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Integrating Wearable Devices for Intelligent Health Monitoring System

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Abstract— *It is known that many individuals suffer from chronic diseases such as heart disease, high blood pressure, and sleep apnea, which requires constant monitoring, which is only found in the hospital, and the high cost that the individual cannot afford, especially at present. This paper proposes a system through which an individual can monitor vital signs and can use the wearable device by himself without the need for assistance. Wearable devices have been used from the sensors where the proposed system uses six sensors which are the electrocardiogram, the pulse oximeter, heart rate, blood pressure, skin temperature, temperature, and humidity as it collects data and then transfers it via Wi-Fi to the microcontroller on the Internet of things. The results of the sensors have been successfully obtained. Finally, linked them to the Blynk platform that displays the desired results for the individual.*

Index Terms— *Arduino Nano3, Arduino Mega, Blynk platform, Healthcare system, Internet of Thing, Raspberry pi3 model B, Sensors, Wearable Devices.*

I. INTRODUCTION

The demand for home health care is influenced by many factors, including demographic trends, home health care patient needs, and improvements in healthcare to more cost-effective solutions, such as managed care and other risk-sharing schemes [1]. Heart disease patients need constant monitoring of their health. One way to provide home health care is by using interactive technologies, such as providing e-health care. Home health care is affected by many factors, For example, heart patients need regular monitoring of their health. One approach to delivering home health services is to use new technologies, such as delivering e-health care, where e-health expands exponentially with a positive effect on patients, which increases users' access to adequate support and improves behavioral and clinical outcomes relative to non-users [2][3].

It is estimated that the global health sector will stream the Internet of Things (IoT) equipment, services, and software for some 410 billion USD in 2022 [4]. IoT is widely used in such areas as intelligent cities, intelligent homes, intelligent agriculture, the intelligent industry, intelligent energy, intelligent health system, and so on [5]. Cloud services that can be accessed anywhere via internet connections around the world have been offered. In real-time, an IoT device collects and analyzes the information, thereby providing an interdependent climate for stakeholder communication. Cloud computing and IoT combine to improve performance and results reliably in a short time [6][7].

Technically, IoT refers to interconnections between physical devices and other embedded electronics, sensors, actuators, and network communication that enable them to collect and exchange information [8]. IoT devices or objects are often in contact with the real world, i.e. physical devices can be linked from anywhere to the virtual world[9]. Due to this remote working, IoT equipment is currently being used for many real-time applications such as smart media, environmental monitoring,

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intelligent processing, medical and health intelligence, intelligent houses, home automation, energy management, transport, etc[10][11].

Some work from previous research is related to the proposed system. A wireless health monitoring system for smartphones is proposed in [12]. The smart case is designed to include a Bluetooth controller. It differs from a chip-focused health tracking system. Mobile, ECG sensor, RF, Arduino, and Android application. The Bluetooth smartphone and the smart case for health monitoring were made.

The authors of [13] proposed a real-time health monitoring system with heart rate monitors using wireless sensor networks. The system uses an electrocardiogram (ECG) attached to the patient's body and sent to the server through ZigBee. Thus, a health monitoring system was built, especially for the elderly.

A real-time heart rate monitoring system for mobile applications and wireless sensor networks is proposed in [14]. The pulse data from the sensor is obtained and forwarded through a microcontroller to a computer or mobile device and displayed online on the web application. This user can view Heart Pulse (HP) data wherever he is and is easy to use. The system used the pulse sensor, Arduino, mobile, web application, and Ethernet shield. The heartbeat was monitored in real-time using mobile applications for continuous monitoring of the patient or the user.

In [15] the author proposed a remote heart monitoring system for remote heart patients (RHMS). The data collected and sent to the server in this structure sensing technology uses various modeling techniques to improve the quality of the remote data. The system used heart rate, blood pressure, temperature, and oxygen saturation sensors. In addition, mobile applications, and web-based applications. Bluetooth and Wi-Fi are used.

The author of [16] proposed a smart health monitoring prototype with or without indoor user mobility support. Arduino Nano temperature sensor with Atmega328 is equipped with a ZigBee module and shielded cable. The software components used a VB-based application, where a smart model is built for monitoring the patient may be at home or in the hospital.

The author in [17] proposed designing a model of surveillance with vital signs testing for patients who rely on sensors and web services. The monitoring system uses an electronic health shield connected to an Arduino Uno that collects medical information from patients. Various parameters, such as blood pressure, heart rate, and blood glucose level were measured which are transmitted via ZigBee to the microcontroller and then uploaded to the system's location platform via a gateway. GPS / GPRS services have been used for transmission.

The goal of this paper is to create an effective health monitoring system that the individual can rely on, depending on web services and medical sensors. Through the use of specific sensors, it can be used easily and is easy to wear. In the proposed system the following sensors were used, (blood pressure, heart rate, skin temperature, electrocardiogram, SPO2, temperature, and humidity), the medical data will be captured and transmitted via a server to the responsible person. The health monitoring system is designed by building three nodes using the Internet of Things that have been linked to the Blynk platform.

Several reasons were stimulated for designing the proposed system: (1) Making medical services easy to use and accessible to individuals who do not have a supplier of health care services, (2) Making medical services simple and accessible for individuals who do not have transportation to go to medical centers. (3) Expanding the family space in clinics, especially during the current events where many individuals meet in one place. (4) To help people who suffer from chronic diseases.

In addition to this Section I, the paper is divided as follows: The proposed system is found in Section II. Section III. explains the result of the proposed system. Section IV. provides the conclusion of this work.

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II. PROPOSED SYSTEMS

The proposed system has three levels of parts: devices people can wear, monitoring, and linking data to things on the Internet. Where the devices consist of sensors that can be wearable, three nodes are designed that includes the first node on the electrocardiogram sensor. The second node includes a sensor to measure the pulse oximeter and heart rate. The third node includes three sensors the first to measure blood pressure, the second to measure the temperature of the skin, and the third to measure Temperature and humidity. Each of these three nodes is connected to the Arduino Nano board, as the 3 Arduino Nano were used. Every Arduino Nano connects to a single node. Thus, each node was used separately, for example, three individuals can measure simultaneously, and the results appear simultaneously. The first can take an electrocardiogram, the second to measure the oxygen pressure, and the third to take the temperature. After wearing the devices or the sensor, it is powered by the Arduino Nano board which collects data from the devices or the sensor and then delivers it to the Arduino Mega which converts the data into serial and becomes a transmitter to transmit the data to Raspberry pi to make IoT.

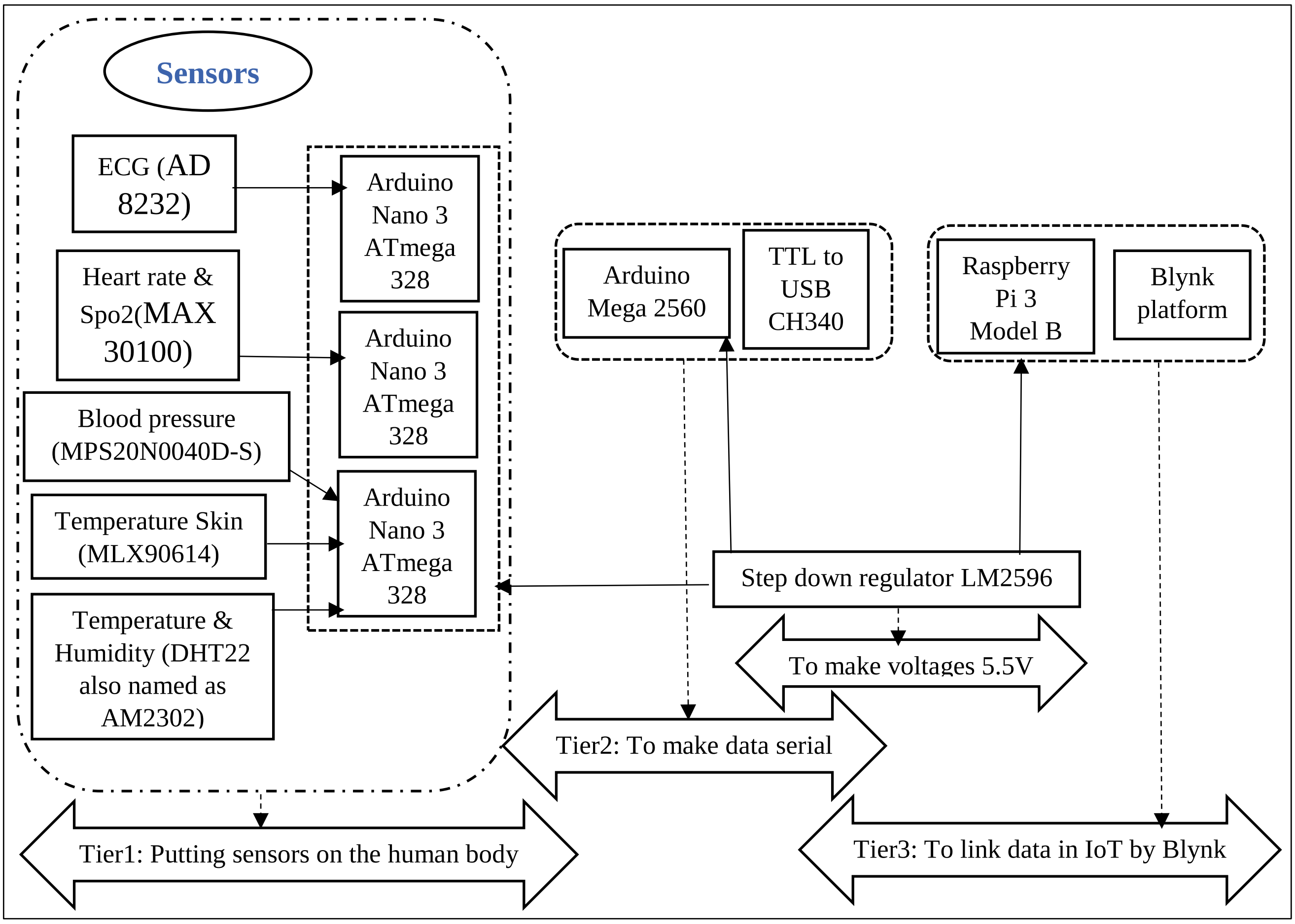

FIG.1. BLOCK DIAGRAM OF THE PROPOSED SYSTEM.

Then, link it to the Blynk platform that is located on the phone in the form of an application through which the results are shown to the individual, with high efficiency, and lower cost. as shown in *Fig.* 1, for the block diagram of the proposed system. This section would describe each layer in detail as follows:

A. Wearable sensors

In this section, the 6 sensors used in the proposed system as well as the connections to the Arduino Nano3 will be described.

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- **ECG Sensor AD 8232** Using an electrocardiogram (ECG), the heartbeat activity is recorded on the skin from above. An electric roller change can be detected on the top of the skin every minute. The ECG amplifier is responsible for receiving qualified information. An ECG is visual tracking of the heart muscle's effort during a heart rate. The electrocardiogram is used together with the MCU to measure the heart rhythm. The heart rate is calculated by simplifying the electrodes into two connections: one to the right and the other to the left[18].
- **SPO2:** The MAX30100 is an integrated sensor solution for pulse oximetry and heart rates. It incorporates both LEDs and photodetector, optimized optics, and analog signal processing with low noise to track heart rate and pulse oximeter signals[19]. This sensor has an industrial problem with the entire three resistors, which have a value of 3.3 volts, to avoid the problem of a resistor, an external resistor of the value of 3.3 volts must be added[20]. The sensor is used in fitness, medical monitoring, and wearable devices. Therefore, it can be used in a Wireless Body Area Network (WBAN) where it monitors the level of oxygen saturation in patients who need oxygen, which is one of the main tasks in the operating room and emergencies. Its features include the pulse oximeter sensor and the heart rate sensor. This sensor communicates through the I2C protocol. The sensor is also used to measure temperature, but it was not used in the proposed system to measure temperature. It was used to measure the oxygen rate of the blood and the number of heartbeats.
  - **Blood pressure sensor:** The air pressure sensor is ideal for biomedicine, weather, and other fields. In the DIP air pressure sensor, the main component is the Microelectromechanical systems (MEMS) pressure technology pressure sensor chip. It is also easy to install and use[21]. This sensor in the proposed system is used as a blood pressure monitor.
  - **Temperature Skin sensor:** MLX90614 is a non-contact temperature measurement infrared thermometer. The 10-bit PWM is standard for the continuous transfer, at an output resolution of 0.14°C, of measured temperature within the range of -20 to 120°C.[22]. The temperature skin sensor is similar in the principle of IR to the SPO2 sensor, but the accuracy is higher, in the range (of 1-3 cm).
  - **Temperature and Humidity sensor:** The DHT22 is a core digital sensor of low-cost temperature and humidity. A capacitive humidity sensor and a thermistor are used for the measurement of the air surrounding the data pin and It uses exclusive technology for digital signal collection and humidity detection, which ensures its reliability and stability. The DHT 22 is suitable for all sorts of hardened applications thanks to its small size, low consumption, and long transmission distance(20m)[23]. Sensors were used to know the temperature and humidity of the place in which was a person.
- **Arduino Nano 3 ATmega 328:** The Arduino Nano is an open-source shortboard based on ATmega328 that is complete and easy to use (Arduino Nano 3.0). Arduino boarding is most commonly used in robotics, embedded systems, and electronics projects, where automation is essential. Works with the Mini-B USB cable[24]. In the proposed system, an Arduino Nano 3.0 was used to configure three nodes in each node. An Arduino Nano was used for each node.

After the sensors used in the proposed system have been described. Table 1 shows the description of each sensor, where to place and for what needs it is used in the examination, and how to connect devices or sensors in the Arduino Nano 3.

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TABLE 1: DESCRIPTION OF WEARABLE DEVICES.

Name of the Sensor	Sensor's specification: Location	Sensor's specification: Communication type	Description	Pin configuration with Arduino: Board Label	Pin configuration with Arduino: Pin Function	Pin configuration with Arduino: Arduino Connection
ECG	Chest	Single hop	Heartbeat electrical activity.	GND	Ground	GND
				3.3V	3.3V Power Supply	3.3V
				OUTPUT	Output Signal	A0
				LO-	Leads off detect-	A11
				LO+	Leads off detect+	A10
				SDN	Shutdown	Not used
SPO2	Fingerprint	Multi-hop	The saturation level of oxygen in the blood and the number of heartbeats.	VIN	Input Voltage	5V
				SCL	SCL	A5
				SDA	SDA	A4
				INT	INT	D2
				GND	Ground	GND
Blood pressure	Left-arm	Muli-hop	Blood pressure maximum and minimum.	VCC	VCC	5V
				OUT	Output	A1
				GND	Ground	A2
Temperature skin	Fingerprint	Multi-hop	Temperature skin measurement.	VIN	Input Voltage	VIN
				SCL	SCL	A5
				SDA	SDA	A4
				GND	Ground	GND
Temperature and humidity	Weather	Single digital	To measure the temperature and humidity of the weather.	VCC	Power Supply	5V
				IN	Input Signal	D4
				GND	Ground	GND

B. To monitor

In this section, it is described how to transfer the data collected in the Arduino Nano through the sensors:

- **Arduino Mega 2560:** The Arduino Mega 2560 is an ATmega 2560-based microcontroller board. The Arduino program consists of a serial monitor allowing the transmission to and from the board of simple textual data. The serial software library enables serial contact with any digital pin of the Mega2560. I2C and SPI communications are also supported by ATmega2560[25]. The Arduino Mega is used in the proposed system to connect the three nodes to it and serially extract the readings of the nodes.

C. To link on the Internet of Thing

This section would explain after the data was collected and became sequentially by the Arduino Mega, which works as a transmitter for Raspberry pi to connect the data to the Internet.

- **Raspberry Pi 3 Model B:** Raspberry Pi 3 Model B is the third generation Raspberry Pi. It is an open-source, Linux-based credit card-sized computer board. This sturdy, single-board, credit card-sized computer can be used for many applications. it adds wireless LAN and Bluetooth connectivity making it the ideal solution for robust connected designs. Pi is ideal for IoT projects due to its processing power[26]. It has been used in the proposed system for making the Internet of Things, and through it, access to the Blynk platform.

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- **TTL to USB:** Built-in USB to TTL Transfer chip. Designed to be used for USB to TTL electronic projects. TTL interface output, easy to connect to special MCU. Status LED. Supports dual power 3.3V and 5V[27]. This chip was used in the proposed project to serialize data to Raspberry via USB port, where it was connected to Arduino Mega and Raspberry pi3 for data transfer sequentially.
- **Step down, regulator:** The LM2596 regulator is a monolithic integrated circuit ideally suited for the easy and ergonomic design of a step-switch (buck converter) regulator. And is used as a Power supply for battery chargers[28]. It was used in the proposed system to run the entire project and standardized the voltages used in the Arduino Nano, Arduino Mega, and Raspberry Pi3, where the voltage used in the power supply was 7.4 volts, but by using the regulator it was reduced to 5.5 volts.

To implement the proposed system, *Fig*. 2 shows a wearable smart health monitoring system that can be divided as follows:

- To connect the three nodes to collect data from individuals and after data collection, an Arduino Mega that receives data from the nodes is used.
- The Arduino Mega then acts as a transmitter for the Raspberry Pi, where it collects the data, converts it into a chain, and sends it to the Raspberry Pi, which receives the data chain and works with splitting and connects the data to the Internet of Things.
- A TTL to USB chip was used in the proposed project to serialize data to a Raspberry via a USB port, where it was connected to the Arduino Mega and Raspberry pi3 to transmit data sequentially.

Fig. 3 shows the complete diagram and the flowchart of the healthcare system which can be summarized as follows:

- Creating connections for the three nodes.
- Creating the components of the three nodes.
- Read sensor values using Node MCU as Local Control Unit.
- Sending sensor readings to serial monitoring, then reading them sequentially.
- Checking the readings of the sensors that were triggered and sent to the Internet of things using Raspberry pi 3.
- Connecting Raspberry Pi to the Blynk platform using the MQTT protocol, which is the fastest and most time-responsive protocol, with an average of 200 milliseconds to 1 second, and with the Blink platform, the final results of the individual will appear via the phone. After that, the system checks the request for a follow-up, non-repetition of the process, or termination of the algorithm.

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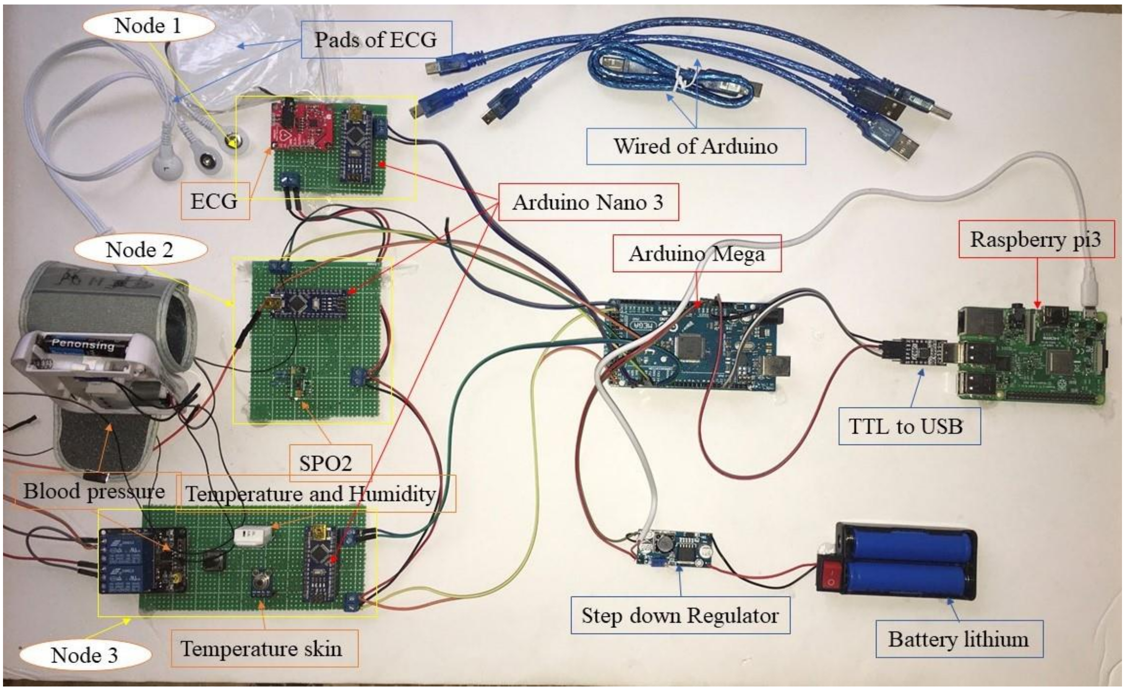

FIG. 2 . THE PROPOSED WEARABLE INTELLIGENT HEALTH MONITORING SYSTEM.

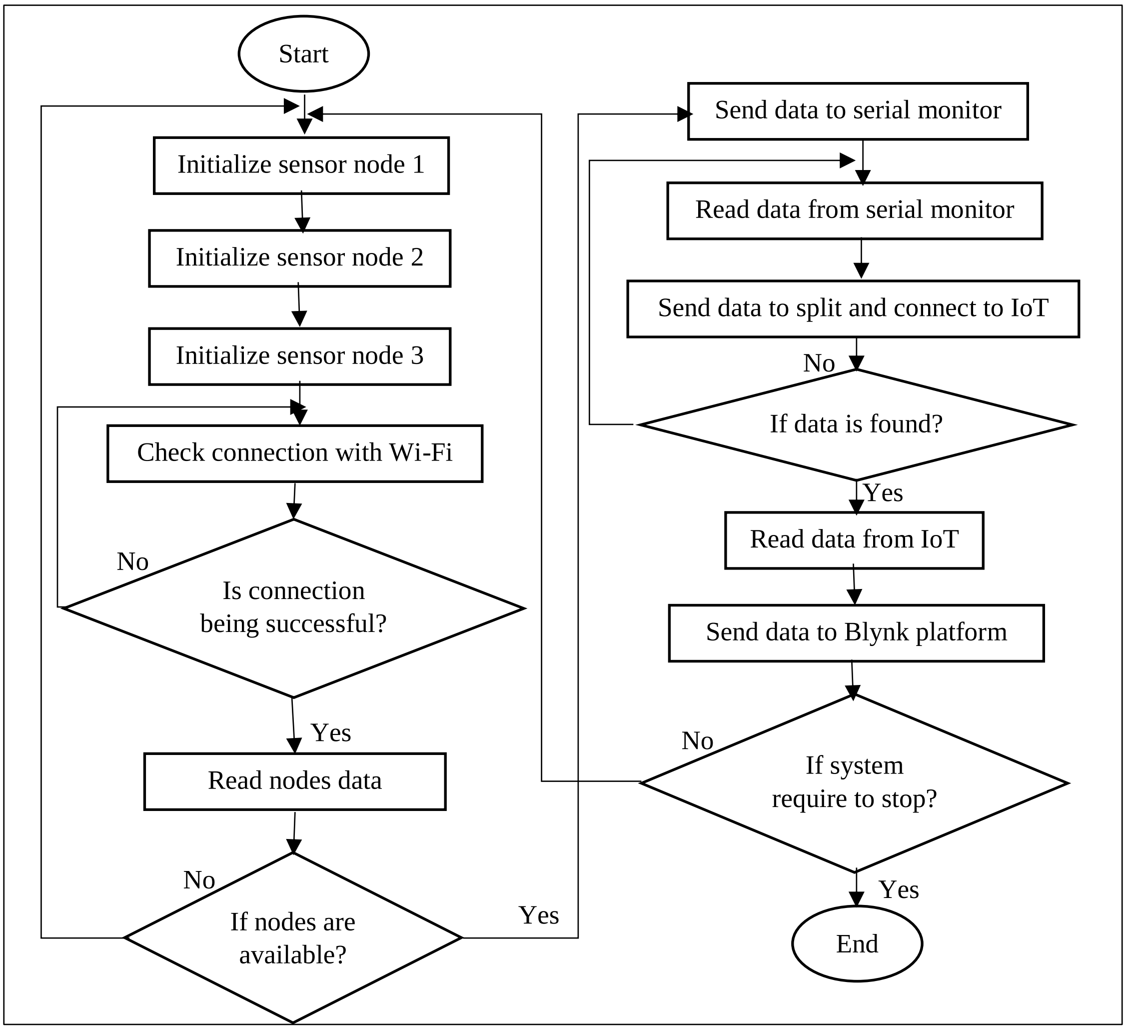

FIG. 3. FLOWCHART OF THE PROPOSED SYSTEM.

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III. RESULT AND DISCUSSION OF THE PROPOSED SYSTEM IMPLEMENTATION

As mentioned in Section II, three nodes have been created and each contains sensors. The result of each node and how the sensors read for each node is shown below. The sensor reading on the ECG is shown in *Fig.* 4 where the reading is close to reality. *Fig.* 5.a shows the reading of the pulse oximeter sensor and the number of heartbeats, and *Fig.* 5.b shows the reading of the blood pressure sensor, the skin temperature sensor, and the temperature and humidity sensor. These figures show us the normal readings of each of the sensors and how the sensor reads through the Arduino Nano 3.

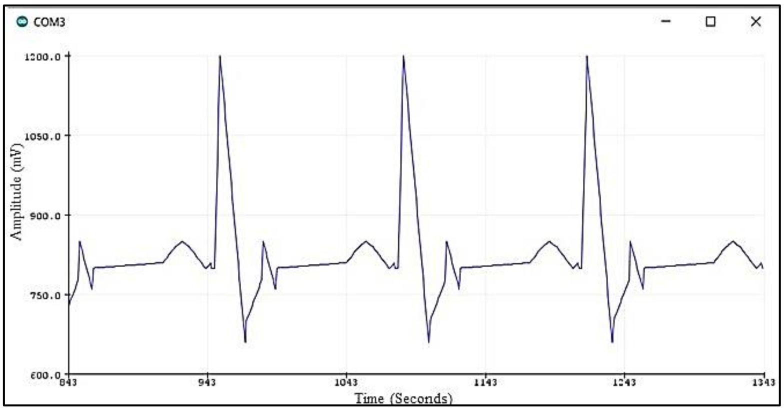
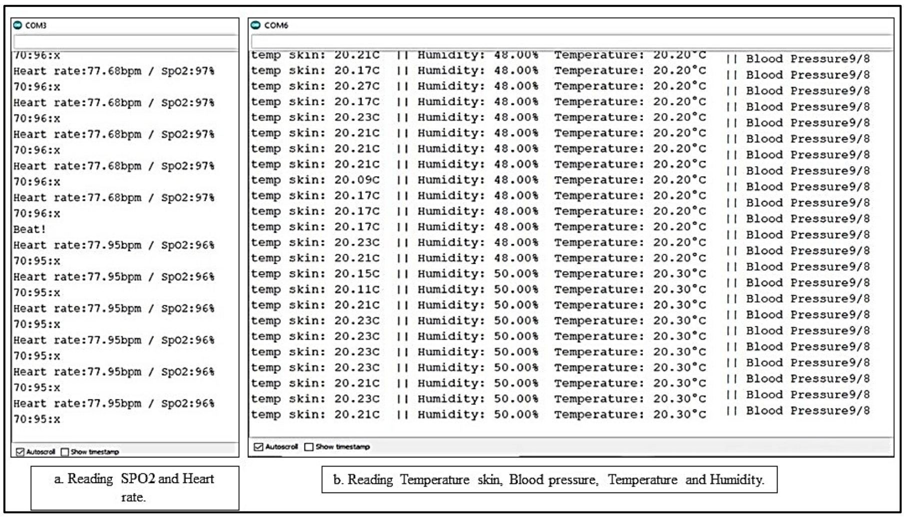


FIG. 4. READING ECG SENSOR.

After reading the three nodes, the data is collected from the nodes and sent to the Arduino Mega, which reads them in the form of a string *in Fig.* 6. We notice the reading of the three nodes in the form of a serial, where the Arduino Mega works, which is the best Arduino for multi-serial data that it is work of TX, RX between the three nodes of Arduino Nano 3 and the Raspberry Pi 3.



a. Reading SPO2 and Heart rate.

b. Reading Temperature skin, Blood pressure, Temperature and Humidity.

FIG. 5. READING NODE 2 AND NODE3.

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FIG. 6. SERIAL MONITORING OUTPUT OF SENSORS.

Fig. 7 shows a Raspberry pi 3 windows that can be accessed remotely by the VNC Viewer installed on the PC. Through this platform, the python code is responsible for displaying the sensor readings that the sensor data has been received from the Arduino Mega in sequence. The Raspberry Pi 3 receives the serial data and split it. finally works the Raspberry pi3 to connect the data to the Internet of Things.

As mentioned in section II, the current and voltage flowing in the devices used where the voltage is equal to 7.4 volts in *Fig.* 8 The following shows the measurement of the current and voltage through the power supply, where the current in the standard is low, the sleep mode is very low, the full load is increased, and the voltage in all cases is equal. 7.4 volts. In *Fig.* 9, the voltage and current are measured by using lithium batteries that give a voltage of 7.3 volts and a current of 3 amperes, and by using a regulator, the voltage was reduced to 5.5 volts, where the standard current is much higher than the full load of the voltage. From Figures 8 and 9, it has been observed that with the power supply, the current at full supply is much higher than the current at the load with lithium batteries. Sleep mode means raspberry pi3 is off and full load means raspberry Pi and the entire project are up and running.

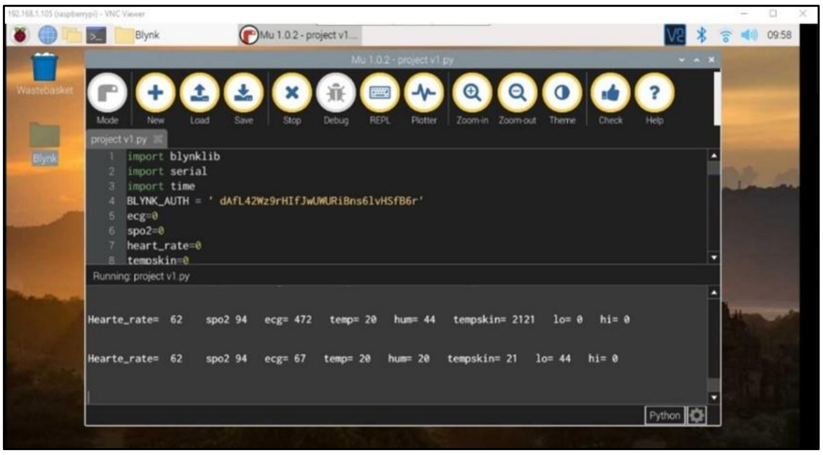

FIG. 7. RASPBERRY PI3 WINDOW.

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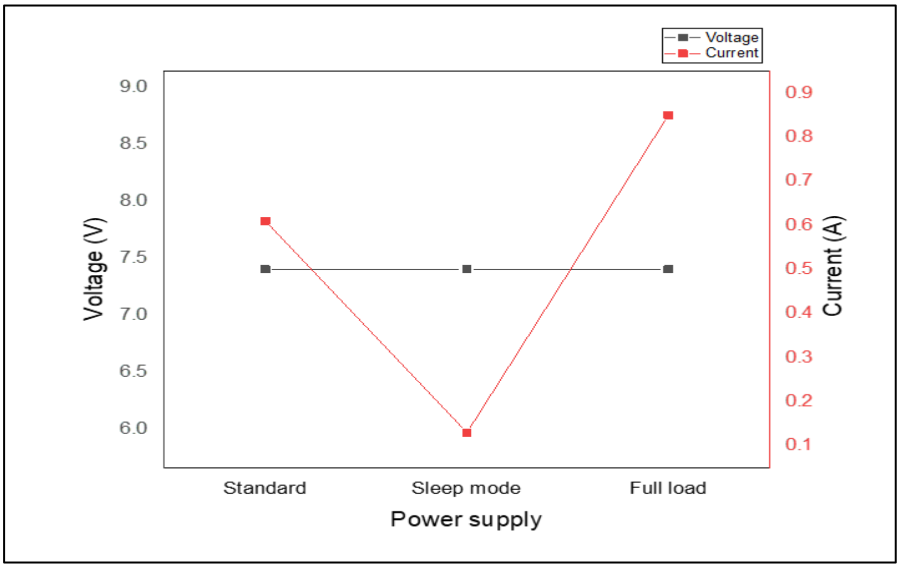

FIG. 8. MEASURE THE CURRENT USING A POWER SUPPLY.

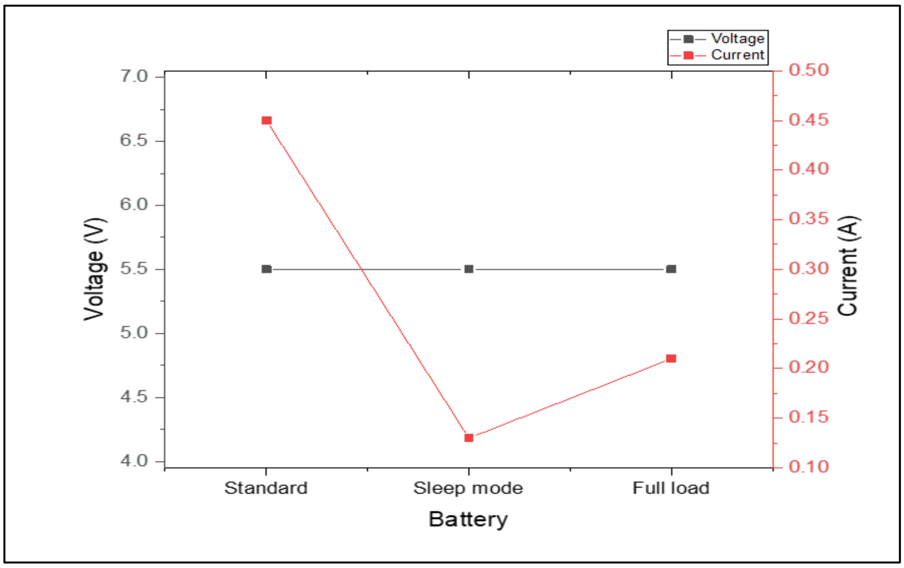

FIG. 9. MEASURE THE CURRENT USING BATTERY.

After connecting the devices to the Raspberry Pi 3, it connects to the Blynk IoT platform, where the devices can be controlled remotely and can view, store, and photograph sensor data and many other things possible. Figures 10 and 11, observed the different readings of the nodes as several people made the appropriate measurements for them simultaneously. In *Fig.* 12, notice is used how the platform displays the sensor data that the individual is using and give him the necessary alerts. In *Fig.* 13, notice that the platform sends notifications over the phone without going to the application and opening it, as it sends the necessary alerts to the individual.

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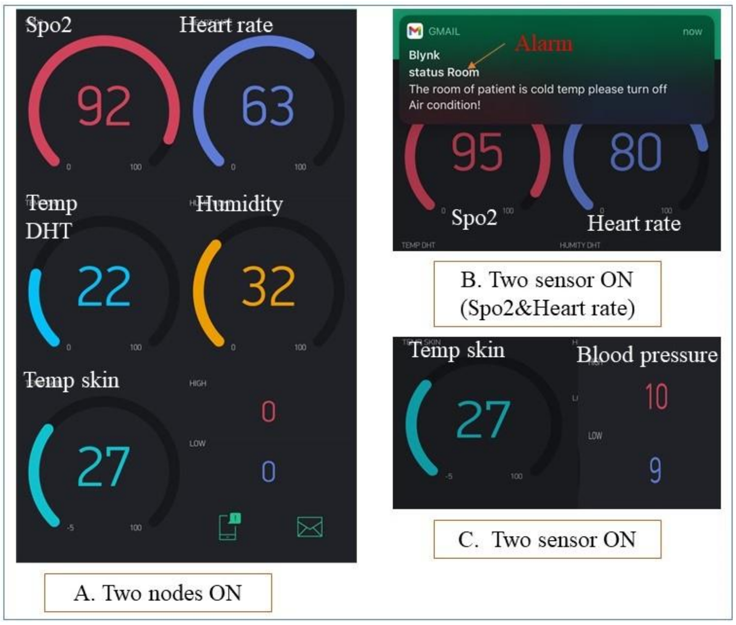

FIG. 10. READINGS OF THE SENSORS ON THE BLYNK PLATFORM.

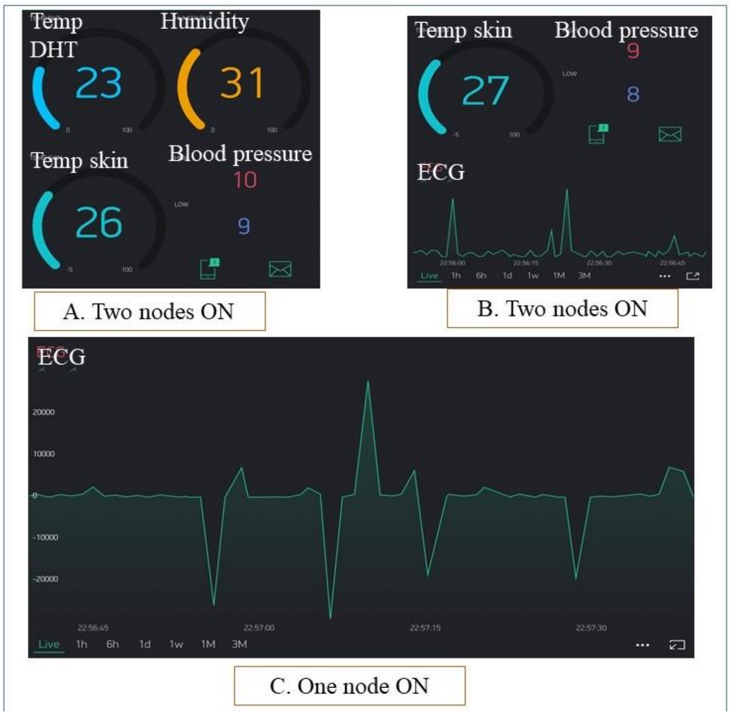

FIG. 11. READINGS OF THE NODES OF DIFFERENT PERSONS ON THE BLYNK PLATFORM.

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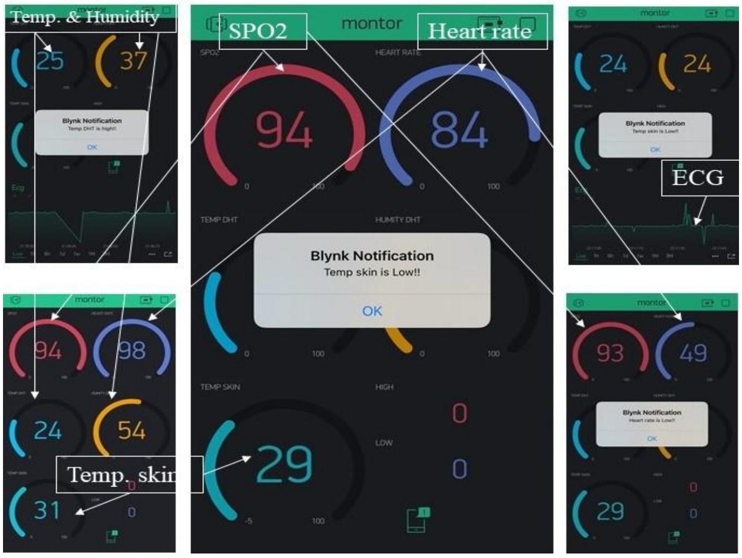

FIG. 12. NUMEROUS READINGS OF THE SENSORS ON THE BLYNK PLATFORM.

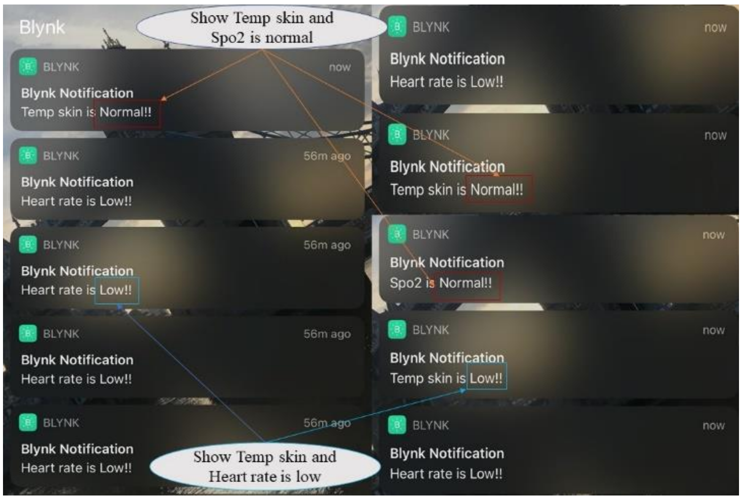

FIG. 13. BLYNK PLATFORM NOTIFICATIONS.

The proposed system in which the Blynk platform was used, is a basic system for the Internet of Things and does not depend on devices, as compared with white-label mobile applications, private clouds, data analytics, device management, and machine learning. Table 2 shows the comparison between the existing work.

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TABLE 2: COMPARISON WITH THE EXISTING WORK.

Author name	Software component	Wearable devices	Description	GSM	Blynk	Year of publication
M. Al-Shaher and N. Al-Khafaji [17]	Arduino Uno.	blood pressure, heart rate, and glucose	Data from the sensor is transmitted via Zigbee to a microcontroller connected to a GSM phone to send an alert message to a doctor.	✓	×	2017
K. Seena Naik and E. Sudarshan[29]	Raspberry Pi.	ECG, BP, temperature, acceleration, and pulse rate.	The patient's data is sent via Wi-Fi to the SIM connected to the phone called GSM via the network.	✓	×	2019
Implemented	Arduino Nano3, Arduino Mega, Raspberry Pi.	ECG, Spo2, Blood pressure, Temperature skin, Temperature, and Humidity.	The data is sent over the wireless network called Wi-Fi and is displayed on the platform called Blynk. The response time in the Blynk platform is much faster than the GSM and the Blynk is free, while the GSM needs a balance. In addition, GSM is part of the Blynk platform.	×	✓	2021

IV. CONCLUSION

This paper presented the healthcare system. This system deals with six sensors which are ECG, heart rate, pulse oximeter, blood pressure, skin temperature, temperature, and humidity. The sensors are distributed on three nodes and the captured data is sent to the Arduino Mega, which in turn sends the data to the base station in the real-time mode represented by Raspberry pi3, through which the connection is made to the Blynk platform, where the results are shown through this platform with high efficiency. The results obtained proved the high sensitivity of the proposed system and the results were compared with other research. That is planning to use the compression sensing technique in a future study.

REFERENCES

[1] O. Obe, F. O. Akinloye, and O. Boyinbode, "An Affective-Based E-Healthcare System Framework," *Int. J. Comput. Trends Technol.*, vol. 68, no. 4, pp. 216–222, 2020, doi: 10.14445/22312803/ijctt-v68i4p132.

[2] M. N. A. and A. A. Jawad, "Performance Evaluation of DSDV and AODV Routing Protocols in E-Health Monitoring Systems," *Res. J. Eng. Appl. Sci. (Rjeas), WWW.emergingresource.org*, vol. 3, no. 2, pp. 73–78, 2014.

[3] H. J. Hassan, N. K. Hadi, and A. K. Taqi, "Implementation of Wireless Body Area Network Based Patient Monitoring System," *J. Inf. Eng. Appl.*, vol. 8, no. 4, pp. 51-64–64, 2018.

[4] "IoT in Healthcare Market to be Worth $409.9 Billion by 2022: Grand View Research, Inc." https://www.prnewswire.com/news-releases/iot-in-healthcare-market-to-be-worth-4099-billion-by-2022-grand-view-research-inc-580614931.html (accessed May 23, 2021).

[5] M. N. Abdullah, M. S. Croock, and A. K. Mousa, "Automation of smart irrigation system based on wireless sensor network," *Sens. Lett.*, vol. 13, no. 1, pp. 92–97, 2015, doi: 10.1166/sl.2015.3416.

[6] R. Babu and K. Jayashree, "Prominence of IoT and Cloud in Health Care," *Int. J. Adv. Rsearch Comput. Eng. Technol.*, vol. 5, no. 2, pp. 420–424, 2016.

[7] A. S. Dawood and M. N. Abdullah, "Adaptive Performance Evaluation for SDN Based on the Statistical and Evolutionary Algorithms," *Iraqi J. Comput. Commun. Control Syst. Eng.*, no. September, pp. 36–46, 2019, doi: 10.33103/uot.ijccce.19.4.5.

[8] Y. H. Tehrani and S. M. Atarodi, "Design & implementation of a high precision & high dynamic range power consumption measurement system for smart energy IoT applications," *Meas. J. Int. Meas. Confed.*, vol. 146, pp. 458–466, 2019, doi: 10.1016/j.measurement.2019.06.037.

[9] M. N. Abdullah and M. J. Ahmed, "Intelligent Autonomous Vehicle for Indoor Mail Delivery Using

Received 19/4/2021; Accepted 27l8l2021

DOI: https://doi.org/10.33103/uot.ijccce.21.4.1

Wireless Sensor Network," *Iraqi J. Comput. Commun. Control Syst. Eng.*, no. September, pp. 12–19, 2019, doi: 10.33103/uot.ijccce.19.4.2.

[10] M. Ambrož, "Raspberry Pi as a low-cost data acquisition system for human powered vehicles," *Meas. J. Int. Meas. Confed.*, vol. 100, no. December, pp. 7–18, 2017, doi: 10.1016/j.measurement.2016.12.037.

[11] O. N.Al-Khayat, S. Y. Ameen, and M. N. Abdallah, "WSNs Power Consumption Reduction using Clustering and Multiple Access Techniques," *Int. J. Comput. Appl.*, vol. 87, no. 9, pp. 33–39, 2014, doi: 10.5120/15239-3780.

[12] M. S. Mahmud, H. Wang, A. M. Esfar-E-Alam, and H. Fang, "A Wireless Health Monitoring System Using Mobile Phone Accessories," *IEEE Internet Things J.*, vol. 4, no. 6, pp. 2009–2018, 2017, doi: 10.1109/JIOT.2016.2645125.

[13] T. S. Sollu, Alamsyah, M. Bachtiar, and A. G. Sooai, "Patients' Heart Monitoring System Based on Wireless Sensor Network," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 336, no. 1, 2018, doi: 10.1088/1757-899X/336/1/012009.

[14] N. S. Ali, Z. A. A. Alyasseri, and A. Abdulmohson, "Real-Time Heart Pulse Monitoring Technique Using Wireless Sensor Network and Mobile Application," *Int. J. Electr. Comput. Eng.*, vol. 8, no. 6, p. 5118, 2018, doi: 10.11591/ijece.v8i6.pp5118-5126.

[15] A. Benjemmaa, H. Ltifi, and M. Ben Ayed, *Design of Remote Heart Monitoring System for Cardiac Patients*, vol. 926. Springer International Publishing, 2020.

[16] Ramesh Saha, S. Biswas, S. Sarmah, S. Karmakar, and P. Das, "A Working Prototype Using DS18B20 Temperature Sensor and Arduino for Health Monitoring," *SN Comput. Sci. A SPRINGER Nat. J.*, vol. 2, no. 1, pp. 1–21, 2021, doi: 10.1007/s42979-020-00434-2.

[17] M. A. Al-Shaher and N. J. Al-Khafaji, "E-healthcare system to monitor vital signs," *Proc. 9th Int. Conf. Electron. Comput. Artif. Intell. ECAI 2017*, vol. 2017-Janua, pp. 1–5, 2017, doi: 10.1109/ECAI.2017.8166485.

[18] M. A. Serhani, H. T. El Kassabi, H. Ismail, and A. N. Navaz, "ECG monitoring systems: Review, architecture, processes, and key challenges," *Sensors (Switzerland)*, vol. 20, no. 6, 2020, doi: 10.3390/s20061796.

[19] I. Pandey, H. S. Dutta, and J. S. Banerjee, "WBAN: A smart approach to next generation e-healthcare system," *Proc. 3rd Int. Conf. Comput. Methodol. Commun. ICCMC 2019*, no. Iccmc, pp. 344–349, 2019, doi: 10.1109/ICCMC.2019.8819713.

[20] A. Abdelgawad, K. Yelamarthi, and A. Khattab, "IoT-based health monitoring system for active and assisted living," *Lect. Notes Inst. Comput. Sci. Soc. Telecommun. Eng. LNICST*, vol. 195 LNICST, pp. 11–20, 2017, doi: 10.1007/978-3-319-61949-1_2.

[21] A. Stojanova, S. Koceski, and N. Koceska, "Continuous Blood Pressure Monitoring as a Basis for Ambient Assisted Living (AAL) – Review of Methodologies and Devices," *J. Med. Syst.*, vol. 43, no. 2, 2019, doi: 10.1007/s10916-018-1138-8.

[22] M. S. Akbar, H. Yu, and S. Cang, "IEEE 802.15.4 frame aggregation enhancement to provide high performance in life-critical patient monitoring systems," *Sensors (Switzerland)*, vol. 17, no. 2, 2017, doi: 10.3390/s17020241.

[23] S. R. Moosavi *et al.*, "End-to-end security scheme for mobility enabled healthcare Internet of Things," *Futur. Gener. Comput. Syst.*, vol. 64, pp. 108–124, 2016, doi: 10.1016/j.future.2016.02.020.

[24] A. Hussain, M. Hammad, K. Hafeez, and T. Zainab, "Programming a Microcontroller," *Int. J. Comput. Appl.*, vol. 155, no. 5, pp. 21–26, 2016, doi: 10.5120/ijca2016912310.

[25] D. Balsamo and S. Das, "Health Monitoring Based on Internet of Things (IoT)," *Heal. Monit. Syst.*, vol. 3, no. 1, pp. 99–120, 2019, doi: 10.1201/9780429113390-4.

[26] R. I. S. Pereira, I. M. Dupont, P. C. M. Carvalho, and S. C. S. Jucá, "IoT embedded linux system based on Raspberry Pi applied to real-time cloud monitoring of a decentralized photovoltaic plant," *Meas. J. Int. Meas. Confed.*, vol. 114, no. September, pp. 286–297, 2018, doi: 10.1016/j.measurement.2017.09.033.

[27] R. Kumar and M. Pallikonda Rajasekaran, "An IoT based patient monitoring system using raspberry Pi," *2016 Int. Conf. Comput. Technol. Intell. Data Eng. ICCTIDE 2016*, 2016, doi: 10.1109/ICCTIDE.2016.7725378.

[28] W. Yue, R. Bishop, M. L. Scudder, and D. C. Craig, *Internet of Things and Big Data Technologies for Next Generation Healthcare*, no. 19. 2017.

[29] K. Seena Naik and E. Sudarshan, "Smart healthcare monitoring system using raspberry Pi on IoT platform," *ARPN J. Eng. Appl. Sci.*, vol. 14, no. 4, pp. 872–876, 2019.

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