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Design and Implementation of Monitoring System for Lethal Events of High-Risk COVID-19 Patients

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Abstract
The monitoring of COVID-19 patients has been greatly aided by the Internet of Things (IoT). Vital signs, symptoms, and mobility data can be gathered and analyzed by IoT devices, including wearables, sensors, and cameras. This information can be utilized to spot early infection symptoms, monitor the illness's development, and stop the virus from spreading. It's critical to take vital signs of hospitalized patients in order to assess their health. Although early warning scores are often calculated three times a day, they might not indicate decompensation symptoms right away. Death rates are higher when deterioration is not properly diagnosed. By employing wearable technology, these ongoing assessments may be able to spot clinical deterioration early and facilitate prompt therapies. This research describes the use of Internet of Things (IoT) to follow fatal events in high-risk COVID-19 patients. These patients' vital signs, which include blood pressure, heart rate, respiration rate, blood oxygen level, and fever, are taken and fed to a central server on a regular basis so that information may be processed, stored, and published instantly. After processing, the data is utilized to monitor the patients' condition and send Short Message Service (SMS) alerts when the patients' vital signs rise above predetermined thresholds. The system's design, which is based on two ESP32 controllers, sensors for the vital signs listed above, and a gateway, provides real-time reports, high-risk alerts, and patient status information. Clinicians, the patient's family, or any other authorized person can keep an eye on and follow the patient's status at any time and from any location. The main contribution in this work is the designed algorithm used in the gateway and the manner in which this gateway collects, analyze, process, and send the patient's data to the IoT server from one side and the manner in which the gateway deals with the IoT server in the other side. The proposed method leads to reduce the cost and the time the system it takes to get the patient's status report.

Keywords
Covid-19, ESP32, Healthcare, IoT, Message Queuing Telemetry Transport (MQTT), Ubidots.

I. Introduction

The Internet of things (IoT) is a growing trend in technology that allows for the monitoring and management of objects and systems in the physical world. Now, with the outbreak of COVID-19 causing heightened health risks for many around the world, there are several ways that IoT can be used to help improve the management of infected patients and reduce the spread of the disease [1]. During the COVID-19 pandemic, IoT devices have been used in a variety of ways to help track the spread of the virus, monitor patients, and provide support to healthcare workers. Here are a few examples:

• Patient monitoring: Vital signs, respiration rate, and blood oxygen levels can all be remotely recorded by IoT devices.

This can assist medical professionals in seeing early indicators of decline and acting swiftly to avert major consequences [2].
• Support for healthcare workers: There are several ways that IoT devices might help support healthcare professionals. For instance, IoT-enabled sensors can be used to track environmental factors in hospitals, such as air quality, and IoT-enabled robots can be used to carry supplies and drugs to patients [3].
• Contact tracing: People who have tested positive for COVID-19 can have their movements monitored and their close contacts identified using wearable IoT devices. Those who may have been exposed to the virus can then be contacted using this information, and they can be advised to get tested and put under quarantine [4].
The following are five ways that one can use IoT devices to better manage patients with COVID-19 [5]:
• Vital Signs Monitoring: Healthcare providers can frequently keep an eye on critical parameters like blood pressure (BP) and temperature (T) by doing a physical assessment of a patient's vital signs at regular intervals throughout the day. However, the caregiver has to keep an eye on these physical inspections all the time, which could take a lot of time. IoT-connected devices have the ability to automatically collect this data and make it available for the caregiver to evaluate at any time [6].
• Monitoring Heart Rate (HR) and Breathing Rate (BR): A patient's heart rate and breathing rate can be tracked over time to determine whether any negative effects are present using Fitbits and other fitness trackers, among other devices. This data can also be compared to historical baseline data to spot any changes that might indicate issues. This is especially important for people who might have an underlying medical condition that makes them more susceptible to COVID-19 issues, like the elderly or those who have already infected the virus [7].
• Making Remote Access Possible: This could be through the use of IoT devices, where caregivers may be able to control their patients and have real time access to their information from any location. This makes it possible for medical personnel to monitor the condition of each patient without necessarily having to visit the patient physically and also makes it easier for the medical personnel to address the needs of the patients more quickly. It also saves time for other patient care related tasks because doctors are not expected to physically go round visiting all patients frequently [8].
• Determining Potential issues: It can also be used to identify certain problems in their patients like having a high temperature or low OL in the blood apart from monitoring the vital signs. These gadgets can be useful when any of these circumstances are identified, as they will inform the caregiver so that they can act accordingly. It can be especially helpful for patients with pre-existing medical conditions which make them more vulnerable to develop complications during COVID-19 [9].
• Improving Patient Care: There is also a possibility to improve the quality of the care delivered to patients with the help of IoT devices as these devices can contribute to more accurate and efficient data collection. Physicians and other caregivers are able to monitor their patients' records on any device and watch for changes that may occur over time or due to other treatments. It can help them in advising each patient on the right treatment to take and also ensure that each patient receives the best treatment possible [10].
As indicated by HPE, some of the most fundamental and sensitive physiological parameters that require monitoring in COVID-19 patients are blood pressure, breathing rate, temperature, heart rate variability, SpO2, and cough [11]. The need for the integration is informed by the ever-increasing computational complexity that is expected to be experienced with the symbiotic relationship between edge computing and 6G heterogenous networks. This was due to the fact that the 6G allows many devices to connect to the network while edge computing will enable many devices to process the data at the edge [12]. Because of this, managing heterogeneous networks with edge computing and 6G presents a few issues, which are as follows:
• Resource management: Since resources are distributed in various devices and technologies in a different nested system of heterogenous networks with edge computing and beyond 6G, it is very much difficult to control resources [12].
• Security and privacy: It is important to ensure security and privacy over such processed data because it is processed and stored across multiple devices using the heterogeneous networks supported by edge computing and even the upcoming 6G technology.
• Interoperability: Edge computing as well as the 6G technology require that different gadgets and technologies in homogeneous and heterogeneous networks should seamlessly integrate with one another [12].
Globally scientists are working on the ways to have a vigil eye on covid patients. These systems pull together data on patient, such as vital signs, symptoms and other health markers possibly with the help of features such as wearables, smartphone, and artificial intelligence. They are intended to help doctors and other healthcare personnel detect signs of deterioration at a very early stage and address them before things escalate to some frightening outcomes [13]. They can also be utilized to assist the patients on how they can manage with their specific symptoms at their homes as well as providing real-time information about their state. Here are some instances of researchers developing patient monitoring systems for COVID-19:
A wearable gadget that can track a patient's breathing rate and vital signs was created by Santos et al. [14]. The gadget can

transmit data to clinicians instantly and is made to be worn comfortably for extended periods of time.
A smartphone application created by Kim et al. [15] can track a patient's symptoms and offer tailored advice on how to manage their treatment. The program analyzes patient symptoms using machine learning to spot trends that might point to a developing illness. A system driven by artificial intelligence was created by Suraj et al. [16] to identify patients who are most likely to experience serious COVID-19 problems. The technology determines risk variables like age, underlying medical conditions, and drug use by using data from patients' electronic health records.
The following is a list of some of these researchers just a drop in the ocean for researchers who are working hard on crafting COVID-19 patient monitoring systems. It is important for their work to advance to minimize the death of patient with this disease and enhance health care services. Still, these technologies can potentially revolutionize how we follow COVID-19 patients' conditions in the first days of their existence. These gadgets also enable health care providers to monitor patient status as it happens, and this make it easier to detect patients who are on the decline and take necessary intervention to prevent adverse outcomes from happening.
The hope here is to work towards the creation of a real time system to which information from the real time broadcasts of the sensors attached to the patients' bodies can be relayed to help healthcare personnel monitor patients' states and promptly act should the need arise. Besides the enhanced COVID-19 patient status tracking, this telemedical technology also gives patients a platform to seek healthcare from the comfort of their homes [17]. Besides making it easier for the patients to get the necessary care, this can also assist in mitigating the odds of the virus transmission. This discovery may be used to create ways of developing the artificial intelligence (AI) that can continuously monitor COVID-19 affected persons for signs of deterioration. Such systems can be capable of thoroughly analyzing data captured from wearable gadgets, telemedicine consultations and other means to come up with a list of high-risk patients [18]. The rest of the research article is organized as follows. Section II. reviews the system design and lists the necessary hardware and software requirements. Section III. describes the IOT gateway setting up. Section IV. provides the details of the cloud computing used. Section V. summarizes the proposed monitoring system architecture. Section VI. shows system implementation. Section VII. describes the transmission of sensors data to cloud server. Section VIII. introduces the results. Finally, Section IX. provides the conclusion on the acquired results.

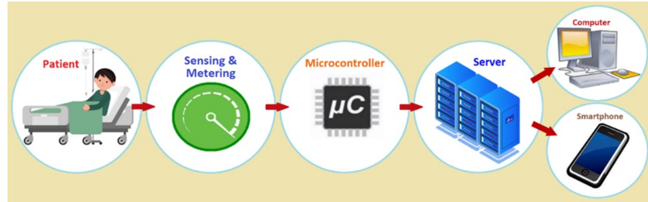

Fig. 1. Schematic diagram of the proposed system.

II. System Design

The schematic diagram of the proposed system is shown in Fig.1. The first part of the proposed system is the sensors that collect vital signs of patient's status and send them to IoT connected microcontroller. This microcontroller is linked through a gateway to a cloud server for publication. This system is provided with an application which is used to display the recorded vital signs in scientific manner for specialists from anywhere at any time. This application was designed by using Ubidots IoT platform and it can work on computer, smart phone, iPads or any type of smart devices. The proposed system contributes to make diagnosis symptoms easy, fast and more accurate.

Various types of sensors can be used with this system, such as Breath Rate (BR) sensor, Heart Rate (HR) sensor, Oxygen Level (OL) sensor, Blood Pressure (BP) sensor, Temperature (T) sensor, patient position sensor, EMG sensor, Galvanic Skin Response (GSR) sensor, and ECG sensor as well as the temperature and humidity of the environment [19], [20]. From IoT point of view, all these sensors would be connected to the microcontroller which is a publisher in this case, as can be seen in Fig.2. The microcontroller is then connected to the MQTT cloud server, which is a broker in this case, through a gateway. The specialists, which may be a doctor, a nurse, or an emergency unit representative all of them can be considered as a subscriber in this system [21].

Flowchart shown in Fig.3, shows how a server binds to a specific device and how it can understand and recognize it.

III. IOT Gateways

IoT gateways are devices located between peripheral systems and servers. Fig. 2 shows the local gateway location within the proposed system. This gateway is 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 shows the flowchart of sensing and data transceiver (Patient's Node).

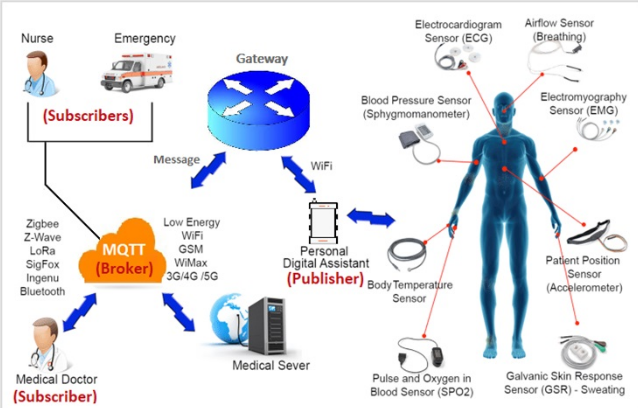

Fig. 2. MQTT deployment and subscription model for IoT sensors.

IV. 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 all his own devices. Cloud computing is based on the fact that the user does not need to store data all his own devices. Flowchart in Fig. 5 shows the communication between the gateway and the link server [22].

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 [23]. Technology can use to identify health problems, recording heart rate, blood oxygen percentage, 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 [24–27].

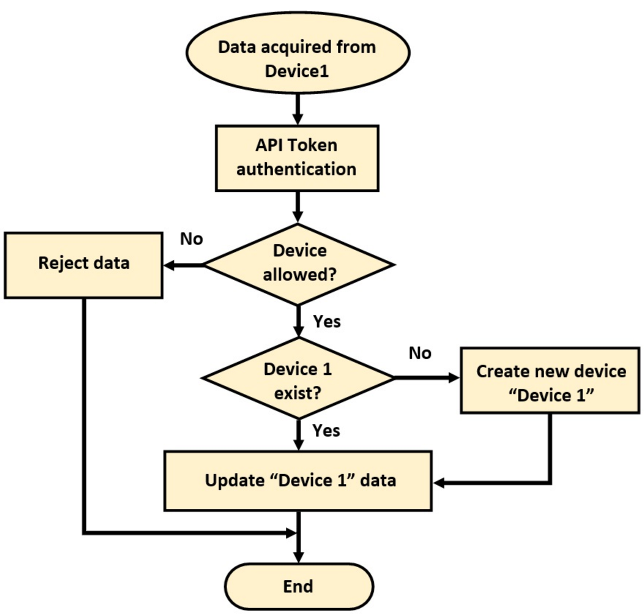

Fig. 3. Flowchart of how server understands and recognized a device.

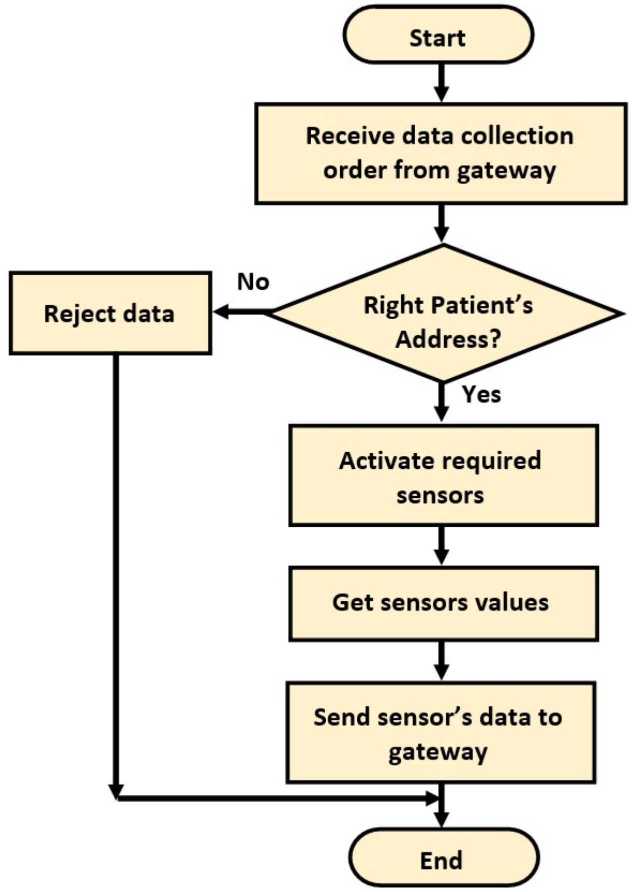

Fig. 4. Flowchart for collecting specific patient’s sensors data.

V. Proposed Monitoring System Architecture

If a patient has, as an example, a heart disease and his symptoms come on for a while then go away, the monitor standard cannot register their symptoms for a short period of time. A portable gadget that measures the body temperature, heart

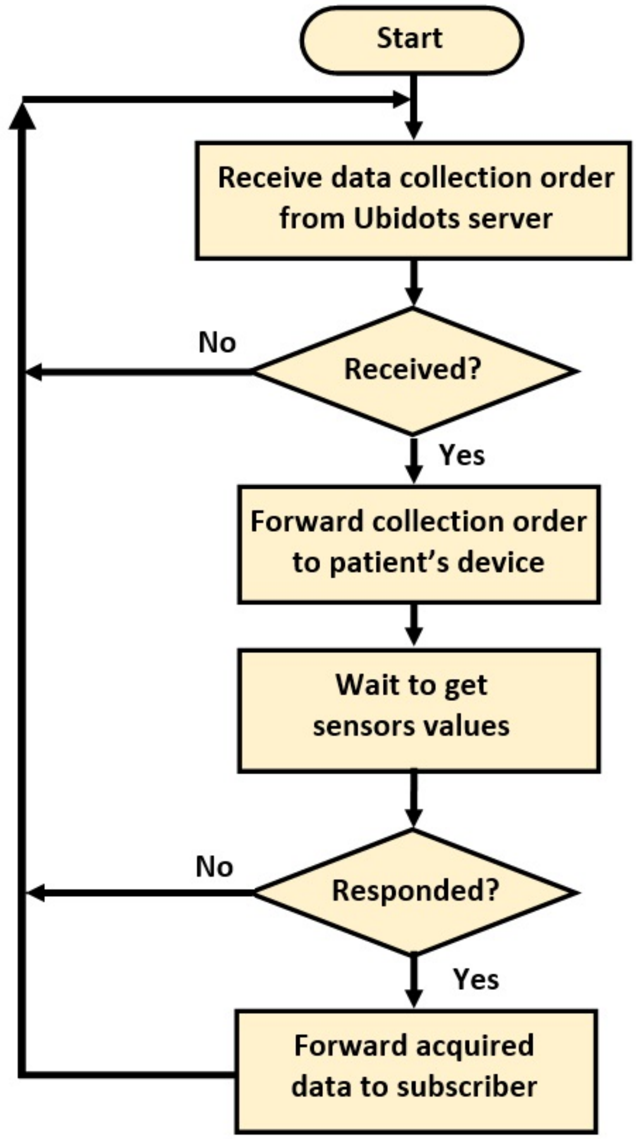

Fig. 5. Flowchart for data/commands transfer between the server and the gateway.

rate, and blood oxygen level over the course of 24 to 48 hours should be suggested by the doctor in this situation. The sensors should be connected to the patient's body and then are connected to a microcontroller which is operated by a battery. 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 WiFi technology. Using WiFi 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

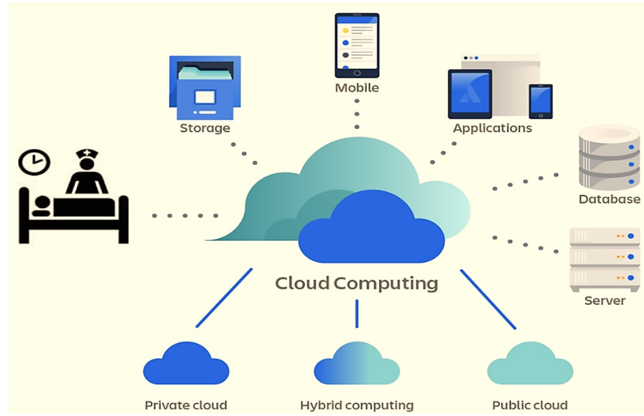

Fig. 6. Data flow diagram through the system.

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 any smart device 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 analysed in the database at any moment and from anyplace. The proposed system is shown in Fig. 6. 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.

VI. System Implementation

The proposed system was implemented using two ESP32 microcontrollers. The first microcontroller acts as a slave which collects sensors data and then send these data to the second microcontroller which is acts as a master. The master microcontroller, which represents the control unit in the patient's node, is used to send slave's collected data to the cloud through the system gateway. The master-slave communication follows the Universal Asynchronous Receiver/Transmitter (UART) protocol. Fig. 7 below shows a master-slave connection prototype.

In the patient's node, the following sensors, as example, are used; Pulse oximeter sensor module (SPO2), heart rate sensor module (MAX30100), non-contact infrared temperature sensor module (GY-906MLX90614), and environment temperature/humidity sensor module (DHT11). All these sensors are connected to slave ESP32 as shown in Fig. 8.

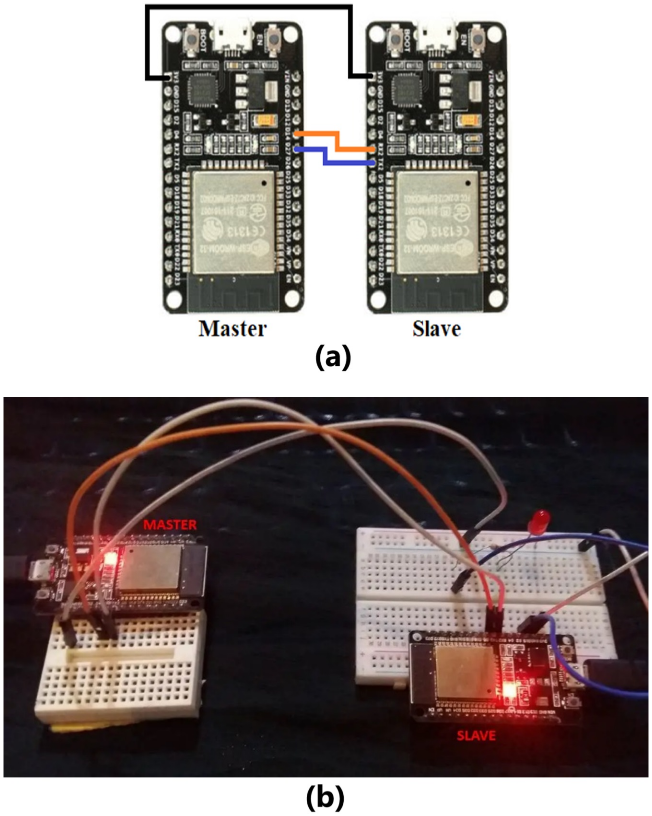

Fig. 7. UART connection of two ESP32 controllers: (a) Schematic diagram. (b) Practical circuit.

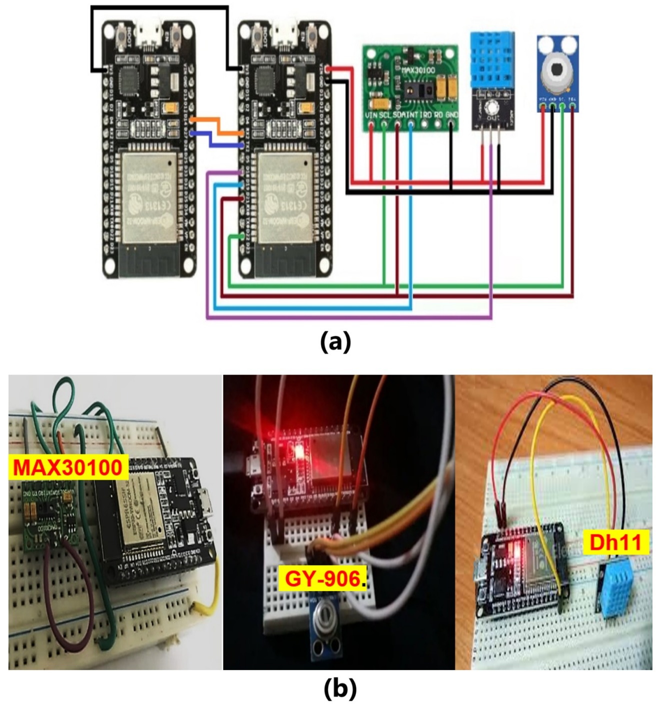

Fig. 8. Sensors connection to slave ESP32: (a) Schematic diagram. (b) Practical circuit.

VII. Transmission of Sensors Data to Cloud Server

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 WIFI technology and in 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 the MQTT protocol is carried out via WiFi 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 in the open-source platform by WiFi. The ESP32 content built-in WiFi unit. Fig. 2 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. 9 shows the prototype of the proposed system architecture. Fig. 10 shows the Flowchart of general operation which shows the process selection weather it is setup process or seeking process within the proposed system. And also, it was shown in this figure the data sensors selection by the authorized person.

VIII. Results and Discussions

The designed program is used to display the collected data of the preselected patient's vital signs from the server which shows sensors measured values. A new widget can be easily added to display the breathing rate, heart rate, blood oxygen, blood pressure, body temperature, as well as the temperature and humidity of the surrounding environment. These vital signs and parameters can be accessed from anywhere in the world via mobile, tablet, or computer by logging into the ac-

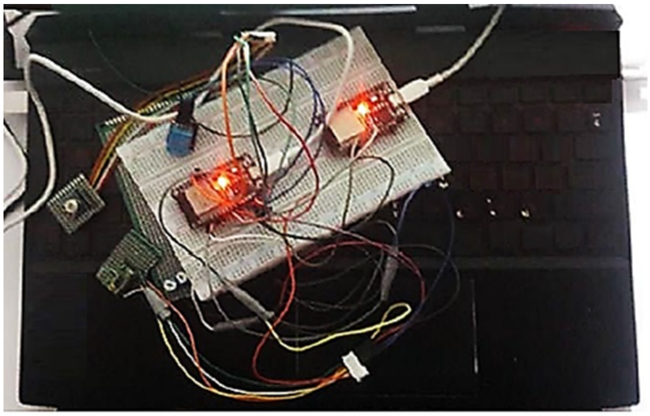

Fig. 9. Overall system implementation.

count that the user owns on the server. All the time the circuit that was designed sends data to the server through the internet and the values is accessed in real-time. The authenticated users can see the data measured on the server as indicators.

The sensors connected to a patient's body can be selected at any time according to the case of the patient and the data published on the MQTT server/broker. Fig. 11 shows some measured values of the preselected patient's vital signs while Fig. 12 shows a programmed emergency alert via SMS of patient in low blood oxygen level condition. These vital signs are (heart rate, blood oxygen level, temperature and humidity in the surrounding environment) using Ubidots IoT platform. The displayed data are for a man who is 27 years old. The measurements are shown as follows: the heart rate is 95.93 bpm, while the oxygen level in the blood is 97.00%. The patient's body temperature is 36.72°C, the ambient temperature is 30.76°C, and the humidity is 30.56%. All the measured vital signs are accessed and monitored remotely. The subscriber (monitor) can access the vital signs readings collected by the sensors by subscribing to the Ubidots dashboard widgets page. Anyone interested in the patient's condition, such as the doctor or the patient's companion, can access these readings through a program installed on phone, tablet or computer. They can follow the real-time state of the patient remotely.

The use of IoT in COVID-19 patient care offers many potential benefits, but there are also some potential risks and issues that need to be considered, these may be one or more of the followings:

• Technical issues: One of the biggest challenges with using IoT in COVID-19 patient care is the need for reliable and secure technology. IoT devices can be complex and difficult to set up and manage. Devices that are not configured correctly could be targets of cyberattacks. IoT devices can also produce a lot of data, which can be challenging to store and process.

• Involving patients in self-monitoring: This way, getting the patients engaged in this do-it-yourself task is a challenge when it comes to IoT in COVID-19 patient management. It is crucial to remember that patients must be willing and capable of using IoT devices properly and as often as needed in order for their vitals and other health parameters essential for analysis to be gathered. Therefore, proper training and support should be provided to the patient to equip him or her with the knowledge necessary to efficiently use the Internet of Things equipment.

Here are some particular instances of possible dangers and problems that could occur when utilizing IoT in the treatment of COVID-19 patients:

• Device failure: Misfortune, by all means, software glitches, hardware failures, and drained batteries are some of the possible ways which Internet of Things devices may fail. If a gadget fails, it could not then properly collect the data or transmit the data as desired.

• Data security: A large amount of personal data including a patient's state of health is collected by smart appliances of the IoT. This information can be easily stolen by hackers or someone with ill intentions if this data is not well protected.

• Patient privacy: It is thus rather surprising that so much information about the movement and activity of patients is collected by IoT devices. This data could be used to keep track of patients, or to target them with advertisements etc.

• Patient fatigue: In patient's panel, the need to follow their health status update and report to their healthcare providers may make them feel quite overwhelmed or even exhausted.

• Of course, it is not easy to implement IoT solutions into practice, but perhaps there are more pros to use IoT in COVID-19 patient treatment than cons. Health care staff can utilize IoT to enhance COVID-19 patients' care outcomes since the risks highlighted by the framework can be effectively managed if health care practitioners take particular care in considering the dangers and acting to minimize these. The following advice will help reduce the dangers related to utilizing IoT in COVID-19 patient care:

• Make use of only approved gadgets: Verify that the Internet of Things (IoT) gadgets you utilize have been approved by a respectable body, including the Health Industry Cybersecurity Consortium (HICSS).

• Update firmware frequently: Ensure that the firmware of your array of IoT devices is up-to-date with the latest security patches.

• Use secure passwords: Ensure that all of your IoT devices have a robust password, especially when setting the device, and change them periodically.

• Dissect your network to create several segments to help ensure that IoT devices are isolated from other networked devices.

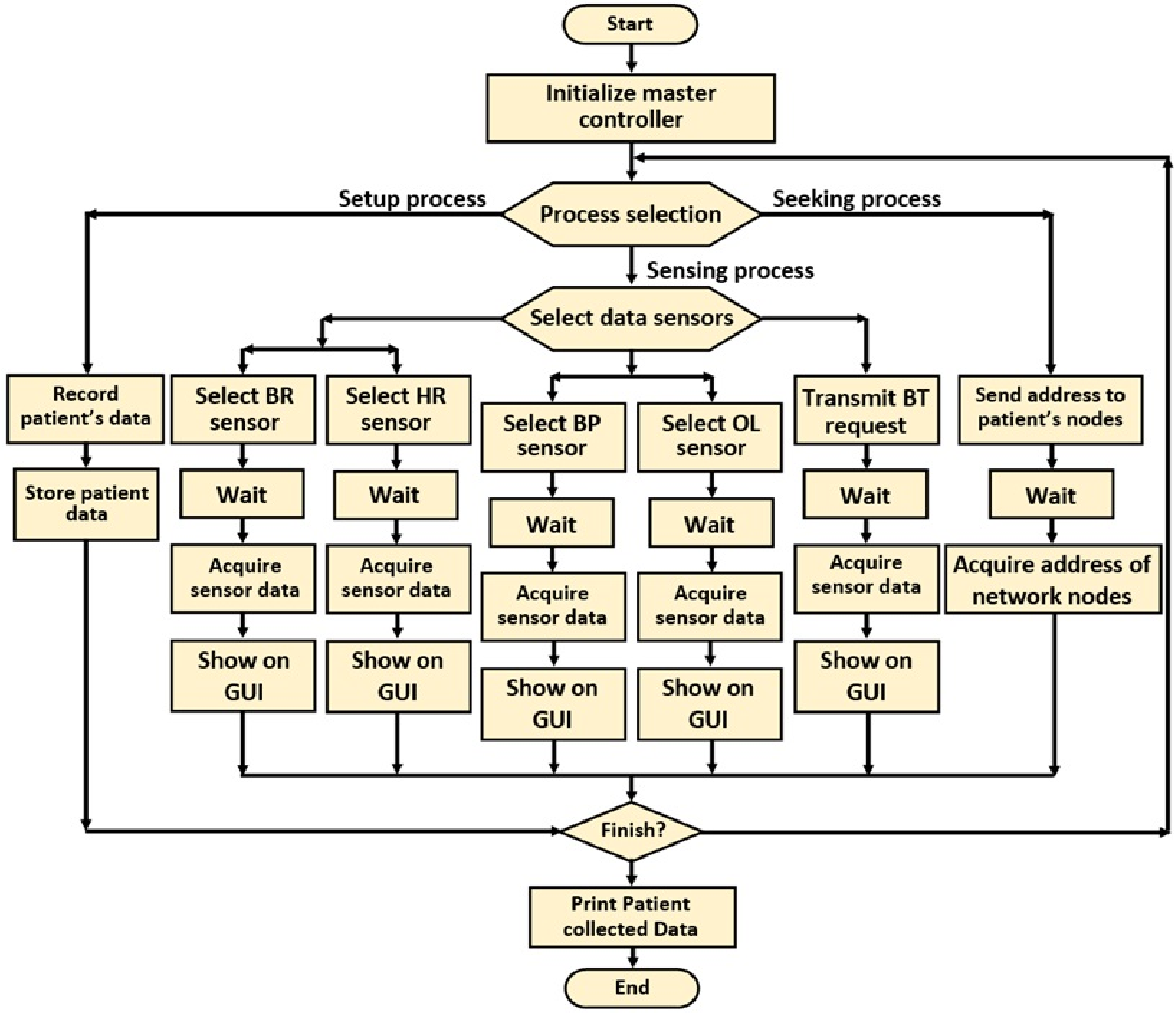

Fig. 10. Flowchart of the overall system operation.

• Keep an eye out for suspicious activity on your network: To enhance the situation, use such measures as monitoring the networks to look for any activity that might hint at a cyberattack.
• Inform patients: Make sure patients understand the benefits and risks associated with the use of IoT devices and proper usage precautions.
By adhering to these suggestions, it can be possible for healthcare providers to minimize risks and thus facilitate the safe and smart use of IoT devices in the management of COVID-19 patients.

IX. Conclusions

In this paper, a remote health monitoring system based on the use of IoT was designed and implemented to monitor the patient vital data. The proposed paradigm of the suggested system was implemented using ESP32 microcontrollers. The Ubidots IoT platform client application used to collect heartbeat, blood oxygen levels, body temperature, environmental temperature and humidity and then send publish of these data to the MQTT broker within the Cloud. The results acquired by experimental work from the suggested model will be displayed on an application program installed on personal computer or smartphone. In addition, the suggested system will

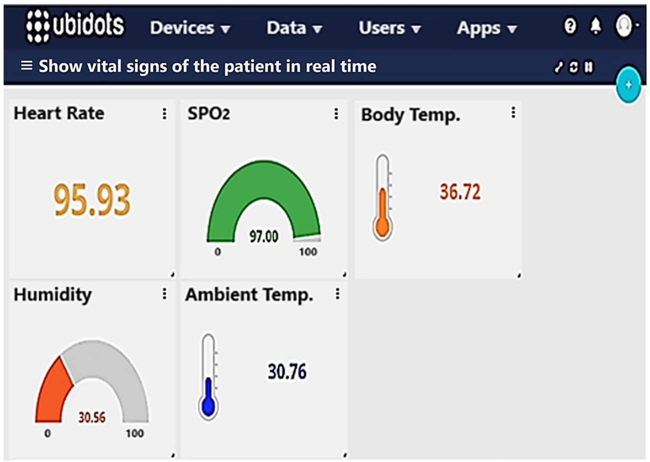

Fig. 11. Real time display of patient's vital signs in Ubidots web page.

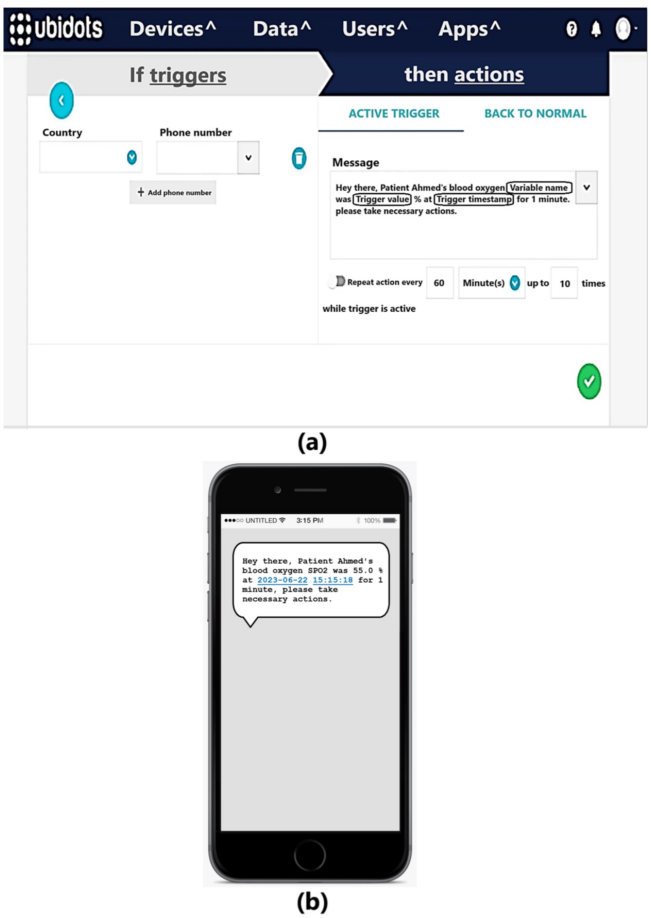

Fig. 12. Emergency alert via SMS for patient during low blood oxygen level condition: (a) Ubidots event setting. (b) SMS shown on mobile.

provide a secure, easy to use and reliable approach to monitor the vital signs of the patient's health using IoT technology. The subscriber, a doctor or a medical staff member in this case, can strictly follows the data coming from all devices linked to the internet and from anyplace in real-time via subscribing to the same MQTT broker topic. The IoT in this paper was implemented in three phases, including "Early Diagnosing," "Quarantine period," and "After health restoration". In each phase, the IoT role was evaluated during enabling/linking of personal monitoring device to the internet and then to the medical staff members. Moreover, the proposed system adds the capability of process selection which enable the system user to choose setup process or seeking process as well as data sensor selection at the same level by an authorised person. The most important issues that may be targeted in future researches could be in the data privacy, data security, secure communication channel and data encryption. Other gadgets design strategies that may be adopted, designed and enhanced to make these gadgets more comfortable and more durable.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this paper.

REFERENCES

[1] M. Umair, M. A. Cheema, O. Cheema, H. Li, and H. Lu, "Impact of covid-19 on iot adoption in healthcare, smart homes, smart buildings, smart cities, transportation and industrial iot," *Sensors*, vol. 21, no. 11, p. 3838, 2021.

[2] A. H. Talal, E. M. Sofikitou, U. Jaanimägi, M. Zeremski, J. N. Tobin, and M. Markatou, "A framework for patient-centered telemedicine: application and lessons learned from vulnerable populations," *Journal of biomedical informatics*, vol. 112, p. 103622, 2020.

[3] C. Li, J. Wang, S. Wang, and Y. Zhang, "A review of iot applications in healthcare," *Neurocomputing*, p. 127017, 2023.

[4] L. V. Coutts, D. Plans, A. W. Brown, and J. Collomosse, "Deep learning with wearable based heart rate variability

for prediction of mental and general health," *Journal of Biomedical Informatics*, vol. 112, p. 103610, 2020.

[5] N. Mukati, N. Namdev, R. Dilip, N. Hemalatha, V. Dhiman, and B. Sahu, "Healthcare assistance to covid-19 patient using internet of things (iot) enabled technologies," *Materials today: proceedings*, vol. 80, pp. 3777–3781, 2023.

[6] M. Cascella, M. Rajnik, A. Cuomo, S. C. Dulebohn, and R. Di Napoli, "Features, evaluation and treatment coronavirus (covid-19)[updated 2020 apr 6]," *StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing*, 2020.

[7] T. H. El Kadi, "Uneven disruption: Covid-19 and the digital divide in the euro-mediterranean region," *IEMed Mediterranian Yearbook*, 2020.

[8] L. Bai, D. Yang, X. Wang, L. Tong, X. Zhu, N. Zhong, C. Bai, C. Powell, R. Chen, J. Zhou, *et al.*, "Chinese experts' consensus on the internet of things-aided diagnosis and treatment of coronavirus disease 2019 (covid-19). clin. ehealth 3, 7–15 (2020)," 2020.

[9] "Memanfaatkan iot dan big data dengan benar bisa putus rantai pandemi covid-19," 2020.

[10] R. Sharma, A. R. Nair, *et al.*, "Iot-based secure healthcare monitoring system," in *2019 IEEE International Conference on Electrical, Computer and Communication Technologies (ICECCT)*, pp. 1–6, IEEE, 2019.

[11] W. Jiang, S. Majumder, S. Kumar, S. Subramaniam, X. Li, R. Khedri, T. Mondal, M. Abolghasemian, I. Satia, and M. J. Deen, "A wearable tele-health system towards monitoring covid-19 and chronic diseases," *IEEE Reviews in Biomedical Engineering*, vol. 15, pp. 61–84, 2021.

[12] A. Al-Ansi, A. M. Al-Ansi, A. Muthanna, I. A. Elgendy, and A. Koucheryavy, "Survey on intelligence edge computing in 6g: Characteristics, challenges, potential use cases, and market drivers," *Future Internet*, vol. 13, no. 5, p. 118, 2021.

[13] H. Hijazi, M. Abu Talib, A. Hasasneh, A. Bou Nassif, N. Ahmed, and Q. Nasir, "Wearable devices, smartphones, and interpretable artificial intelligence in combating covid-19," *Sensors*, vol. 21, no. 24, p. 8424, 2021.

[14] M. D. Santos, C. Roman, M. A. Pimentel, S. Vollam, C. Areia, L. Young, P. Watkinson, and L. Tarassenko, "A real-time wearable system for monitoring vital signs of covid-19 patients in a hospital setting," *Frontiers in Digital Health*, vol. 3, p. 630273, 2021.

[15] J. H. Kim, W. S. Choi, J. Y. Song, Y. K. Yoon, M. J. Kim, and J. W. Sohn, "The role of smart monitoring digital health care system based on smartphone application and personal health record platform for patients diagnosed with coronavirus disease 2019," *BMC infectious diseases*, vol. 21, pp. 1–8, 2021.

[16] V. Suraj, C. Del Vecchio Fitz, L. B. Kleiman, S. K. Bhavnani, C. Jani, S. Shah, R. R. McKay, J. Warner, and G. Alterovitz, "Smart covid navigator, a clinical decision support tool for covid-19 treatment: Design and development study," *Journal of Medical Internet Research*, vol. 24, no. 2, p. e29279, 2022.

[17] S. Ashique, N. Mishra, S. Mohanto, A. Garg, F. Taghizadeh-Hesary, B. J. Gowda, and D. K. Chellappan, "Application of artificial intelligence (ai) to control covid-19 pandemic: Current status and future prospects," *Heliyon*, 2024.

[18] M. Aal-Nouman, H. Takruri-Rizk, and M. Hope, "Transmission of medical messages of patient using control signal of cellular network," *Telematics and Informatics*, vol. 35, no. 1, pp. 267–281, 2018.

[19] B. Myroniv, C.-W. Wu, Y. Ren, A. Christian, E. Bajo, and Y.-C. Tseng, "Analyzing user emotions via physiology signals," *Data Science and Pattern Recognition*, vol. 1, no. 2, pp. 11–25, 2017.

[20] J. J. Duair, A. I. Majeed, and G. M. Ali, "Design and implementation of iot-based scada for a multi microgrid system," *ECS Transactions*, vol. 107, no. 1, p. 17345, 2022.

[21] A. Shaout and B. Crispin, "Using the mqtt protocol in real time for synchronizing iot device state.," *Int. Arab J. Inf. Technol.*, vol. 15, no. 3A, pp. 515–521, 2018.

[22] Z. Zhang, L. Wang, R. Liu, and J. Fan, "Development of cloud computing platform based on neural network," *Mathematical Problems in Engineering*, vol. 2022, no. 1, p. 1513081, 2022.

[23] L. S. Wilson and A. J. Maeder, "Recent directions in telemedicine: review of trends in research and practice," *Healthcare informatics research*, vol. 21, no. 4, pp. 213–222, 2015.

[24] X. Zeng, "The impacts of electronic health record implementation on the health care workforce," *North Carolina medical journal*, vol. 77, no. 2, pp. 112–114, 2016.

[25] A. Y. Mahdi and S. S. Yuhaniz, "Automatic extraction of knowledge for diagnosing covid-19 disease based on text

mining techniques: A systematic review," *Periodicals of Engineering and Natural Sciences*, vol. 9, no. 2, pp. 918–929, 2021.

[26] A. E. Ezugwu, I. A. T. Hashem, O. N. Oyelade, M. Almutari, M. A. Al-Garadi, I. N. Abdullahi, O. Otegbeye, A. K. Shukla, and H. Chiroma, "A novel smart city-based framework on perspectives for application of machine learning in combating covid-19," *BioMed Research International*, vol. 2021, 2021.

[27] M. Jabraeil Jamali, B. Bahrami, A. Heidari, P. Allahverdizadeh, and F. Norouzi, "Towards the internet of things: Architectures, security, and applications," 2019.