DEVELOPMENT OF PATIENT HEARTBEAT AND TEMPERATURE MONITORING SYSTEM FOR SECURED HEALTH USING IoT

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Abstract: The emergence of the coronavirus (COVID-19) pandemic has significantly increased the global demand for healthcare services in Nigeria. A large numbers of elderly and vulnerable people are battling with prolonged chronic health conditions such as hypertension, diabetes, acute malaria, and heart-attack. However, access to reliable, dependable and effective medical and healthcare services in remote areas are practically impeded by the absence of medical specialists and health caregivers coupled with insufficient health facilities and equipment which are not only expensive but also not available. Hence, heartbeat rate and body temperature have been identified as the major vitals' physiological parameter to monitor the patient's health status. Thus, this paper aims to design and implement an affordable and smart healthcare system that allows continuous assessment of patient pulse rate and body temperature via sensors and transmits the data over a wireless network through Wi-Fi module that facilitates data analytics and visualization by healthcare staff. The model consists of four-tier architecture features, Tier-1 is the data sensing module (input unit), Tier-2 is the data processing module, Tier-3 data communication module and Tier-4 is the output unit. Furthermore, the patient's temperature and heartbeat rate data are monitored and stored in the cloud using the internet of things (IoT) application. Also, t he experimental results indicate an average error rate of 2.86% and 0.44% for heartbeat and body temperature respectively as compared to the conventional medical devices. An indication that the error rate is within the acceptable limit (<5%). Based on the questionnaires assessed by fifty (50) respondents, a high percentage of acceptance is noticeable in the age group of 35-40, 50-55 and 60-65. The further result shows that the average body temperature lies within 36.2±1.14%.

Keywords: Patient monitoring, heartbeat, body temperature, Arduino Uno, IoT, COVID-19

Introduction

The Heart is analogous to a pump engine system that aids oxygen absorption, blood circulation, transportation of cellular waste product from tissues and blood pressure regulation in the body. It is one of the human body's most vital organs. A healthier lifestyle is linked to human longevity (Li *et al*., 2018). Therefore, continuous health check-up enhances early detection of chronic diseases and also triggers immediate medical therapeutic which may either avert untimely death or lengthen patients 'life expectancy in most cases. Health, in medical term, referred to as a state characterized by mental and physical conditions of the body or mind and freedom from social stress and physical impairment which surpasses lack of ailment or disability. It is imperative to note that health and welfare is an essential condition for stimulating economic and societal development.

Unfortunately, several formidable challenges have hindered the rapid development of healthcare sectors in responding to global health demand and the effects are notable in most developing countries especially in Nigeria. These problems include mass migration of medical practitioner in the quest for green pasture, outdated medical/healthcare facilities, primitive diagnosis centers, long terrain of urban healthcare centres, poor file and record management, poor healthcare management scheme, high patient-to-doctor ratio and shortage of healthcare centres. Unexpectedly, the recent emergence of the coronavirus (COVID-19) pandemic has significantly increased the local demand for healthcare services in most remote areas in Nigeria.

In Nigeria, studies have shown that cardiovascular diseases account for 86.1% death with majority above 60 years of age (Adegoke *et al.*, 2018), hypertension and diabetes account for about 48.2 and 15.7% respectively and of which adults age 25 and above are the most affected (Akinroye, 2013); malaria is estimated at 97% of the population and 50% of the adults is susceptible one type or another, of which 35% is estimated to be an elder person above 60 years of age and 27.5% of which are urban dwellers. However, there is need to mitigate the risk of health challenges on the vulnerable people and migrate to a secured patient health monitoring system (PHMS) in Nigeria.

Advancement and recent innovation in information technology communication (ICT) and embedded system have paved-way for improvement in healthcare and medical sector. The Internet-of-Things (IoT) has been adopted in healthcare for different applications such as Internet-of Healthcare-Things (H-IoT) (Albesher, 2019; Dhanvijay & Patil, 2019), Internet-of-Medical-Things (IoMT) (Polu, 2019) , used as Automated Telemedicine and Diagnosis system for health delivery (Barazanchi *et al.*, 2019), as Wireless Body Area Network (WBAN) to detect human body condition (Barazanchi *et al.*, 2019; Saba *et al.*, 2020), mobile health (M-Health) and e-health for healthcare support through IoT (Rani *et al.*, 2018). IoT is simply interconnection of physical devices via the internet using sensors and networks. These connected devices can be used to improve efficiencies, minimize healthcare cost and provide better medical treatment in remote patient monitoring.

Heart rate and body temperature are vital signs of the health parameter directly related to the human cardiovascular system. Heart rate otherwise known as pulse rate indicates the number of beats per unit time, generally expressed in beat per minute (bpm). Usually, pulse rate varies from person-to-person and influenced by certain factors such as physical activity like exercise, sleep, anxiety and mental condition like stress and medication. In a healthy adult, the pulse rate range from 60-100 bpm, 120-160 is common for athlete and children pulse rate is between 75 and 100 bpm. Adults and aged people have common heart rate conditions like high heart rate Tachycardia (above 100 bpm), too-low heart rate Bradycardia (below 60 bpm) and irregular heart rate known as Arrhythmia. The body temperature is the degree of heat maintained by the body. The typical average body temperature for an adult lies within the range of 97 ^{o}F (36.1^{o}C) to 99 ^{o}F (37.2^{o}C) and in most cases, these temperature changes due to

infection, illness, age, emotional status, hormone change, food diet, fasting, depression, smoking etc. study has confirmed that healthy elderly people have lower temperature as compared to growing adults and in adults, as a result of the high percentage of fat distribution in females' body, their body temperature is higher than the male peers (Geneva, Cuzzo, Fazili, & Javaid, 2017). A temperature higher than (35ºC, 97 ºF) is termed as hypothermia.
Also, a temperature low than (38ºC, 100.4 ºF) is referred to as hyperthermia. Also, fever or pyrexia is the first clinical indicator of illness, infection, inflammation and diseases in the human body.
Saba *et al*. (Saba *et al*., 2020) proposed an internet of medical things (IoMT) for e-healthcare with the aim to minimize communication and biosensors energy consumption during healthcare data transmission. Rani and co-workers (Rani *et al.*, 2018) developed a mobile device based health monitoring system that is equipped with IoT devices to improve a real-time online information about the patients' health conditions. The authors in (Natarasan, 2020) designed a novel outpatient android application (Op App) that the doctor or consultant can use to monitor the health status of the patient in terms of heartbeat rate, and oxygen saturation (SpO_2). This design App permits teleconference with the patient without physical contact through IoT. Valsalan *et al*. (Valsalan *et al.*, 2020) presented an IoT health monitoring framework for checking and monitoring the patient's heartbeat and temperature. The authors integrated a GSM and Wi-Fi module that sends a notification to the doctor indicating the patient's health status. Leonardo and co-worker (Garcia & Ramı, 2019) introduced internet of things in the healthcare monitoring system to optimize the development of application in real-time with minimum energy consumption, The model was validated with measurement data on oxygen saturation, heart rate and body temperature in patients with respiratory disorders. The result shows the efficient performance of the model under clinical testing of the parameters. Ameen (2020) developed a mobile healthcare monitoring system based on IoT and cloud computing. In his study, a mobile application platform-based is used to monitor the ECG signal, heart rate, SpO_2 and the patients 'body temperature. Further result verification was performed by comparing measurement data with the in-used medical devices. For the sake of brevity, all the reviewed works of literature, along with their major findings are summarized in Table 1.

Table 1: A Summary of literature on the health monitoring system

Author(s)/ year	Ref.	Brief Title	Technology used	Physiological parameter	Highlights
Aseena *et al.* (2018)	(…Rahim, 2018)	IoT based health monitoring system	IoT, Wi-Fi	Pulse rate, sugar level, humidity	The Proposed system resulted in decreased healthcare cost and enhanced self-health monitoring
Ibrahim and Zhuopeng (2018)	(Ibrahim & Zhuopeng, 2018)	IoT patient health monitoring system	IoT, Wi-Fi	Body temperature, Heartbeat rate, Blood pressure.	It promotes remote health data acquisition and smart storage system
Arshad *et al*. (2014)	(Jagnade *et al.*, 2013)	A study on health monitoring system: recent advancements	WBAN	Pulse rate, Oxygen saturation, (SpO_2)	The paper focused on a comprehensive review of approaches, principles and methodologies used in the health management system
Kotevski and Koceki (2016)	(Kotevski *et al.*, 2016)	e-health monitoring system	Open health platform MSSQL	Blood sugar Electrocardiogram (ECG)	Developed an e-health platform to enhance the level of patients' medical support
Saranya *et al*. (2018)	(Banka *et al.*, 2018)	A survey on health monitoring system by IoT	-	-	The paper examined various IoT mechanisms and algorithms employed in the healthcare
Fezari *et al*. (2015)	(Fezari *et al.*, 2015)	Ambulatory health monitoring system using wireless sensors node	Wi-Fi, GUI programme, cloud	Body temperature level Blood pressure Heart rate	The paper proposed an improvement on previous HMS by integrating real-time algorithms for heartbeat rate analyzer and also fussed data on different sensors.
Gómez *et al*. (2016)	(Gómez *et al.*, 2016)	Patient monitoring system based on internet of things	IoT, SWRL, Wi-Fi	Sugar level ECG	Developed an interactive platform for patient-doctor interaction.
Islam *et al*. (2020)	(Islam *et al.*, 2020)	Development of smart healthcare monitoring system in the IoT environment	IoT, Wi-Fi, Bluetooth	Herat rate Body temperature Room temperature Co ,Co_2	Proposed a prototype model for the treatment of COVID-19 patients.
Vani Yeri (2020)	(Yeri, 2020)	IoT based real-time health monitoring	Wi-Fi, GSM	Pulse rate body temperature oxygen saturation (SpO_2) ECG	Implemented a wireless health monitoring system that is capable of the given health status of the patient in real-time for emergency intervention.
Vigneshwaran *et al*. (2020)	(Tamilselvi *et al.*, 2020)	IoT based multi-node health monitoring system	IoT, Wi-Fi	Body temperature Heartbeat rate Blood pressure ECG	Presented a low cost and reliable communication for a health monitoring system that is suitable remotely located patient.
Wang *et al*. (2020)	(Wang *et al.*, 2020)	A personalized health monitoring system for community-dwelling elderly people in Hong-Kong: design, implementation and evaluation study	Bluetooth Data mining Cloud database	Body temperature Heartbeat rate Blood pressure	The proposed model provides a personalized community- based telehealth system

Tuna *et al*. (2020)	(Tuna *et al.*, 2015)	Wireless sensor network-based health monitoring system for the elderly and disable	Wireless sensor network (WSN)	Oxygen saturation, Body temperature, Electrocardiogram (ECG), Galvanic skin response.	Examined the use of the wireless sensor in monitoring the health status of an elderly and disabled patient
Osheen *et al*. (2017)	(Sharma *et al.*, 2017)	Design of a Bluetooth enable health monitoring system for infants using wearable technology	Bluetooth	ECG, Heart rate, Body temperature,	Developed a smart neonatal health monitoring system to minimize the risk of pre-term and term babies during childbirth.
Ankita *et al*. (2020)	(Ramtirthkar & Koli, 2020)	IoT based healthcare system for a coma patient	Thing speak cloud, Raspberry-pi	Body temperature level, Blood pressure	Proposed a health supervisory system based on IoT for a comatose patient
Tayebeh *et al*. (2020)	(Baniasadi *et al.*, 2018)	Study of challenges to utilize mobile-based healthcare monitoring systems: a descriptive literature review	-	-	Presented a survey of different concepts, challenges and applications of health monitoring system
Swayamsiddha and Mohanty (2020)	(Swayamsiddha & Mohanty, 2020)	Application of cognitive internet of medical things for COVID-19 pandemic	IoT, Wi-Fi	-	A review on various novel application of cognitive internet of medical things (IoMT) for combating the evolving COVID-19 health crisis.
Ganesh (2019)	(Haripriya *et al.*, 2016)	Health monitoring system using raspberry-pi and IoT	Raspberry-Pi IoT	_	Developed a health model that enhances medical care for the vulnerable patient and integrated Pi-camera to ease face-to-face communication.
Saeed *et al*. (2019)	(Saeed *et al.*, 2019)	IoT health monitoring system for preventing and controlling risk in confined space using microcontroller	GSM Wi-Fi	Body temperature Heartbeat rate blood pressure oxygen saturation LPG Carbon dioxide	Developed a health monitoring system suitable for health workers in a restricted area
Tartan *et al*. (2018)	(Tartan & Ciflikli, 2018)	An android application for geo-location based health monitoring, consultancy and alarm system	Android-based application GSM Bluetooth GPS-sensor	Heart rate	Proposed an android based health application which provides caregiver instant access to the patient location and heart rate status
Manirabona *et al*. (2017)	(Manirabona *et al.*, 2017)	Investigation on healthcare monitoring system: innovative services and application	-	-	Presented a comprehensive review on the WBAN application, requirement for healthcare and emphasized on the strength , weakness and design limitation
Jeyaraj *et al*. (2019)	(Jeyaraj *et al.*, 2019)	Smart-monitoring system for IoT based healthcare system using Deep learning	Wi-Fi Wearable sensor cloud	ECG Body temperature Heart rate	Designed a smart physiological monitoring system that is low cost and high accuracy. It further, developed a deep learning algorithm for signal feature extraction.

This paper aims to design and implement a user-friendly and smart healthcare system that allows continuous assessment of patient pulse and body temperature via sensors and transmits the data over a wireless network through Wi-Fi module that facilitates data analytics and visualization by healthcare staff and also to point out the significance of embedded system and IoT devices in enhancing medical and healthcare services.

Material and Methods

In this paper, various hardware components are integrated into designing and implementing a customized patient healthcare monitoring system. These components are well-detailed as follows

ESP8266 Processor

ESP8266 is one of the most commonly used integrated Wi-Fi chips in an embedded system. Its low cost and high compatibility with other microcontroller make it a universal choice in IoT-based applications. The integration of ESP8266 and IoT are rapidly transforming the healthcare and medical system. ESP8266 referred to as wireless enable system-on-chip (SOC) integrated with a 32-bit Tensilica controller, standard digital peripheral interfaces, antenna, switches, RF balun, power amplifier, low noise receiver amplifier, filter coupled with a power management module in a small-chip. It supports IEEE 802.11/b/g/n, 2.4 GHz Wi-Fi. Wi-Fi Direct (P2P), WPA/WPA2 and uses full TC/IP protocol stack. It is enhanced with GIPO pin that enables interfacing with different sensors and actuators. Due to its cross-functionality, it is easy to integrate with Arduino. ESP8266 enables communication with other Wi-Fi, Bluetooth and microcontroller devices via SPI/SDIO or IC2/UART interfaces. Also, it communicates with server/client via TCP/UD communication protocol. It can perform as either a stand-alone application or as the slave to a host MCU. The ESP8266 microcontroller is shown in Fig. 1a.

Arduino Uno

Arduino Uno is the most prominent Arduino board in the Arduino series or family. It is regarded as an open-source microcontroller board that employs ATmega328P as microchip controller. The board comprises of digital and analog (I/O) pins, shield and other circuits. The Arduino Uno features 6 analog pins, 14 digital pins, a USB connector, power jack, and ICSP. It is programmable with the Arduino IDE (integrated development environment) via a type USB cable. It is powered with a USB cable or an external 9-volt battery. Arduino Uno uses an STK500 protocol. It can communicate with various modules like Wi-Fi (ESP8266), Bluetooth, GPS, GSM via USART/UART interface, PC and laptop over USB and sensors via 12C/SPI. The Arduino Uno is depicted in Fig. 1b.

Heart Beat (HB) Sensor

Heartbeat sensor also identified as pulse sensor is an electronic monitoring device for measuring the non-invasive heart rate. It provides means for examining the function of the heart and this can be measured based on the principle of photoplethysmography. It measures the amount of blood in the fingertip changes to light modulation changes. In the proposed system, to ensure accurate pulse detection a sensing probe is attached to the patients' index fingertip with an adhesive band and green LED flashes indicating that the sensor is functioning as intended. The pulse sensor measures the real-time heartbeats and calculates beat per minute based on the code implemented on the Arduino Uno. The heartbeat sensor is illustrated in Fig. 1c.

Body Temperature (BT) Sensor (LM35)

The LM35 is regarded as a solid-state sensor whose output voltage linearly corresponds to the centigrade temperature. It is a heat sensitivity based sensor that has a temperature range of -55 to 150^{o}C. It is known as linear monolithic series 35 and it is preferred to both thermistor and thermocouples due to its low heating ability, calibration-free, and high precision. LM35 has an output voltage in centigrade (Celsius) with a sensitivity of 1omV/degree Celsius, less than 0.1^{o}C self-heating, temperature ratio of 100^{o}C equivalents to 1 volt, a linear temperature sensor calibrated in ^{O} Kelvin. It interfaces with Arduino Uno via ADC (analog to digital converter) module. LM35 is shown in Fig. 1d.

Mobile Hotspot (MH)

Mobile hotspot is otherwise known as Wi-Fi sharing or tethering. It is a mobile Wi-Fi router (access point) that provides internet connectivity to mobile devices (MiFi). Mobile hotspot allows sharing of cellular data connection through a Wi-Fi connection. It supports up to 10 devices to share an internet connection. The connectivity can be in form of 3G, 4G, 4G LTE and 5G LTE. The mobile hotspot converts Long-Time Evolution (LTE) to Wi-Fi signal. It uses IEEE802.11ac or IEEE802.ax protocol and supports WPA2/WPA3 encryption. In the proposed system, the mobile hotspot acts as an access point through which ESP8266 access internet connectivity. Mobile hotspot is shown in Fig. 1e.

LCD: 16 X 2 (Liquid Crystal Display)

Liquid crystal display is shortened as LCD. It is a liquid crystal modulation light and polarizer based flat-panel displayed technology. It is currently replacing the bulky and high energy consumption cathode ray tube. Furthermore, due to its energy-efficient, low-cost, durability, backlight-enabling it is commonly used in various electronic devices as a textual display unit. A 16 X 2 LCD is a 16 pin device with 2 rows that can display 16 characters each and each character is display in 5 x7 pixel matrix. It can operate as a 4-bit or 8-bit mode. It supports IC2/UART communication interfaces with the most microcontroller. The LCD is depicted in Fig. 1f.

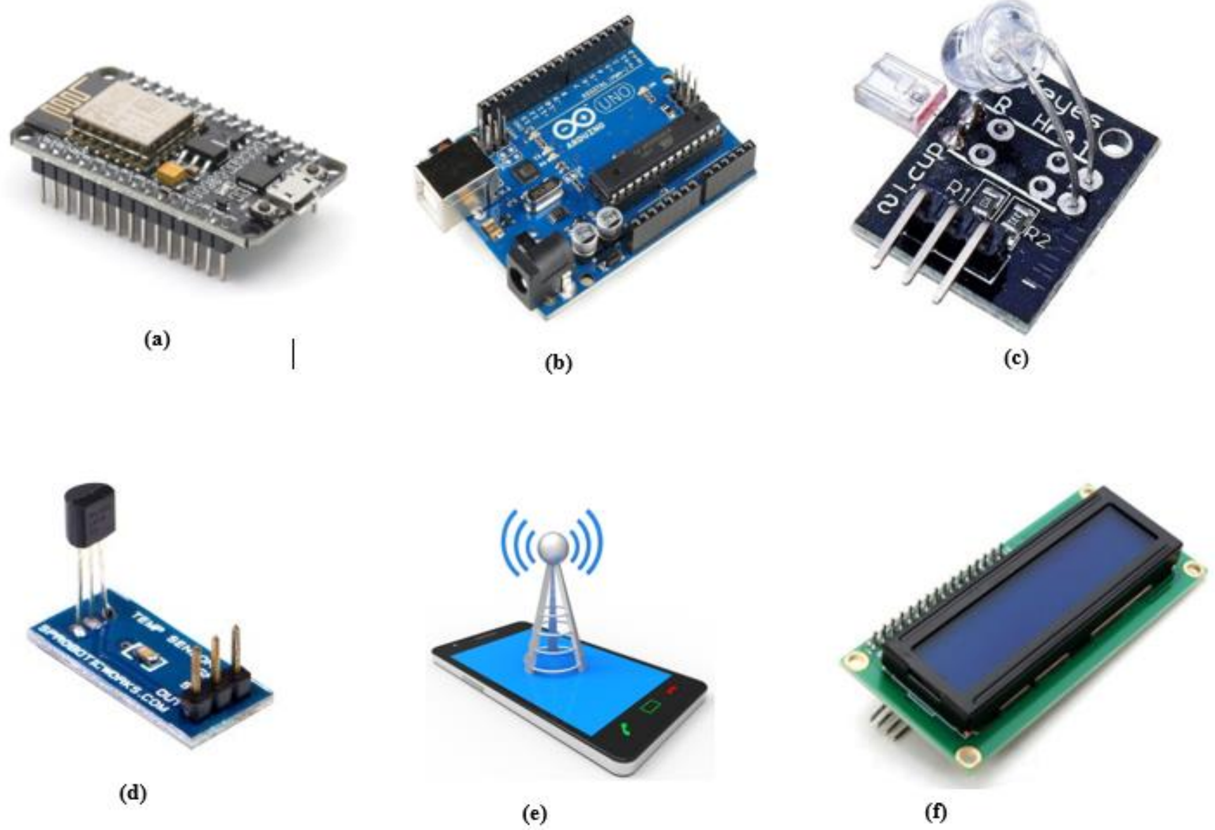

Fig. 1: The hardware components for the patient health monitoring system; (a) ESP866 (b) Arduino Uno c heartbeat sensor (d) body temperature sensor (e) mobile hotspot (f) liquid crystal display

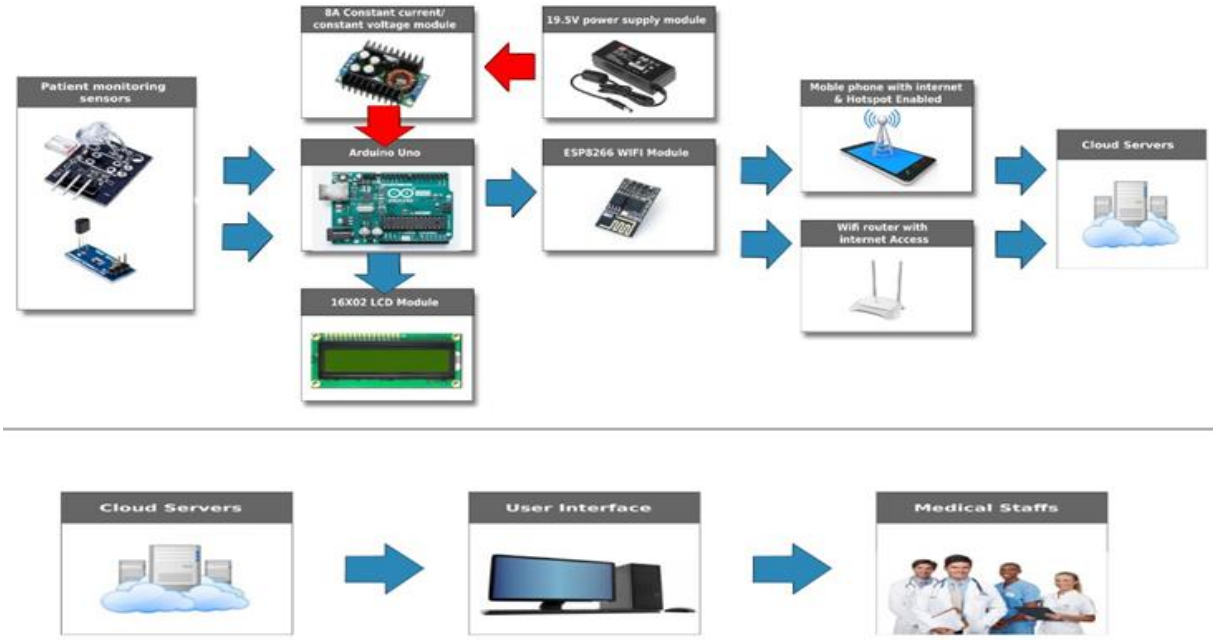

Fig. 2: System Architecture

System architecture

A secured assessment of patients' health based on the two vital physiological parameters has been the main focus of the proposed IoT-based healthcare monitoring system. The technique employed in the design is purely non-invasive, that is patient bodies are free from the incision. The system architecture is the conceptual framework of the proposed patient health monitoring system. The system consists of four-tier structural features. Tier-1 consists of data sensing module (input unit) for detecting vital physiological parameters and it includes user fingerprint capturing unit, the power supply, and the user interface unit. Tier-2 is the data processing module in which the microcontroller-Arduino Uno acts as a processing unit that is responsible for data processing, monitoring, and controlling. The Arduino Uno microcontroller uses a set of AT commands via SPI/UART interface to transmit sensor data in real-time to the cloud via ESP8266 for further visualization and analytics. Tier-3 is concerned with remote data transmission via a secured wireless communication (internet).An ESP8266 Wi-Fi module and mobile hotspot are associated with Tier-3. Tier-4 is the output unit which displays the patient physiological status via LCD. Diverse wireless communications are accessible for Tier-2 and Tier-4 such as Wi-Fi and Bluetooth. The developed system operates on the Arduino platform that uses the Arduino software integrated development environment (IDE). The sensors connected to the microcontroller communicate via pin interfaces and the LCD, BT sensor, HB sensor, Wi-Fi module (ESP8266) are programmed via Arduino IDE using embedded C^{++} codes. The interconnection between various components is explained using the system architecture shown in Fig. 2.

System implementation

The system is implemented based on the previously discussed hardware components. The HB sensor and TB sensor are connected to the Arduino Uno using the physical pins as exemplified in Fig. 3. Arduino Uno serves as a processing unit which has an inbuilt analog-digital- converter (ADC) to convert the sensors' data to a digital signal. The V_{cc} and GND of both sensors are bridged to V_{cc} and GND pins of the Arduino Uno. For HB sensor, the signal pin (OUTpin) is connected with AO pin of Arduino Uno and the data pin of LM35 is linked with analog pin A1 of the Arduino Uno. The data pins D4-D7 of the LCG module are connected with the Arduino Uno digital pins 4-7. Subsequently, the sensors' data are processed and formatted to a compatible 16x2 LCD format. An 8A constant voltage module steep-down the dc voltage of 19.5V power adapter to 5V constant voltage to drive the Arduino Uno and other peripheral devices. The connection of ESP8266 with Arduino Uno microcontroller is achieved via TX serial pins (transit) and RX serial pins interface. The transit signal pin (TX) and receive signal pin of a serial portion of the Arduino Uno is connected with the corresponding signal pins of the serial interface of ESP8266. The GND pins of both ESP8266 and Arduino Uno are connected, with CH_PD and Vcc pins of the ESP8266 are mapped with 3.3V pin of the Arduino Uno as depicted in Fig. 4. Furthermore, the Arduino Uno then transmitted the sensors' data via UART interface using a set of AT commands to the cloud server through ESP8266 either by connecting to a phone hotspot or by connecting to a wireless Wi-Fi router with internet access. The complete circuit diagram of the patient health management system is shown in Fig. 5.

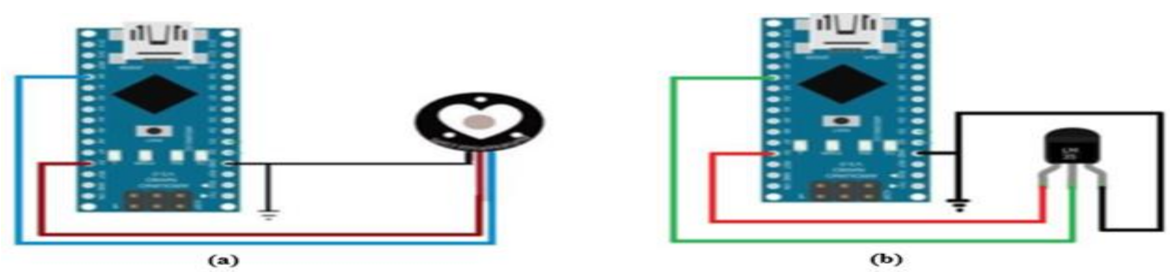

Fig. 3: Circuit Configuration of (a) heartbeat sensor and (b) body temperature sensor (LM35) with Arduino Uno

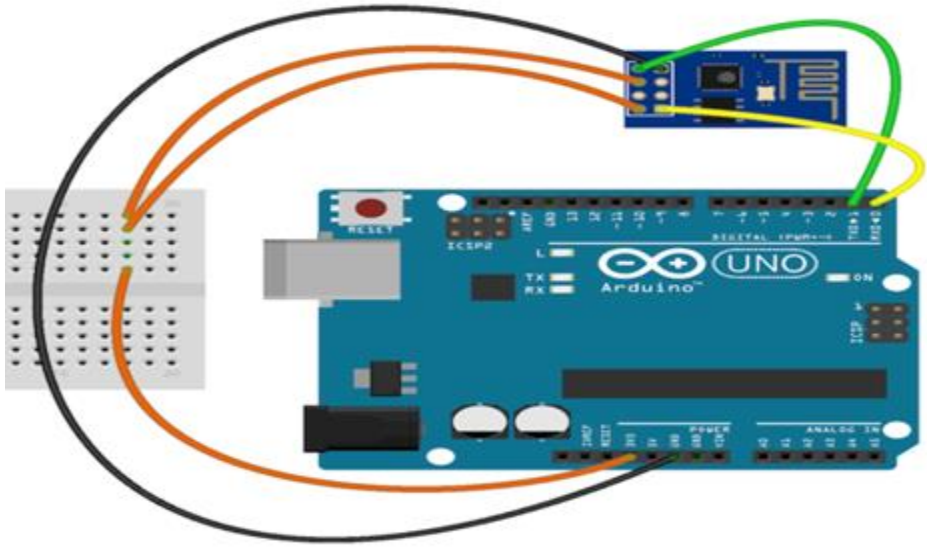

Fig. 4: Interfacing of ESP8266 with Arduino Uno Microcontroller

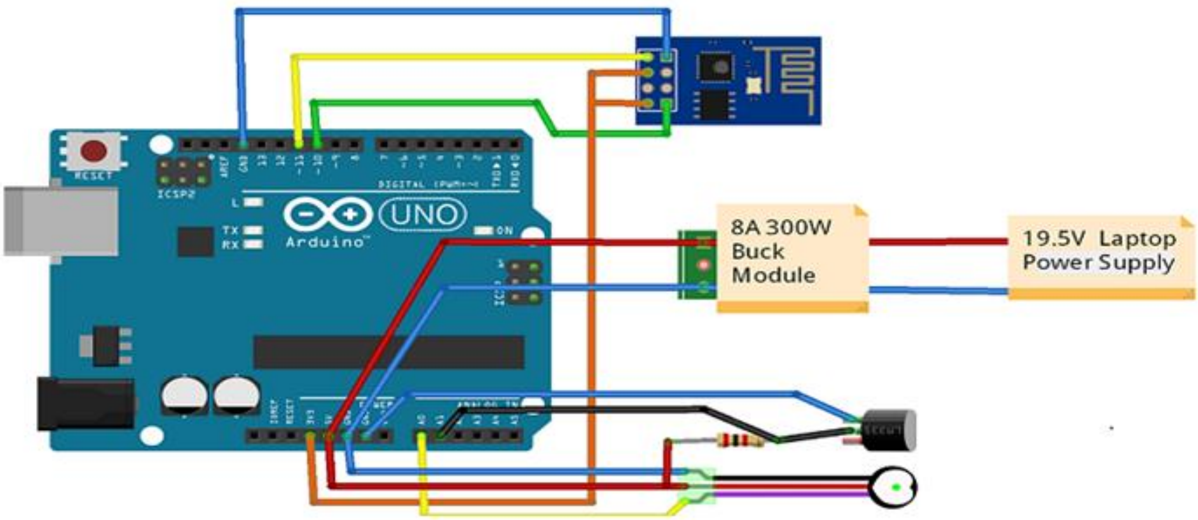

Fig. 5: Arduino Uno patient health management system

Results and Discussion

The results of the patient health monitoring system were evaluated based on testing of designed device prototype and interview via questionnaires. The developed system was tested with ten (10) patients and the questionnaire was administered to 50 subjects between the age group of 30 years to 100 years determine the usability and authenticity of the system and to ascertain the level of the health status of the patient relating to_healthy or unhealthy conditions. In an attempt to ensure accurate data measurement, five experiments each (to obtain the average value generated by the sensors) were taken from the subjects with a time duration of 1 min for heartbeat measurement and 3 min for body temperature measurement. The developed system was compared with the conventional heartbeat stethoscope and digital thermometer for measurement deviation. Also, the difference between the developed system (measured data) and the conventional measuring devices (actual data) was evaluated to show the effectiveness of the developed system. The measured and actual data with the error rate for heartbeat and temperature sensors are shown in Tables 1 and 2. Further, the acceptability of the developed system based on questionnaires is demonstrated in Fig. 6.

Table 2: Heartbeat data comparison between the conventional system and the developed system

Patients	Name	Gender/ Age	Actual data (bpm)	Measured Data (bpm)	Error rate(%)
P_1	Micheal	Male/35	92	93	1.08
P_2	Olusola	Female/65	84	86	2.38
P_3	Omotayo	Male/55	95	98	3.16
P_4	Folarin	Male/60	62	65	4.84
P_5	Anieka	Male/67	74	76	2.70
P_6	Nwobodo	Male/54	68	70	2.94
P_7	Segun	Female/80	84	85	1.19
P_8	Tope	Male/72	70	72	2.85
P_9	Titilayo	Female/68	88	91	3.40
P_{10}	Busola	Female/62	110	114	4.00
	Average Error rate				2.86
	Average Heart B		82.7	85	2.78

Table 3: Body temperature data comparison between the conventional system and the developed system

Patients	Name	Gender/ Age	Actual data (^oC)	Measured Data (^oC)	Error rate (%)
P_1	Micheal	Male/35	36.3	36.4	0.27
P_2	Olusola	Female/65	36.4	36.6	0.55
P_3	Omotayo	Male/55	35.5	35.6	0.28
P_4	Folarin	Male/60	36.4	36.6	0.27
P_5	Anieka	Male/67	35.4	35.6	0.55
P_6	Nwobodo	Male/54	35.3	35.4	0.28
P_7	Segun	Female/80	36.1	36.2	0.28
P_8	Tope	Male/72	35.8	36.0	0.56
P_9	Titilayo	Female/68	36.5	37.0	0.55
P_{10}	Busola	Female/62	36.5	36.8	0.82
	Average Error rate				0.44
	Average Body Temp.		36.3	36.1	0.55

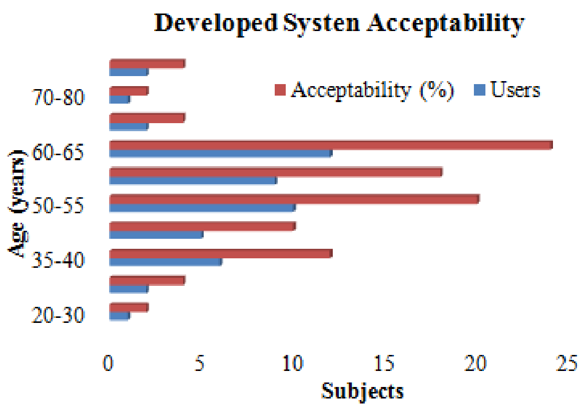

Fig. 6: Developed system acceptability

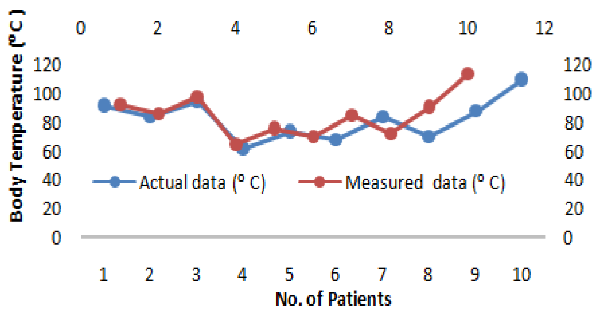

Fig. 7: Body temperature data comparison

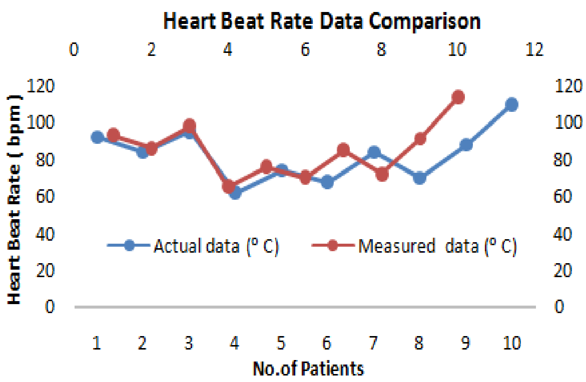

Fig. 8: Heart beat data comparison

Furthermore, the developed system performance evaluation based on the accuracy was conducted for the body temperature sensor and the heartbeat sensor with the conventional physiological tools. So, the index finger of the patients was used as a yardstick for measuring patients' heartbeat rate. Table 4 outlines the results of the test conducted on ten (10) patients for five consecutive times via the developed system. Also, the body temperature of ten patients was tested with the implemented device prototype and each patient was counted five times to enhance data accuracy. The measured data are described in Table 5.

Table 4: Experimental right index fingers measured data

Patients	Heart Beat Data (bpm) No. of Experiment					Mean	SD	RSD (%)
	5	4	3	2	1			
P_1	93	94	93	92	93	93	0.71	0.76
P_2	86	84	85	87	88	86	1.57	1.84
P_3	98	96	98	99	99	98	1.22	1.25
P_4	65	62	64	66	68	65	2.23	3.44
P_5	76	75	74	78	77	76	1.58	2.08
P_6	70	68	69	72	71	70	1.58	2.26
P_7	85	85	86	84	85	85	0.71	0.83
P_8	72	70	74	72	72	72	1.41	1.96
P_9	91	90	89	91	94	91	1.87	2.06
P_{10}	114	112	116	114	114	114	1.41	1.24
Average (RSD %)								1.43
Average Heart Beat (bpm)						85		

Table 5: Experimental body temperature measured data

Patients	Body temperature data (°C) No. of Experiment					Mean	SD	RSD (%)
	5	4	3	2	1			
P_1	36	37	35	37	37	36.4	0.89	2.46
P_2	36	37	36	37	37	36.6	0.55	1.50
P_3	35	36	35	37	35	35.6	0.89	2.51
P_4	36	37	37	37	36	36.6	0.55	1.50
P_5	36	35	35	36	36	35.6	0.55	1.54
P_6	35	34	35	37	36	35.4	1.14	3.22
P_7	36	36	35	37	37	36.2	0.84	2.31
P_8	36	36	36	36	36	36.0	0.00	0.00
P_9	37	36	38	37	37	37.0	0.71	1.91
P_{10}	37	38	36	37	36	36.8	0.75	1.24
Average (RSD %)								0.69
Average Body Temperature (^oC)						36.2		

The developed patient health monitoring system performance was further examined via a questionnaire based on 5-point Likert scale rating on 1 to 5 scale with 1 specified 'dissatisfied' and 5 specified 'very satisfied' as illustrated in Fig. 9. About 70% of the users rated with 'very satisfactory' and 30% users rated with 'satisfactory'. The users' rating distribution as well as the questionnaire's assessment statements are shown in Table 5.

The 5-Point Likert Scale

Scale	Range	Interpretation
5	4.6 - 5.0	Very satisfied
4	3.7 - 4.5	satisfied
3	2.8 - 3.6	Neutral
2	1.9 - 2.7	Unsatisfied
1	1.0 - 1.8	Dissatisfied

Fig. 9: Data measurement index

The data presented in Tables 2 and 3 indicate that deviation of the measured data from the actual data. It can be inferred that the maximum error rate for the heartbeat rate and body temperature are 4.00 and 0.82% and the minimum error rate for the two cases are 1.08 and 0.27%. The average heartbeat error rate and body temperature are as well tagged at 2.86% and 0.44%. These show that the developed system performance is much closed to conventional measuring devices. Also, the values indicated that the error rate is within the limit of 5% acceptable value. As illustrated in Fig. 6, the age group of 34-40, 50-55 and 60-65 show a high percentage of acceptance of the developed system. These groups are most vulnerable that need persistent assessment of their health status, especially during COVID-19 pandemic. Similarly, Figs. 8 and 9 shows that both measured data actual data for the two cases are correlated.

Table 6: Test data interpretation

Design	**5**	**4**	**3**	**2**	**1**	**Aggregate**	**Mean**	**Description**
Compare to other physiological monitoring instruments I have used, I noticed that the PHMS more accurate, reliable and dependable	25	15	10	0	0	50	4.3	Satisfied
The developed system (PHMS) is user-friendly	25	20	5	0	0	50	4.4	Satisfied
The PHMS interface is user interactive	20	20	10	0	0	50	4.2	Satisfied
The sensing interface does not delay or crash	15	25	10	0	0	50	4.4	Satisfied
Patient's data is easy to retrieve via cloud server without data loss.	10	30	10	0	0	50	4.0	Satisfied
The doctors or caregivers response to emergency cases are unmatched	17	25	8	0	0	50	4.2	Satisfied
Average Mean							**4.2**	

The result presented in Table 4 shows the highest RSD of 3.44% and lowest RSD of 0.76% with an average RSD of 1.43%. Comparing the individual RSD of the patients' shows that patient with identification number P_1 has the best precision value. In case of body temperature experimental data as summarized in Table 5, the results revealed that the average RSD of the patients is 1.14% or an average body temperature of 36.2 with a tolerance of 1.14%. Furthermore, the test data presented in Table 6 indicated that the respondents are much satisfied with the developed with their rating.

Fig. 10: Developed patient health monitoring system

In terms of accessibility, usability, connectivity, emergency response, interactivity etc, the system was rated on a scale of "very satisfied". The developed system was integrated with a password-protected system to secured patients' data and prevent unauthorized access of an imposter and only the authorized medical or caregiver staff can access the data from the back end. The conventional methods of measurement lack data confidentiality. To further strength the data security, the developed system is integrated with medical login authentication platform for doctors or caregivers to assess patient's information, view patient's record history, medication-in-use, prescribed drugs and changes in heartbeat and body temperature. Also, the doctors or caregivers and the patients can as well communicate via an SMS in case of emergency or appointment. The overall system design is shown in Fig. 10.

Conclusion

In this paper, a smart patient heartbeat and body temperature monitoring system for secured health based on IoT is developed. The developed system allows continuous assessment of the patient's pulse rate and body temperature via sensors and transmits the data over a wireless network to the cloud server for further medical prediction. The proposed framework embraces four-tier architectural features to facilitate data sensing, data processing, data transmission/communication and to produce output for further analysis of the patient's health status through a secured cloud-based data retrieval databased managed by medical specialists. In this study, the sensors, microcontroller and the wireless communication device were integrated via an IoT based platform with a cloud-based server to enhance patient-doctor interaction and to further maintain real-time update of patient's information and medical specialist response. Furthermore, the integration of IoT and embedded system in the developed system had significantly improved rapid medical care to the patients in remote areas by eliminating long hospital queues and also reduces manual patient record keeping. The experimental results indicate an average error rate of 2.86% and 0.44% for heartbeat and body temperature respectively as compared to the conventional medical devices. An indication that the error rate is within the acceptable limit (<5%). Based on the questionnaires assessed by fifty (50) respondents, a high percentage of acceptance is noticeable in the age group of 35-40, 50-55 and 60-65. The further result shows that the average body temperature lies within 36.2±1.14%. In terms of accessibility, usability, connectivity, emergency response and interactivity, the system was rated on a scale of "very satisfied" by the respondents. In contrast to other existing design, the developed system has an advantage of a password-protected system that enhances data security of the system against an imposter. With this IoT based health monitoring system, the patient can get personalized recommendation of actions for health status and health tips to avert other health-related diseases and strengthen their immune system.

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Conflicts of Interest
The authors affirm that there are no conflicts of interest related to this work.

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