communication Technologies: Iot Concepts and Applications." *Future Internet* 12(11):1–30. doi:10.3390/fi12110206.

Majumder, Shubha, Muhammad Asad Rahman, Md Sajedul Islam, and Diponkar Ghosh. 2018. "Design and Implementation of a Wireless Health Monitoring System for Remotely Located Patients." *4th International Conference on Electrical Engineering and Information and Communication Technology, ICEEiCT 2018* (September):86–91. doi:10.1109/CEEICT.2018.8628077.

Merlec, Mpyana Mwamba, and Hoh Peter In. 2024. "Blockchain-Based Decentralized Storage Systems for Sustainable Data Self-Sovereignty: A Comparative Study." *Sustainability (Switzerland)* 16(17).

Mohammed, Shoaib, and Ivan Tashev. 2017. "Unsupervised Deep Representation Learning to Remove Motion Artifacts in Free-Mode Body Sensor Networks." *2017 IEEE 14th International Conference on Wearable and Implantable Body Sensor Networks, BSN 2017* (May):183–88. doi:10.1109/BSN.2017.7936037.

Ngo Manh Khoi, Saguna Saguna, Karan Mitra, and Christer Ahlund. 2015. "IReHMo: An Efficient IoT-Based Remote Health Monitoring System for Smart Regions." *2015 17th International Conference on E-Health Networking, Application and Services, HealthCom 2015* (October):563–68. doi:10.1109/HealthCom.2015.7454565.

Nguyen, Dinh C., Pubudu N. Pathirana, Ming Ding, and Aruna Seneviratne. 2019. "Blockchain for Secure EHRs Sharing of Mobile Cloud Based E-Health Systems." *IEEE Access* 7:66792–806. doi:10.1109/ACCESS.2019.2917555.

Rezayi, Sorayya, Ali Asghar Safaei, and Niloofar Mohammadzadeh. 2021. "Design and Evaluation of a Wearable Smart Blanket System for Monitoring Vital Signs of Patients in an Ambulance." *Journal of Sensors* 2021. doi:10.1155/2021/8820740.

Sunil, Kumar, Bansal Ayush, Tiwari Vijay, Nayak Mithun, and Narayan Ranga. 2014. "Remote Health Monitoring System for Detecting Cardiac Disorders." in *IEEE International Conference on Bioinformatics and Biomedicine*.

Teng, Xiao Fei, Carmen C. Y. Poon, Yuan Ting Zhang, and Paolo Bonato. 2008. "Wearable Medical Systems for P-Health." *IEEE Reviews in Biomedical Engineering* 1(February):62–74. doi:10.1109/RBME.2008.2008248.

Yahaya, Suleiman Abimbola, Lydia John Jilantikiri, Kehinde Hassan, Suleiman A Yahaya, Lydia J Jilantikiri, Kehinde A. Hassan, Kareem A. Akande, and Abdullahi Yahaya. 2019. "Development of an Automated Healthcare Record Management System Passive Cooling View Project Health Care Management System View Project Development of an Automated Healthcare Record Management System." *Adeleke University Journal of Engineering and Technology* 2(2):79–90. https://www.researchgate.net/publication/337950678.

Yilmaz, Tuba, Robert Foster, and Yang Hao. 2010. "Detecting Vital Signs with Wearable Wireless Sensors." *Sensors* 10(12):10837–62. doi:10.3390/s101210837.

Zang, Hannie, Ho Kim, and Jongwon Kim. 2024. "Blockchain-Based Decentralized Storage Design for Data Confidence Over Cloud-Native Edge Infrastructure." *IEEE Access* 12:50083–99. doi:10.1109/ACCESS.2024.3383010.