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Monitor Human Vital Signs based on IoT Technolgy using MQTT Protocol

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Abstract. General healthcare is essential due to the rapidly growing population and current medical costs. People living far away from cities suffer from poor medical care due to a lack of medical resources. Important to finding an active healthcare monitoring system capable of detecting deterioration of health over time in order to act quickly and taking the necessary measures on the basis of the information obtained. In case the patient has heart disease and symptoms appear for some time and disappear, the monitor standard cannot record of symptoms during a few minutes. In this case, the doctor should recommend a portable device that monitors the blood oxygen level, heart rate and body temperature which usually takes 24 to 48 hours. This paper aims to provide better healthcare for people across developing a system for detecting human vital signs such as heart rate, blood oxygen level, body temperature, temperature and humidity of the surrounding environment based on the Ubidots Internet of Things (IoT) platform. The device consists of a two-part Master and Slave. A master part is a control unit responsible for the operation of sensors remotely in real-time. Slave does collect, calculate and send data to the server using the Message Queuing Telemetry Transport (MQTT) protocol depending on the signal that sends from Master to Slave to activate the sensor required. Multiple sensors have been integrated to measure and display the vital parameters of the patient simultaneously from anywhere and at any time. All collected data displayed in a scientific manner through a program designed and installed on the smartphone or computer. This device allows medical staff to continuously monitor the patient and accurately detect changes in patient status in real-time.

Keywords: MQTT, IoT, healthcare, blood oxygen level, body temperature system

INTRODUCTION

The IoT concept focuses on gathering and processing data from anywhere and at any time [1]. In healthcare, devices are designed for a variety of purposes, such as patient monitoring to manage chronic states, recovery from injury, or ambient assisted living environments. Mobile health is a concept used by smart mobile devices to create effective healthcare services and solutions [2].

The medical industry will increasingly rely on IoT in the next years [3]. The presence of portable medical devices and portable health care applications contributing to enhancing health care services [4-5]. Also, the widespread of new technologies such as robots, artificial intelligence and the possibility of uploading medical information in real-time on the internet help the doctors to take a more precise diagnosis and achieve better therapeutic results to improve efficiency of medical services [6-7]. The integration of IoT with medical devices gives a positive impact on patient care through discovering modern treatment methods [8].

IoT technologies in medical care will improve daily work in hospitals, especially in-hospital care. Also, the availability of data exchange between medical devices played an important role in maintaining the safety and health

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of patients [9]. As well as, help the patient to communicate more time with his doctor. The Internet of medical objects connects to several sensors associated with the human body by using a microcontroller connected to intelligent medical applications and health systems over the Internet [10-12]. Fig.1 shows block diagram for the proposed system architecture.

In the IoT system, Sensors associated with the microprocessor collect data and send it to the central unit which works as a server to store and process it. The data exchange between devices must be under a suitable network and controlled by efficient protocol [13]. Using wireless networks such as IEEE 802.11 gives movement reliability and possible integration with other networks type. MQTT protocol ensures the exchange of a huge stream of data in a safe way and in real-time [14].

Already, healthcare professionals can analyze data in the server using mobile or paramedical devices in health centers using a computer or mobile phone. There are many factors affect the heart rate such as temperature and humidity [15]. A change in temperature and humidity of the weather leads to a change in body temperature and that leads to change heart rate ranges from 5 to 10 beats per minute [16-17]. Also, when the heart pumps more blood than normal, it compensates the lack of oxygen in the blood leading to an accelerated heartbeat [18].

In Ref [19] authors designed a low price device to measure oxygen in the blood and display measurement values on a projector, but device cannot display measured values remotely. Other studies implemented to show measurement data on a wireless screen, but these studies support monitoring only in the surrounding area [20-21]. Other studies [22-23] implemented to measure the heart rate remotely in real-time based on the IoT concept but do not support measuring oxygen in the blood, body temperature, temperature and the humidity of the surrounding environment.

The aim of the paper is design and implement a health care system to monitor the patient's life activities through a set of sensors that have been linked through a wireless network. This paper provides a proposed system for detection of health problems and monitoring vital signs of patient such as heart rate, the oxygen level in the blood, body temperature as well as the temperature and humidity of the environment. The proposed system provided with application used to display recorded vital signs in scientific manner for specialists from anywhere at any time. This application designed by using Ubidots IoT platform and can works on computer or any type of smart phone. The proposed system contributes to make diagnosis symptoms easy, fast and more accurate.

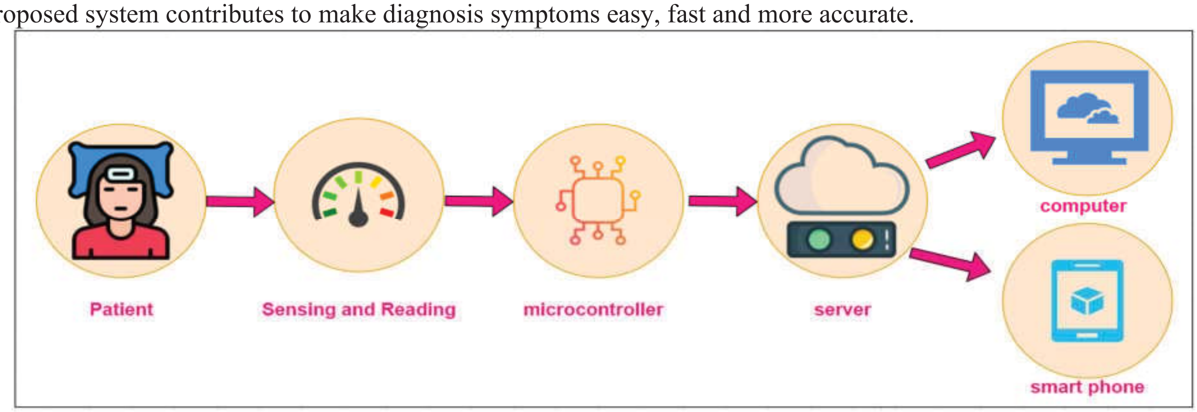


FIGURE 1. Block diagram for the proposed system architecture

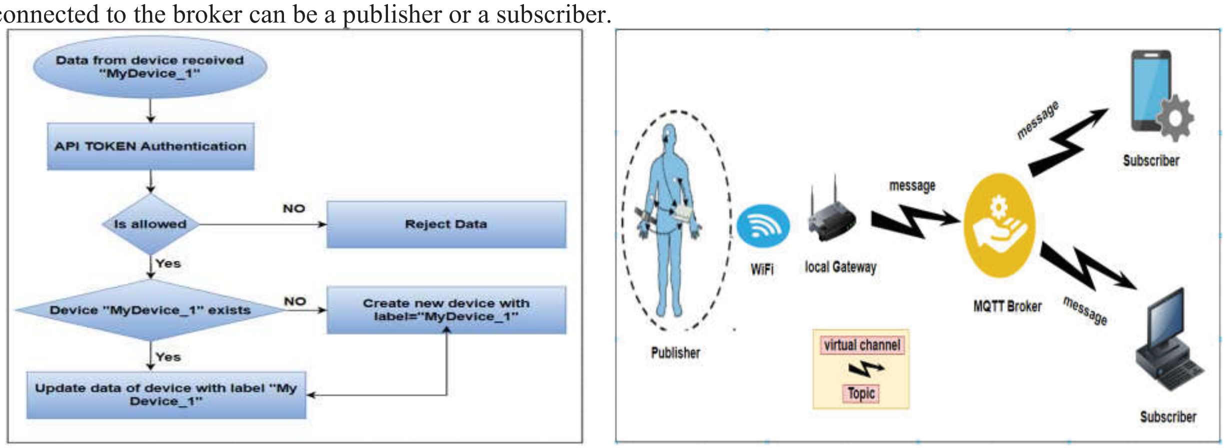
NETWORK IOT PLATFORM DESIGN

In general, Internet-connected devices can divide into two categories servers and clients. Devices providing services or resources called servers. While devices that use services are called clients. The general idea for IoT applications is allowing the server to extract private information and then send it to the client without requesting. The rapid development of information and communication technologies made the possibility to transfer data in real-time. This development reducing the size of tools and increasing the speed of operation, where can perform the most complex information operations in a matter of moments. The collected data sent from servers to the client without challenges through using the appropriate protocol. Fig.2(a) displays a flow diagram of how the server understands and recognized a device.

The main method to solve this connection problem is the quick query. The client regularly asks the server whether new data is available. This is the easiest solution, although it is not recommended if you need to notify a device in real-time. The next option is a long ballot. In this case, the client makes the request and the server does not respond until something has been sent. This enables real-time push notifications from the server to devices. However, this requires the device to leave the connection open every time clients need to listen to the server. The use of this technology consumes more energy and carries the risk of interrupting communication. The third option using newer protocols such as CoAp or MQTT, which are designed for low latency, small packets and stable connections in weak networks [24]. These protocols provided a bidirectional communication channel that supports push notifications. This makes it a good option for IoT projects where connected devices need to be controlled in real-time. Choosing the right protocol depends on the application and how often clients need to connect to a device. The MQTT protocol will be used in this project because the data must be updated in real-time. MQTT is a light and flexible network protocol that offers IoT developers the right balance. The lightweight protocol can be implemented in both very small devices and broadband networks. Due to its flexibility, it can support different application scenarios for IoT devices and services.

Publication and Subscription Form

The MQTT protocol defines two types of entities in the network: A message broker and multiple clients. The broker is a communication bus able to forward the data among the gateway and central platform. It is based on the publishing and subscribes principle. Fig.2(b) displays the MQTT deployment and subscription model for IoT sensors. The process of communication with the server is done by using the MQTT protocol. It is a new protocol used extensively in IoT. One of the advantages of this protocol is that lightweight used for sending simple data. That is used in the process of transferring data and orders between devices IoT. The general idea of how this protocol works will assume there are a number of devices like mobile, computer and a set of sensors that exchange the data with each other and this data is called messages. The part between these devices is called MQTT Broker. The MQTT Broker manages the process of sending and receiving messages between devices. The broker will be considered a server and each device that want to communicate with other devices called a client. In proposed system sensor use to measure a temperature. Other devices such as the mobile or the computer that wants to display the temperature measured by the sensor. Inside the broker will initial store that receives messages come from the sensors. And the second devices, whether mobile or computer, want to receive this data. The store is called a topic, will assume to give it a name, and let it be the temperature. So that the temperature that will come from the sensors is entered on the server in the topic whose name is the "temperature" and stored inside it. After that comes any device, whether mobile or computer wants to know the temperature enters the broker in the topic name "temperature" read the temperature receives. So, in this case, all the devices connected to the broker joint with each other in one topic which is the "temperature". A device that sends a temperature is called a publisher. The devices that receive a temperature form a topic that is found in a broker is called subscriber. Therefore, every subscriber can entry on the topic takes the data to him, any device connected to the broker can be a publisher or a subscriber.



(a) (b)

FIGURE 2. (a) Flow diagram of how Server understands and recognized a device, (b) MQTT deployment and subscription model for IoT sensors

Platform Analysis

Hospital information systems are one of the most advanced software covers all technical and administrative health activities. It ensures that the medical facility has complete control over all of its activities and resources. Their success depends more on their suitability for the various users of healthcare providers such as doctors, nurses, technicians, and even administrators. So, important to find an integrated information system that enables the exchange of information between the various hospital staff. The IoT platform is based on three elements:

Things

IoT concept allows everything in our life to connect to the internet or send and receive data remotely in real-time to perform certain functions over the network. Everything such as sensors, actuators, devices in commercial and industrial environments, watches, TVs, eyewear, clothing, furniture, household items, body parts, and roads can identify itself, communicates and interacts with something in the world of IoT. The things used in this paper are (Pulse oximeter (SPO2) heart-rate sensor module MAX30100, temperature humidity sensor module DHT 11, contactless temperature sensor module GY-906 MLX90614ESF). Fig.3 shows the types of sensors used. All sensors connected by ESP32 microcontroller.

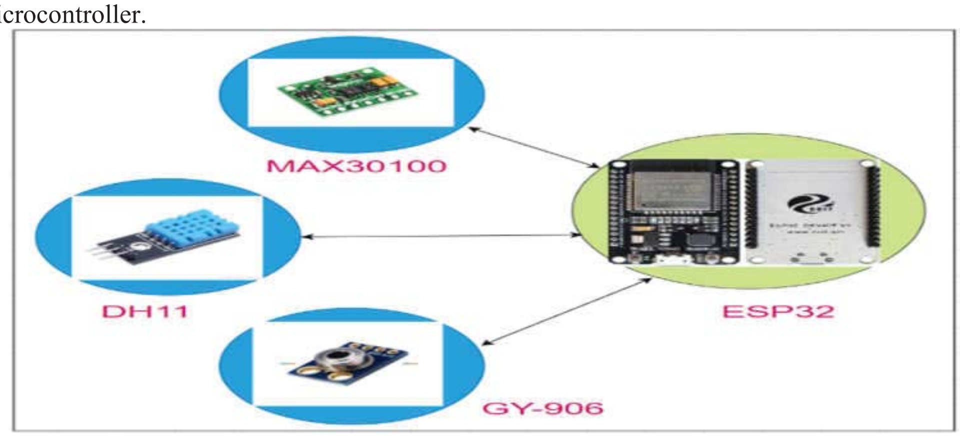


FIGURE 3. types of sensors used and connect by ESP32

IoT Gateways

IoT gateways are devices located between peripheral systems and servers. Fig.2(b) shows the local gateway location. That used to perform functions such as protocol translation, storage, data processing, filtering, and device security. Modern IoT gateways play an important role when importing because they enable sophisticated analysis. So that only the most important information and warnings about work are sent to the cloud. Fig.4(a) shows the flowchart of sensing and data transceiver (Patient's Node).

Cloud Computing

This is a technology-based on the transfer of processing and storage space from the microcontroller or computer to the cloud, which a server machine accesses via the internet. In contrast, traditional computing requires all the data, programs and applications that a user uses and builds on his own devices. Cloud computing is based on the fact that the user does not need to store data on his own devices. Fig.4(b) shows the flowchart of the gateway operation to link server.

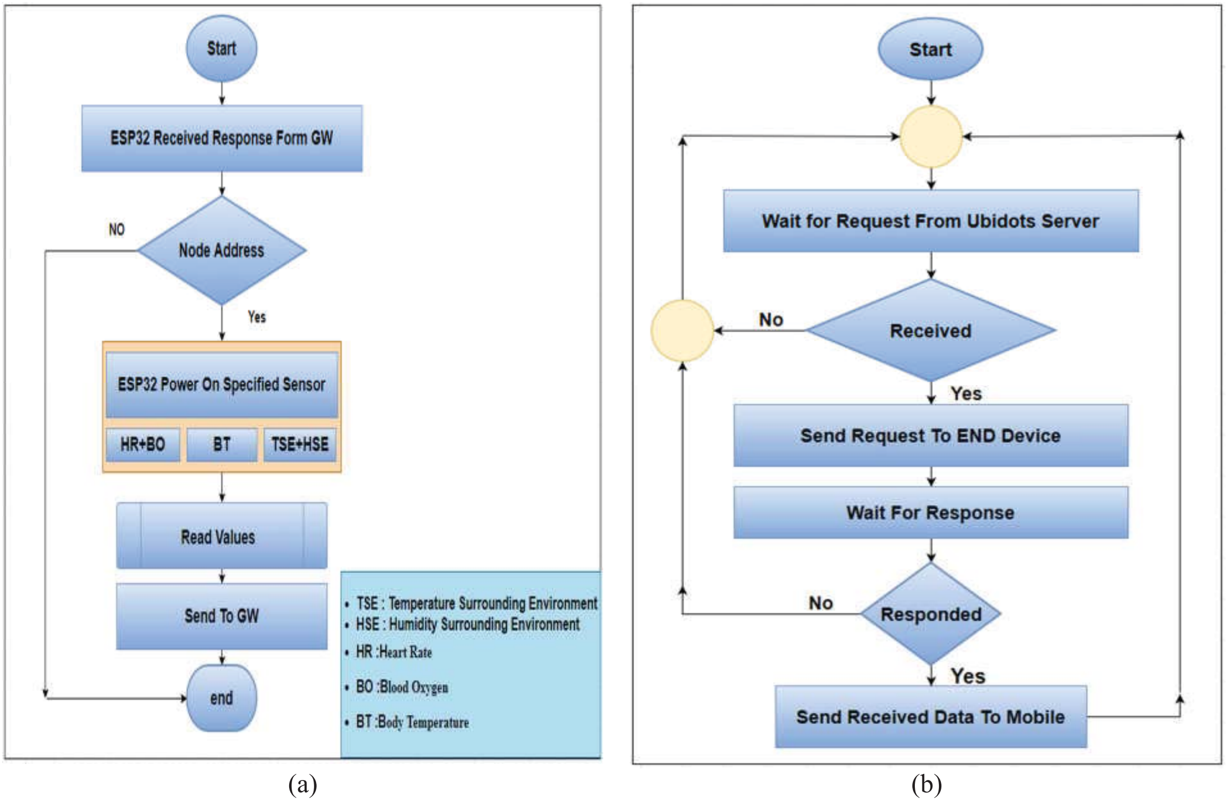


FIGURE 4. (a)flowchart of sensing and data transceiver (Patient's Node), (b)Flowchart of gateway operation

The integration of medical devices gives the availability of data exchange functions that have played an important role in maintaining the safety and health of patients and particularly in improving the way of medical care promoting the participation and satisfaction of patients. By giving the patient more time to interact with his doctor. Technology can use to identify health problems, recording heart rate, oxygen content in the blood, body temperature, temperature and humidity of the environment to help diagnose health problems and the ability to send information to a doctor for analysis and action appropriate medical treatment. Connected devices transmit important body data throughout the day wirelessly to doctor's devices, such as a computer or a smartphone.

PROPOSED HEART MONITORING SYSTEM ARCHITECTURE

If the patient has heart disease and symptoms appear for some time and disappear, the monitor standard cannot record of symptoms during a few minutes. In this case, the doctor should recommend a portable device that monitors the blood oxygen level, heart rate and body temperature which usually takes 24 to 48 hours. The sensors connect to the patient's body then are connected by a microcontroller that a battery-operated. A patient can carry the device in his pocket, or which is attached to a belt or shoulder strap. The device sends measuring results to the server over an internet connection using Wi-Fi technology. Using Wi-Fi gives patient ability to move without constraint. It can continue normal activities as long as keeping the device. Additionally, doctor ask to create a notebook write what do as when symptoms appear. The doctor compares the measuring data with the note recordings to determine the cause of the symptoms. The patient, doctor, and anyone interested in the patient's condition can access the server over the phone and view the patient's measured data. A system is configured to send and receive vital signs of the patient by communication using the MQTT protocol. Many advantages have been gained in this system. The common important point is that the resulting data can be stored and analyzed in the database at any moment and from anyplace. Our proposed system is shown in Fig.5. The MQTT protocol used as transmission protocol in this proposed system because it uses lower payload data, has a small subscription structure for publishing, and small message size, making it ideal for memory-constrained devices.

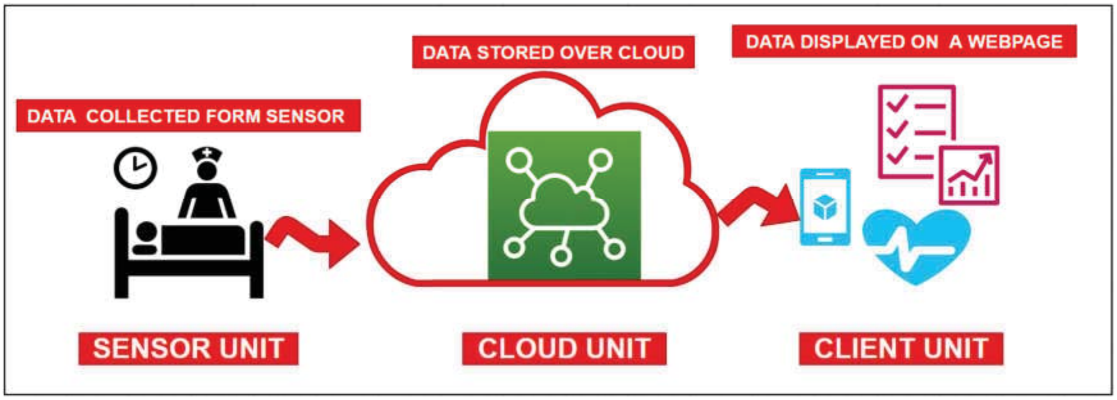


FIGURE 5. Flow diagram of data transfer using the system

IMPLEMENTATION DETAILS

Master and Slave Contact

In the wearable sensor node, the sensors are used (Pulse oximeter (SPO2) heart-rate sensor module MAX30100, temperature humidity sensor module DHT 11, contactless temperature sensor module GY-906 MLX90614ESF). The sensors are interfaced with ESP32 which acts as a slave. Another ESP32 act as the control unit is used to send interaction from the server to the slave to control the operation the sensor connects to the slave which is acting as a master. Through this, the master device will link with the slave device by using the Asynchronous Serial Transport Protocol (UART).

UART protocol is used in communication among several processors or among the processor and the computer. This protocol is asynchronous, and the transmission speed varies depending on the parties and their capabilities to support the high speed of transmission. There are two single ports in this protocol are the TX transmitter port and RX receiving port. When linking two ESP32 with each other, then TX pin for the master ESP32 is connected to the RX for the salve ESP32 as well as for the TX for the salve ESP32 is connected to the RX for the master ESP32. The data is sent in a sequential manner through an offset recorder that pushes the bits one after the other where the byte transmission process is via a fixed framework and fixed speed agreed between the two parties. Fig.6 display frame of UART protocol in each frame content following.

- bit transmitter start
- The data bits, which are from 5 to 8 bits, determined by the user through a specific registrar register in each controller, and usually 8 bits.
- The equality bit, which is either odd, even, or non-existent, used to ensure that the data has been successfully received, and the principle of its work depends on calculating the number of 1 in the binary number.

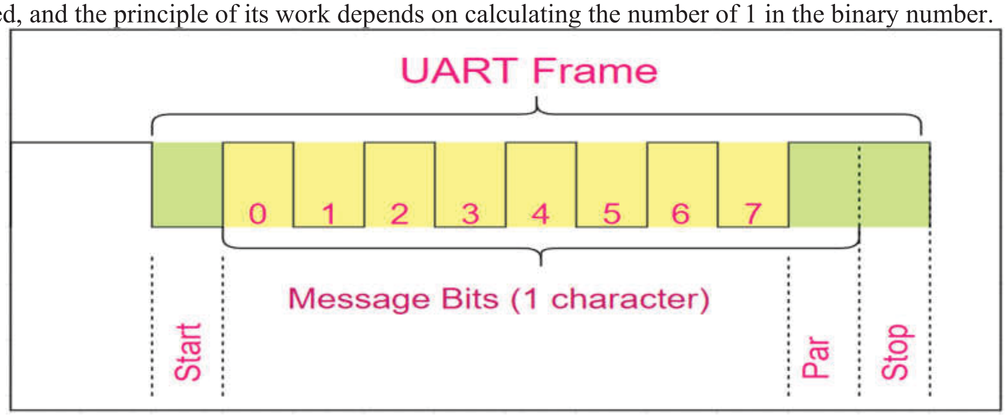


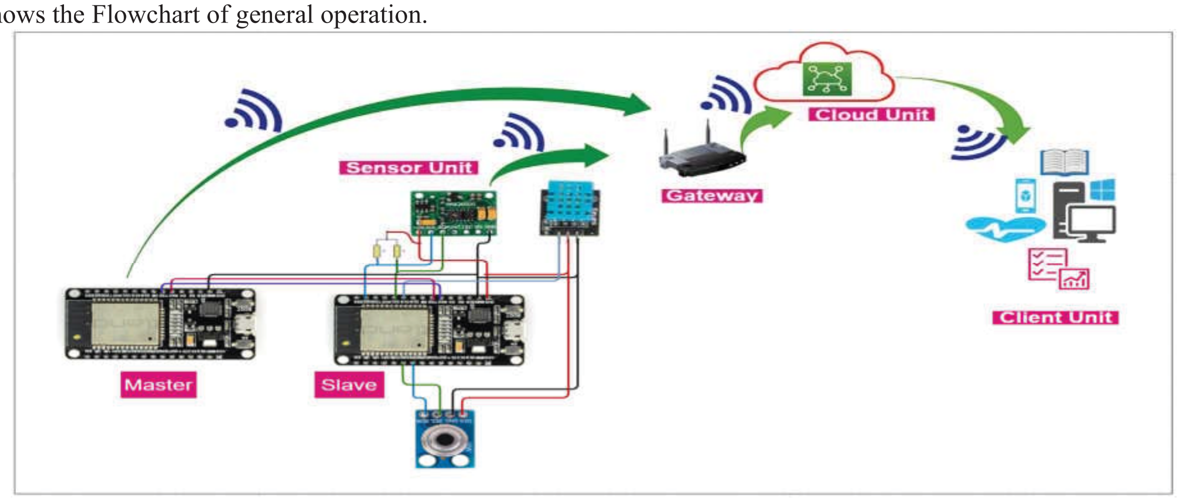
FIGURE 6. Frame of UART protocol

Transfer of Measurement Data to Cloud Via MQTT Protocol

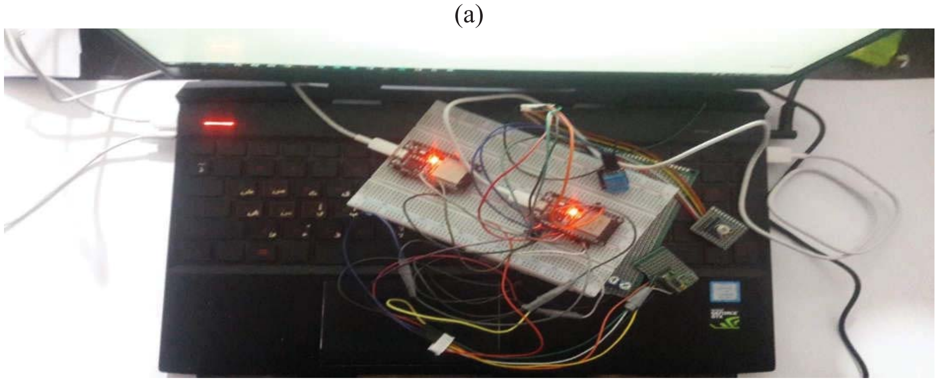
A device designed to measure the vital signs of the human heart consists of two parts master and slave. A master part is a control unit linked to the server via Wi-Fi technology and on the other hand, Master is connected with a slave through the use of the serial UART protocol. The second part is the slave that connects the sensors. The process of sending the measurement data from the sensors to the server by used the MQTT protocol is carried out via Wi-Fi technology. It can send a command from the server to the master part to operate a specific sensor. The master receives the command sent from the server using the MQTT protocol. Then the master interprets the data sent from the server and sends a command to the slave part. The slave receives the command sent from the master and interprets it after that. Then the slave sends a reply to the master telling him that the transmission process has been completed successfully and asks him if there are any other data wants to send. At the moment slave receives the data sent from the master is interprets it and performs the required steps from it.

The data measured from the patient's body is sent using the MQTT protocol. After that, the communication stage begins. The ESP32 processes the data measured by the sensors via the Arduino code and sends it to the cloud account created on the open-source platform by WiFi. The ESP32 content built-in WiFi unit. Fig.2(b) shows the MQTT publish and subscribe methodology for getting data remotely. Now the doctors receive the data from the cloud and diagnose the data details and thus provides the necessary feedback required for patient well-being. Fig.7(a) shows the prototype of the proposed system architecture. Fig.7(b) shows the device connection in particular.

The sensor (Pulse oximeter (SPO2) heart-rate sensor module MAX30100, DHT 11 temperature humidity sensor module, contactless temperature sensor module GY-906 MLX90614ESF) was connected to the Slave (ESP32). Fig.8 shows the Flowchart of general operation.



(a)



(b)

FIGURE 7. (a) The schematic diagram form all the connection done for prototyping of the proposed system, (b) components connection in particular

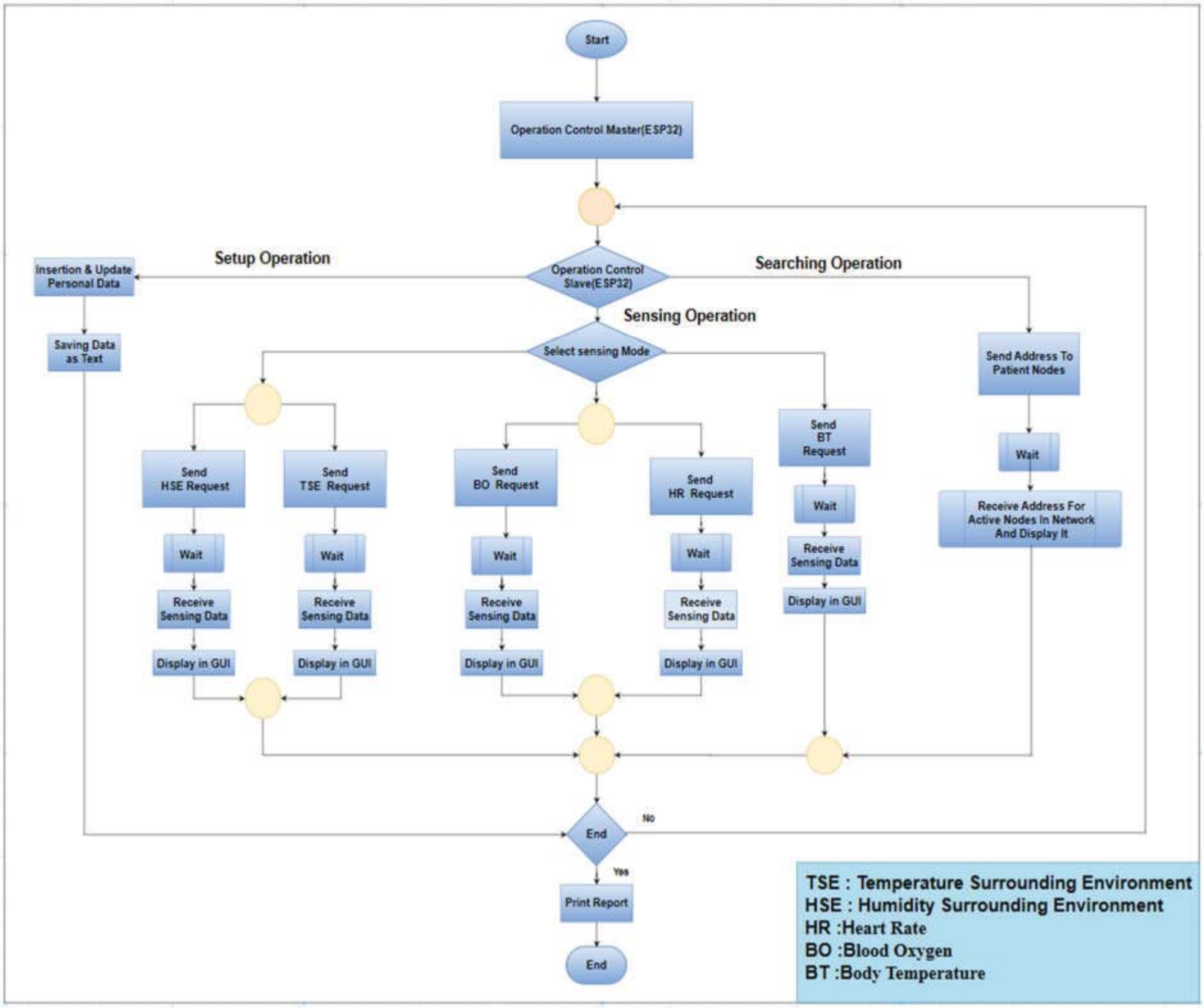


FIGURE 8. Flowchart of General Operation

RESULTS

The program designed to display the recorded data from the server which shows sensors measured values. A new widget added to display the heart rate, blood oxygen level, body temperature, temperature and humidity of the surrounding environment. This program able access to measuring data from anywhere in the world via mobile or computer by entering the account that owns on the server. All the time the circuit that was designed sends data to the server through the internet and the values talk in real-time. The authenticated users can see the data measured on the server as indicators. The sensors connected to a patient's body then the device switches on and the data published on the MQTT server/broker. Fig.9 shows the quantities measured for a person's vital functions, which relate to the work of the human heart. The figure shows measurements of quantities (heart rate, blood oxygen content, body temperature, temperature and humidity in the surrounding environment) with the Ubidots IoT platform. Measurement data are taken for a male who is 25 years old, where the measurements are shown as follows: the heart rate value is 63.88 bpm, While the oxygen level in the blood is 94%, the body temperature and the temperature of the surrounding environment are 35.67 °C and 20 °C respectively, and the humidity in the surrounding environment is 40 H. These vital functions can be monitored remotely. The monitoring system can receive the measured data from the sensors by subscribing to the topic. Anyone interested in the patient's condition, such as the doctor or the patient's companion, can view this information through a program designed and installed on the smartphone or PC. They can enter to check the patient's health remotely in real-time. The necessary information are installed such as name, user name, password, port number, customer identification, etc. The measured body data displayed on a graphical user interface. Also, an order from the server to the device in real-time can be sent to control the work of the sensors. By pressing the dedicated key that exists to execute any command such as in Fig. 9

FIGURE 9. measurements of vital signs of the patient's heart through application

CONCLUSION

This article proposed a remote heart monitoring system based on the MQTT protocol to upload and download measuring data. The proposed implementation of the system carried out using a prototype developed with ESP32. The Ubidot IoT platform client application used to collect (heartbeat, blood oxygen levels, body temperature, temperature and humidity from the environment) and then publish data in the Cloud MQTT broker. The results obtained experimentally from the proposed model displays on an application install on smart phone or computer. Also, the proposed system provides a reliable, flexible and confidential approach to monitor the vital signs of the heart through the use of IoT technology. The End-user, a doctor or a medical technician can view the data of all devices connected to the internet in realtime and from anyplace via subscribing to the identical MQTT topic.

FUTURE WORK

The work in this paper can be developed by using required hardware and software components to identify emergency vital signs that affect the patient's situation. These improvements will give proposed system ability to send urgent alarm in critical status through call, E-mail or SMS notification.

REFERENCES

1. Lanza, J., Sotres, P., Sánchez, L., Galache, J. A., Santana, J. R., Gutiérrez, V., & Muñoz, L. (2016). Managing large amounts of data generated by a smart city internet of things deployment. International Journal on Semantic Web and Information Systems (IJSWIS), 12(4), 22-42.
2. Santos, J., Rodrigues, J. J., Silva, B. M., Casal, J., Saleem, K., & Denisov, V. (2016). An IoT-based mobile gateway for intelligent personal assistants on mobile health environments. Journal of Network and Computer Applications, 71, 194-204.
3. Shah, S. H., & Yaqoob, I. (2016, August). A survey: Internet of Things (IOT) technologies, applications and challenges. In 2016 IEEE Smart Energy Grid Engineering (SEGE) (pp. 381-385). IEEE.
4. M. S. Jassas, Qasem, and Q. H. Mahmoud, "A smart system connecting e-health sensors and the cloud," 2015 IEEE 28th Canadian Conference on Electrical and Computer Engineering (CCECE).

5. P. N. Jain, and T. P. Agarkar, "An embedded, gsm based, multi parameter, realtime patient monitoring system and control; an implementation for icu patients," 2012 World Congress on Information and Communication Technologies.
6. M. M. Baig and H. Gholamhosseini, "Smart Health Monitoring Systems: An Overview of Design and Modeling," Journal of Medical Systems, vol. 37, no. 2, pp. 1-14, 2013.
7. S. Czaja, S. Beach, N. Charness, and R. Schulz, "Older Adults and the Adoption of Healthcare Technology: Opportunities and Challenges," Technologies for Active Aging, vol. 9, A. Sixsmith and G. Gutman, Eds., ed: Springer US, 2013, pp. 27-46.
8. Bansal, M., & Gandhi, B. (2019, February). IoT & Big Data in Smart Healthcare (ECG Monitoring). In 2019 International Conference on Machine Learning, Big Data, Cloud and Parallel Computing (COMITCon) (pp. 390-396). IEEE.
9. Cui, Y., Shi, G., Liu, X. S., Zhao, W., & Li, Y. Q. (2015, November). Research on Data Communication Between Intelligent Terminals of Medical Internet of Things. In 2015 International Conference on Computer Science and Applications (CSA) (pp. 357-359). IEEE.
10. Whitmore, A. Agarwal, and L. Xu, "The Tnternet of Things– A Survey of Topics and Trends," Information Systems Frontiers, vol. 17,no. 2, pp. 261–274, Apr. 2015.
11. S. Li, L. D. Xu, and S. Zhao, "The Internet of Things: A Survey," Information Systems Frontiers, vol. 17, no. 2, pp. 243–259, 2015.
12. GSMA, "Gsma: The impact of the internet of things - the connected home," KRC RESEARCH, Tech. Rep., 2012.
13. Chaudhary, A., Peddoju, S. K., & Kadarla, K. (2017, October). Study of internet-of-things messaging protocols used for exchanging data with external sources. In 2017 IEEE 14th International Conference on Mobile Ad Hoc and Sensor Systems (MASS) (pp. 666-671). IEEE.
14. Su, W. T., Chen, W. C., & Chen, C. C. (2019, June). An Extensible and Transparent Thing-to-Thing Security Enhancement for MQTT Protocol in IoT Environment. In 2019 Global IoT Summit (GIoTS) (pp. 1-4). IEEE.
15. Madaniyazi, L., Zhou, Y., Li, S., Williams, G., Jaakkola, J. J., Liang, X., ... & Guo, Y. (2016). Outdoor temperature, heart rate and blood pressure in Chinese adults: effect modification by individual characteristics. Scientific reports, 6, 21003.
16. Davies, P., & Maconochie, I. (2009). The relationship between body temperature, heart rate and respiratory rate in children. Emergency Medicine Journal, 26(9), 641-643.
17. Madaniyazi, L., Zhou, Y., Li, S., Williams, G., Jaakkola, J. J., Liang, X., ... & Guo, Y. (2016). Outdoor temperature, heart rate and blood pressure in Chinese adults: effect modification by individual characteristics. Scientific reports, 6, 21003.
18. Daly, W. J., & Bondurant, S. (1962). Effects of oxygen breathing on the heart rate, blood pressure, and cardiac index of normal men—resting, with reactive hyperemia, and after atropine. The Journal of clinical investigation, 41(1), 126-132.
19. AlSharqi, K., Abdelbari, A., Abou-Elnour, A., & Tarique, M. (2014). Zigbee based wearable remote healthcare monitoring system for elderly patients. International Journal of Wireless & Mobile Networks, 6(3), 53.
20. D'Mello, Y., Skoric, J., Xu, S., Roche, P. J., Lortie, M., Gagnon, S., & Plant, D. V. (2019). Real-Time Cardiac Beat Detection and Heart Rate Monitoring from Combined Seismocardiography and Gyrocardiography. *Sensors*, *19*(16), 3472.
21. Abdulhamid, M., & Victor, K. (2019). Patient health monitoring system based on zigbee communication protocol. Imam Journal of Applied Sciences, 4(2), 49.
22. Abba, S., & Garba, A. M. An IoT-Based Smart Framework for Human Heartbeat Rate Monitoring and Control System.
23. Ali, N. S., Alyasseri, A., Abdi, Z., & Abdulmohson, A. (2018). Real-time Heart Pulse Monitoring Technique Using Wireless Sensor Network and Mobile Application. *International Journal of Electrical & Computer Engineering (2088-8708)*, *8*.
24. Yassein, M. B., Shatnawi, M. Q., Aljwarneh, S., & Al-Hatmi, R. (2017, May). Internet of Things: Survey and open issues of MQTT protocol. In 2017 International Conference on Engineering & MIS (ICEMIS) (pp. 1-6). IEEE.