Improving The Efficiency Of Medical Information Systems Using The Techniques Of Iot

Marah M. Aboutaleb, Abdelwahab Alsammak, Tarek Elshishtawy

Abstract: Healthcare in all countries faces a lot of problems because of the outbreak of coronavirus (COVID-19). This includes weakness of capabilities and the lack of medical centers and hospitals. Also, the treatment of "pandemic diseases" chronic diseases needs daily reports about the patient health status, which enable doctors to recommend the suitable treatment. In this research, we propose an intelligent healthcare system that helps to improve healthcare organization using the techniques of IoT, allowing monitoring of patients at hospitals or remotely at their homes and sending a warning notification to the specialist. To decrease the required bandwidth, the time intervals between two successive readings is adaptive. The intervals increase as stable readings are noticed by the system.

Index Terms: COVID-19, Healthcare, IOT, Oximeter sensor, Patient Monitoring, Temperature sensor,

1 INTRODUCTION

Nowadays, the information technology is involved in everything and in the daily life. It facilitates life, working, learning and entertaining. Information technology has a large impact in developing medical techniques from collecting patient history to diagnosing the diseases and in the medication process. Although the medical sciences are grown and achieve a marked progress, the developing countries suffers from the lack in medical care. This lack happens because of the lack of financial resources, the medical devices used in measuring or diagnosing. So, even if the development in information technology is used to achieve more luxury for humans, using the latest developments in information technology in developing healthcare systems is a must. Especially in the present global pandemic situation and COVID-19 outbreak. The COVID-19 was first reported to affect human life in Wuhan City, in the Hubei province of China in December 2019. Since then, the COVID-19 has spread like wildfire throughout the rest of the world [1]. Globally, as of 11 June 2021, there have been 174,502,686 confirmed cases of COVID-19, including 3,770,361 deaths, reported to WHO [2]. Internet of Things (IoT) as a new promising technology is gaining growing global attention and becoming increasingly available for predicting, preventing and monitoring emerging infectious diseases [3]. Internet of Things (IoT) is a network of Interconnected things or objects - such as RFID tags, actuators, sensors, mobile phones and so on. These things are uniquely addressable and can interact with each other to achieve the system goals. IoT generally uses sensors to collect data, the collected data may be sent over the internet via Bluetooth or Wi-Fi, stored in cloud, can be accessed from different resources. IoT requires to make things interact together dynamically in real-time. There are several application domains that impacted by the evolution of internet of things, this evolution would likely improve the quality of our lives: at home, while travelling, when sick, at work, when jogging and at the gym, just to cite a few. These can be grouped into the following domains [4]:

- Transportation and logistics domain.
- Healthcare domain.
- Smart environment (home, office, plant) domain.
- Personal and social domain.

In the healthcare domain, the applications resulting by the evolution of IoT technology can be grouped mostly into: tracking of objects and people (staff and patients), identification and authentication of people, automatic data collection and sensing. The main purpose of this proposed system is to provide an intelligent solution in health care to help COVID-19 patients and monitor the progress in their health. The system should collect data via sensors, send it over cloud and store it in Database. This enables doctors to monitor the health status of their patients and take recommendations. The proposed system allows multi-patient data to be stored on the same database. Using this model, Medical Service Provider can monitor more than one patient at a time according to their privilege. Also, single patient can follow his/her medical status. In addition to summarized reports about the general health is adopted to health care governmental organization helping them having statistics, reports and percentages about the health status of its citizens. The remainders of the paper are organized as follows: Section 2 introduces the related work; Section 3 describes the proposed system; Experimental results are discussed in section 4; and finally, our paper is concluded in Section 5.

2 RELATED WORK

The concept of IoT is firstly proposed by Kevin Ashton in 1999 depending on radio- frequency identification (RFID) technology which is used in logistics, pharmaceutical production, retail and diverse industries [5]. In 2005, and after the development of wireless sensing technologies, IoT used the new technologies such as wireless sensor networks (WSNs), low energy wireless communications, and cloud computing. In 2012, the IoT moved towards the next generation of Internet where the physical things could be identified and accessed through Internet. In 2017, within an IoT, Things can exchange data and process it if needed. There are a lot of applications in the field of IoT that serve the healthcare, most of the medical systems based on IoT depend on the same architecture: data collecting, middleware gateway, storing data, visualizing. [6] as shown in fig. 1. Firstly, data collecting, this phase depends on collecting biological data from patient using sensors. Secondly, Middleware gateway level, in this phase the collected data transmitted and upload it to a server for further analysis and storing. Then data stored in compatible way based on its homogeneity or heterogeneity structure also, based on its size. This was the third level. At the last level, visualization, data collected displayed in meaningful way for a patient and the physician. Here, we will present the most important medical healthcare applications. Geng et al. [7] try to solve the problem of the medicine misuse problem, they introduce a medicine box (iMedBox) consisting of a RFID reader, a Wi-Fi unit, a Zigbee receiver, and a tablet PC integrated with A high-resolution weight bridge sensor in the bottom of the iMedBox to track the weight variation of the medicine stored in the box. The iMedBox serves as a home healthcare gateway. IoT devices (e.g., wearable sensors, intelligent medicine packaging (iMedPack), etc.) are seamlessly connected to the iMedBox via a heterogeneous network which is compatible with multiple existing wireless standards. The body-worn Bio-Patch can detect and transmit the user's bio-signals to the iMedBox in real time. The iMedPack is connected with the iMedBox via a RFID link to assist the users with their prescribed medication. All the collected information is interpreted, stored and displayed locally on the iMedBox. The processed information can also be forwarded to the Health-IoT network for a clinical diagnosis or further analysis. This solution lacks intelligent communication, the interaction between user and remote physician are based on short messages, phone calls or simple notices on the iMedBox's

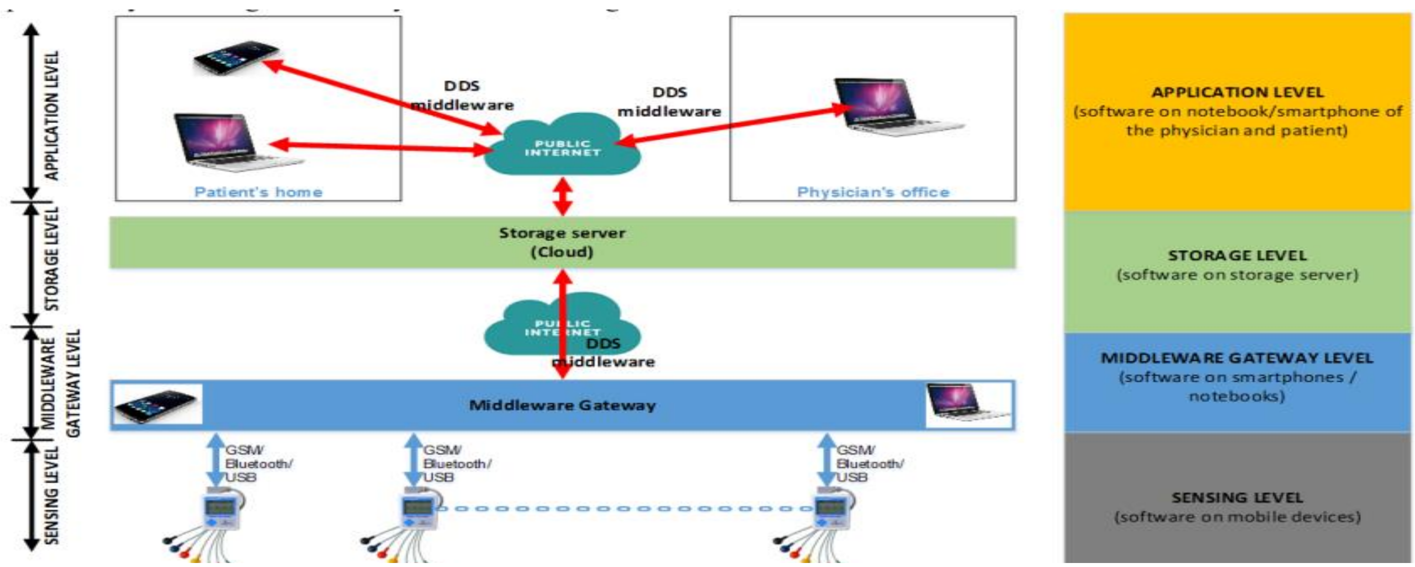


Figure 1: IoT medical system architecture [6]

GUI. Using the idea of IoT and cloud techniques, Junaid et al. [8] present a solution to use an IOIO microcontroller board, which obtains the bio-signal data from a person using ECG electrodes and sends it to the mobile device wirelessly using Bluetooth. The data displayed on the mobile app is stored in the form of a binary file on the secure digital (SD) card of the device and the user has the ability to upload it to a structured query language (SQL) Server private database. The Filestream and Filetable technologies present in Microsoft SQL Server 2012 allow the storage of unstructured data. With the proper hardware components like the IOIO microcontroller and the ECG electrodes. One of the most important services provided by IoT is the monitoring of electrocardiogram (ECG), The solution presented by Punit et al. [9] is an IoT system used for acquiring ECG signals from the home patient and transmitting them to specialists for analysis. The core component of this system is a mobile tele-electrocardiograph that may acquire the ECG signals from the patient. Another system is proposed by Ioan and Adrian [6] to monitor ECG using sensors that collect data, sending it wirelessly to cloud, processing data to obtain digitized data and analyze it, so system can obtain decision (send alarm to emergency, doctor or patient family). 3 electrodes placed around the heart and from a triangle to get ECG diagram for the patient. Yang et al. [10] propose a new method for ECG monitoring based on Internet-of-Things (IoT) techniques. ECG data are gathered using a wearable monitoring node and are transmitted directly to the IoT cloud using Wi-Fi. Both the HTTP and MQTT protocols are employed in the IoT cloud in order to provide visual and timely ECG data to users. Rasid et al. [11] present a Network mobility solution for hospital wireless sensing networks based on 6LoWPAN protocol, the system uses mobile sensors connected to patients to provide continuous and real-time monitoring while patients moving from department to another in the hospital. While hospital's network divided into small networks (PAN), each department has its own network. when patient moves, sensors detect that he is out of its PAN scope and detect the new covering PAN, processing a scenario namely 'mobility scenario'. Since the outbreak of the COVID-19 pandemic in 2019, many researches, surveys and applications have been published. El-Din et al. [12] propose a basic IoT sensor-based system to monitor COVID-19 infected patients with coronavirus remotely, which uses ear sensor, blood sensor and motion sensor to measure the patients' physical information (i.e., temperature, respiratory rate, and blood pressure) and sends alerts to hospitals if anomaly is detected. Otoom et al. [13] proposed an IoT-based framework used to employ potential COVID-19 case information to develop a machine-learning-based predictive model for disease. Vedaei et al. [14] present a potential application of the Internet of Things in healthcare and physical distance monitoring for pandemic situations. This framework consists of three parts: a lightweight and low-cost IoT node, a smartphone application, and fog-based Machine Learning tools for data analysis and diagnosis. The IoT node tracks health parameters, including body temperature, cough rate, respiratory rate, and blood oxygen saturation, then updates the smartphone app to display the user health conditions. Siriwardhana et al. [15] presents how 5G, IoT and related technologies can be used in the fight against the COVID-19 pandemic. And discuss some use cases in different areas, including telehealth as a solution to COVID-19 pandemic impact. Hussain et al. [16] highlighted the need to deploy AI in the fight against the COVID-19 pandemic. The study presented an overview of different intelligence techniques that can be deployed for various categories of medical information-based pandemics. The existing AI techniques in clinical data analysis were classified by the authors into neural systems, classical support vector machines and edge significant learning. Finally, a detailed discussion of the advantages of AI in combating similar viruses was presented. Elavarasan and Pugazhendhi [17] presented the roles that technologies play in controlling the COVID-19 pandemic. The study showed that presented strategies implemented alongside innovative technologies had better results in protecting society during the pandemic and in controlling the spread of pandemic infections. Additionally, Nižetić et al. [18] presented various aspects of IoT with a focus on progress made by IoT technologies in sustainable energy for the environment, IoT smart cities, IoT E-Health-Ambient assisted living systems, as well as in IoT transportation and low carbon products. Singh et al. [19] showed the benefits of implementing IoT in fighting the COVID-19 pandemic to include reduced healthcare cost and improved treatment outcome of the infected patient. The study identified and discussed twelve (12) significant applications of IoT in tackling the COVID-19 pandemic. Furthermore, Mbunge [20] analysed the potential opportunities and challenges of integrating emerging technologies for COVID-19 contact tracing. Kamal et al. [21] explain the impact of using IoT devices in the context of global pandemic of Covid-19. They reviewed various IoT based scenarios which may fight against the Covid-19 pandemic, such as digital health monitoring, IoT enabled ambulances, social distancing forecasting using AI and smart shopping cart as a solution to keep social distancing in super markets and malls. They also describe challenges with their proposed scenarios which are scalability of the system, limited bandwidth, data security and privacy. Finally. They suggest some solutions to implement Lightweight security algorithms which have less computational cost using Blockchain technology. In order to deal with the scalability, using CRIoT and mmWave based communication systems provide support to enable end-to-end communication. In a related study, Javaid et al. [22] presented a review of the application of industry 4.0 technologies that may help in COVID 19 outbreaks. The application of drone-based technology in the fight against COVID-19 was presented by Kumar et al. [23]. They presented a UAV-based smart healthcare system for COVID-19 monitoring, sanitization, social distancing, data analysis, and statistics generation for the control room. Additionally, an architecture for tackling pandemic related emergencies in several scenarios using real-time and simulation-based scenarios was also proposed. Vaishya et al. [24] identified seven (7) significant applications of AI for detecting cluster cases of COVID-19 infections as well as for predicting future incidences of infections by collecting and analyzing previous data. El-Din et al. [25] propose a basic IoT sensor-based system to monitor COVID-19 infected subjects, that simulates the Quarantine for patients in their houses to monitor patients and classify the patients based on observing disease risks which uses ear sensor, blood sensor and motion sensor to measure the patients' physical information (i.e., temperature, respiratory rate, and blood pressure) and sends alerts to hospitals if anomaly is detected. Vedaei et al. [26] presented an IoT framework to monitor patients' health conditions and notify them to maintain physical distancing using a Radio Frequency (RF) distance-monitoring method. It integrates a wearable IoT node with a smartphone app, by which the IoT sensor node can collect a user's health parameters, such as temperature and blood oxygen saturation. Another IoT framework is proposed by Otoom et al. [27] for early detection and monitoring of COVID-19 cases, using ML algorithms to effectively and quickly identify potential COVID-19 cases. Mohammed et al. [28] developed an innovative real-time early detection of coronavirus and monitoring system using smart helmet which integrated with thermal imaging system. The smart helmet was equipped with two different types of cameras, Optical camera and infrared thermal camera. When the thermal camera detects high temperature body, the system notifies the authorities to alert them about the threat. At the same time the system will take a picture and sent to the health officer.

3 Proposed System

3.1 Operation Overview

The main concept of the proposed system is to monitoring of the COVID-19 confirmed cases over internet via mobile application in real-time. If patients located in an isolation rooms at hospital or remotely isolated at their homes. Each patient is connected to a device that monitoring his heartbeat,

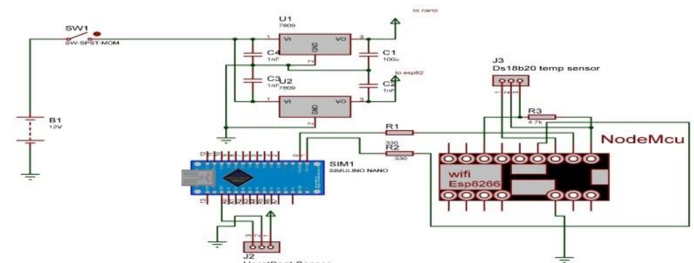
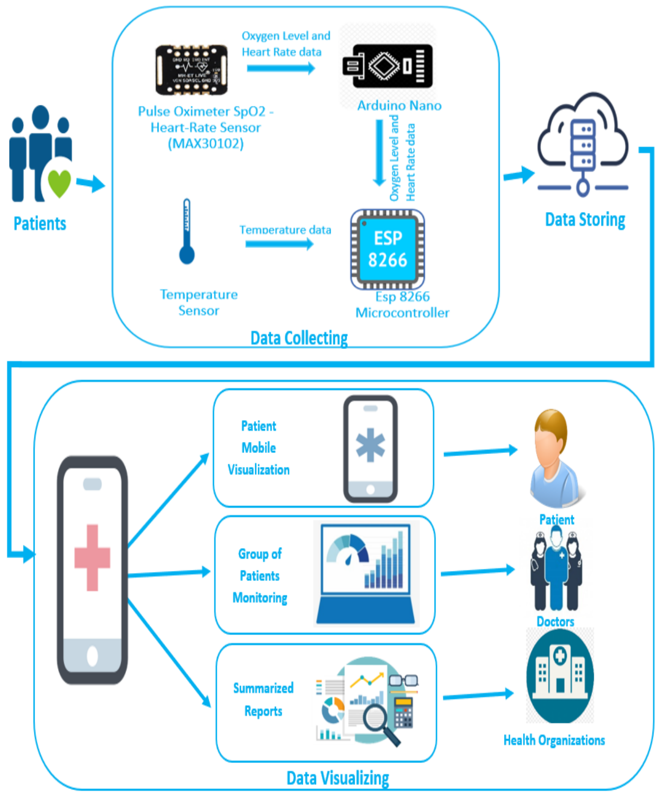


Figure 2: Hardware Design

oxygen level and temperature. The pulse oximeter-heart rate and temperature sensors collect this vital data, and sending it via WIFI to Database server, storing each record at real-time.



A mobile

Figure 3: Proposed System Architecture

application is designed to fetch the stored information and displays it as a line diagram, keeping the medical service provider updated with real-time vital data of patients. The medical service provider/the specialist can view all stored data for any patient at any time. In case vital data exceed normal ranges, the app will send a warning notification to the specialist, Fig. 2 shows an overview of the proposed system architecture. The following subsections describe different stages of operation.

3.2 Hardware Model

The Proposed hardware model architecture for IoT Healthcare is as shown in the Fig. 3. The model basically consists of Arduino nano, ESP8266 NodeMCU, Temperature sensor (DS18B20), Pulse Oximeter SpO2 - Heart-Rate Sensor (MAX30102) and dc adaptor (power supply). MAX30102 sensor is connected to Arduino nano, measuring the oxygen level reading and sending it to ESP8266 microcontroller. The ESP8266 is serving as a Wi-Fi adapter, collecting the temperature reading from DS18B20 temperature sensor and send it along with the oxygen level and heartrate readings via Wi-Fi to be stored at “Firebase” database server. The MAX30102 [29] can be used as an oximeter by measuring the oxygen concentration in the blood (SpO2 percentage) and also can be used as heart rate sensor (beats per minute). The device has two LEDs, one emitting red light, another emitting infrared light. For pulse rate, only the infrared light is needed. Both the red light and infrared light is used to measure oxygen levels in the blood. When the heart pumps blood, there is an increase in oxygenated blood as a result of having more blood. As the heart relaxes, the volume of oxygenated blood also decreases. By knowing the time between the increase and decrease of oxygenated blood, the pulse rate is determined. It turns out, oxygenated blood absorbs more infrared light and passes more red light while deoxygenated blood absorbs red light and passes more infrared light. This is the main function of the MAX30102: it reads the absorption levels for both light sources and store them in a buffer that can be read via I2C. The DS18B20 [30] digital thermometer provides 9-bit to 12-bit Celsius temperature measurements. The DS18B20 communicates over a 1-Wire bus that by definition requires only one data line (and ground) for communication with a central microprocessor. It has an operating temperature range of -55°C to +125°C and is accurate to ±0.5°C over the range of -10°C to +85°C.

3.3 Data Collection and storing

Fig.4 shows the data structure of the proposed system. The structure is implemented in Firebase, NoSQL cloud database. It stores the data across all patients in real-time. The time intervals of reading patient data are adjusted to add a new readings every 2 minutes.

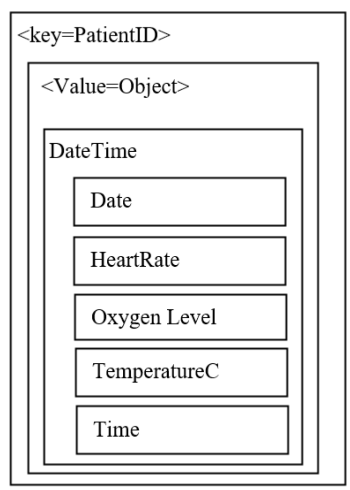


Figure 4: Database Design

Each patient is defined by a unique id, named by (Bed1, Bed1, ……) for hospital patients or national ID number for patients monitoring remotely in homes, under each patient, the records of oxygen level, heartrate and temperature grouped and identified by the captured full date and time. Fig.5 shows an example of raw data collected.

3.4 Summarization and Visualization

Mobile application plays an essential role in visualizing the important data, and presenting it to recipients’ hands. The mobile application visualizes information in readable and interpreted way to the user to make reading of the data faster and easier. The proposed mobile application, is developed using Android, an open-source Linux-based operating system for mobile devices. MPAndroidChart library, a powerful Android chart view / graph view library, supporting line- bar- pie- radar- bubble- and candlestick charts as well as scaling, panning and animations used to draw a diagram showing the results. Medical Service Provider can monitor multiple

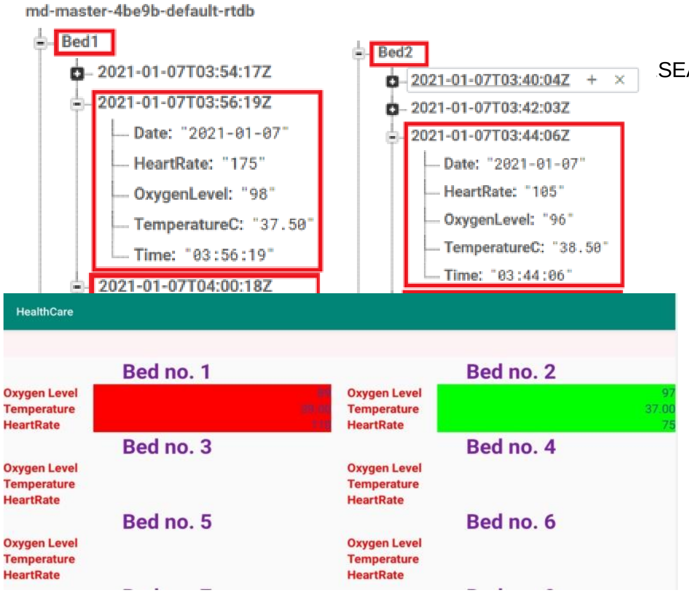


Figure 6: Report showing patients' status

patients and be notified in case the vital data of any patient exceed normal ranges. Summarized reports about patients and their status can be delivered to healthcare organization continually. Fig.6 shows an example of reports showing two different patients and their updated vital information. As

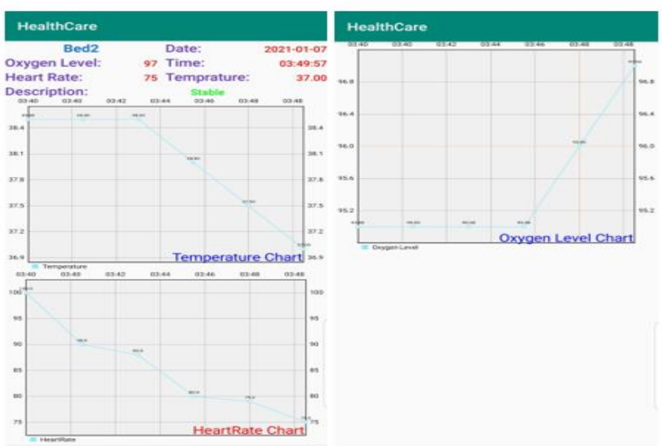


Figure 8: Bed 2 patient detailed information

shown in fig.6 Bed no. 1 patient has a critical condition and his vital data highlighted with red coclor as it exceeds the normal ranges, Bed no. 2 patient has a stable condition and his vital data highlighted with green coclor as it is within the normal ranges.

\

4 EXPERIMENTAL RESULTS

The proposed HealthCare device is connected to two patients to measure their oxygen level, temperature and heart rate every 30 minutes (120*1000 milliseconds), and send it with the exact date and time. To decrease the required bandwidth, the time intervals between two successive readings is adaptive. It starts with 30 minutes, and increases gradually to six hours when last 4 successive readings are stable.

Healthcare mobile application reads a data from firebase database and listing all patients with a latest reading as shown in fig. 6, when selecting any patient or any bed number, detailed information will be represented as a line real-time diagram, giving the medical service provider a complete vision of the medical data (oxygen level, heartrate and temperature) across the time. It also provides a description of the patient's case. If the vital data is in normal

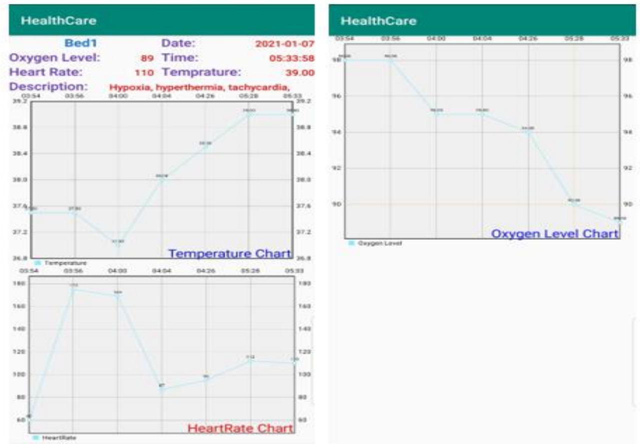


Figure 7: Bed 1 patient detailed information

ranges, the word "stable" will be appear in green color in the description. If the vital data exceed the normal ranges, the description will describe in red color the status using the following criteria showing in table 1.

Table 1: Description Criteria

Vital Measurements	Danger criteria	Description
Oxygen level	<90	Hypoxia
Temperature	>=38	Hyperthermia
Heart rate	<50	Bradycardia
	>90	Tachycardia

All data represented in the application updated automatically once any new record added to database. The results are shown in figure 7 and 8. Fig.7 shows the detailed information about the vital signs of patient 1/ bed 1 as it shown in the mobile application. It shows the date and time of the latest record, oxygen level, heart rate and temperature of the patient 1. According to the real-time values of oxygen level, heart rate and temperature, the description shows that patient 1 is suffering from hypoxia (oxygen level = 89, < 90), hyperthermia (temperature = 39, > 38) and tachycardia (heart rate = 110, >90). Fig.8 shows the detailed information about the vital signs of patient 2/ bed 2 as it shown in the mobile application. It also shows the date and time of the latest record, oxygen level, heart rate and temperature of the patient 2. But the description of patient 2 case is shown that his case is stable, as his vital measurements showed to be in normal ranges.

5 CONCLUSIONS

In this paper, we presented a healthcare system that improves the efficiency of health care systems in the present pandemic time by designing an IoT cloud system so that the experts and doctors could monitor their patients' data whatever patients locate in hospital or remotely in their homes, providing a description about patient's case. It uses medical sensors (oxygen level, heartrate, temperature sensors) to actuate vital data of the patients, sending this data to store in firebase database cloud. This system can be used to serve patients in hospitals, or patients- remotely at homes, also can serve healthcare organizations about health status statistics. The system protects medical service provider from any infection by reducing overcrowded in hospitals.

REFERENCES

[1] V. a. H. V. a. G. V. a. G. M. Chamola, "A comprehensive review of the COVID-19 pandemic and the role of IoT, drones, AI, blockchain, and 5G in managing its impact," Ieee access, vol. 8, pp. 90225--90265, 2020.

[2] "WHO Coronavirus (COVID-19) Dashboard," [Online]. Available: https://covid19.who.int/.

[3] N. C. P. N. S. R. Z. U. H. S. H. A. H. Md. Siddikur Rahman, "Defending against the Novel Coronavirus (COVID-19) outbreak: How can the Internet of Things (IoT) help to save the world?," Health Policy and Technology, vol. 9, pp. 136-138, 2020.

[4] S. a. S. I. Kaur, "A survey report on internet of things applications," International Journal of Computer Science Trends and Technology, vol. 4, pp. 330--335, 2016.

[5] S. a. D. X. L. a. Z. S. Li, "The internet of things: a survey," Information Systems Frontiers, vol. 17, pp. 243-259, 2015.

[6] I. Ungurean and A. Brezulianu, "An Internet of Things Framework for Remote Monitoring of the HealthCare Parameters," Advances in Electrical and Computer Engineering, vol. 17, pp. 11-16, May 2017.

[7] L. X. M. M. Geng Yang, "A Health-IoT Platform Based on the Integration of Intelligent Packaging, Unobtrusive Bio-Sensor and Intelligent Medicine Box," IEEE transactions on Industrial Informatics, 2014.

[8] A. T. Junaid Mohammed and A. F. Ocneanu, "Internet of Things: Remote Patient Monitoring Using Web Services and Cloud Computing," in International Conference on Internet of Things, 2014.

[9] P. Gupta, D. Agrawal, J. Chhabra and P. K. Dhir, "IoT based smart healthcare kit," in 2016 International Conference on Computational Techniques in Information and Communication Technologies (ICCTICT), New Delhi, India, 2016.

[10] Z. Yang, Q. Zhou, L. Lei, K. Zheng and W. Xiang, "An IoT-cloud Based Wearable ECG Monitoring System for Smart Healthcare," springer, 2016.

[11] W. M. W. M. A. M. N. M F A Rasid, "Embedded Gateway Services for Internet of Things Applications in Ubiquitous Healthcare," in International Conference on Information and Communication Technology, 2014.

[12] D. Mohey El-Din, A. E. Hassanein, E. E. Hassanien and W. M. E. Hussein, "E-Quarantine: A Smart Health System for Monitoring Coronavirus Patients for Remotely Quarantine," arXiv e-prints, 2020.

[13] M. Otoom, N. Otoum, M. A. Alzubaidi, Y. Etoom and R. Banihani, "An IoT-based framework for early identification and monitoring of COVID-19 cases," Biomedical Signal Processing and Control 62, 2020.

[14] S. S. Vedaei, A. Fotovvat and M. R. Mohebbian, "COVID-SAFE: An IoT-Based System for Automated Health Monitoring and Surveillance in Post-Pandemic Life," IEEE Access, vol. 8, pp. 188538 - 188551, 2020.

[15] Y. Siriwardhana, C. de Alwis, G. Gur, M. Ylianttila and M. Liyanage, "The Fight Against the COVID-19 Pandemic With 5G Technologies," IEEE Engineering Management Review, vol. 48, no. 3, pp. 72 - 84, 2020.

[16] A. A. Hussain, O. Bouachir, F. Al-Turjman and M. Aloqaily, "AI Techniques for COVID-19," IEEE Access, vol. 8, pp. 128776 - 128795, 2020.

[17] R. M. Elavarasan and R. Pugazhendhi, "Restructured society and environment: A review on potential technological strategies to control the COVID-19 pandemic," Science of The Total Environment, vol. 725, 2020.

[18] S. Nižetić, P. Šolić, D. L.-d.-I. González-de-Artaza and L. Patrono, "Internet of Things (IoT): Opportunities, issues and challenges towards a smart and sustainable future," Journal of Cleaner Production, vol. 274, 2020.

[19] R. P. Singh, M. Javaid, A. Haleem and R. Suman, Diabetes Metabolic Syndrome: Clinical Researrch & Reviews, vol. 14, pp. 521-524, 2020.

[20] E. Mbunge, "Integrating emerging technologies into COVID-19 contact tracing: Opportunities, challenges and pitfalls,," Diabetes & Metabolic Syndrome: Clinical Research & Reviews,, vol. 14, no. 6, pp. 1631-1636, 2020.

[21] M. a. A. A. a. A. E. Kamal, "IoT meets COVID-19: Status, Challenges, and Opportunities," arXiv preprint arXiv:2007.12268, 2020.

[22] M. Javaid, A. Haleem, R. Vaishya and S. Bah, "Industry 4.0 technologies and their applications in fighting COVID-19 pandemic," Diabetes & Metabolic Syndrome: Clinical Research & Reviews, vol. 14, no. 4, pp. 419-422, 2020.

[23] A. Kumar, K. Sharma, H. Singh, S. G. Naugriya, S. S. Gill and R. Buyya, "A drone-based networked system and methods for combating coronavirus disease (COVID-19) pandemic," Future Generation Computer Systems, vol. 115, pp. 1-19, 2021.

[24] R. Vaishya, M. Javaid, I. H. Khan and A. Haleem, "Artificial Intelligence (AI) applications for COVID-19 pandemic," Diabetes & Metabolic Syndrome: Clinical Research & Reviews, vol. 14, no. 4, pp. 337-339, 2020.

[25] D. M. a. H. A. E. a. H. E. E. a. H. W. M. El-Din, "E-quarantine: A smart health system for monitoring coronavirus patients for remotely quarantine," arXiv preprint arXiv:2005.04187, 2020.

[26] S. S. a. F. A. a. M. M. R. a. R. G. M. a. W. K. A. a. B. P. a. M. H. R a. M. M. a. S. R. Vedaei, "COVID-SAFE: An IoT-Based System for Automated Health Monitoring and Surveillance in Post-Pandemic Life," IEEE Access, vol. 8, pp. 188538--188551, 2020.

[27] M. a. O. N. a. A. M. A. a. E. Y. a. B. R. Otoom, "An IoT-based framework for early identification and monitoring of COVID-19 cases," Biomedical Signal Processing and Control, vol. 62, p. 102149, 2020.

[28] M. a. S. H. a. A.-Z. S. a. A. R. R. a. Y. E. Mohammed, "Novel COVID-19 detection and diagnosis system using IOT based smart helmet," International Journal of Psychosocial Rehabilitation, vol. 24, pp. 2296-2303, 2020.

[29] "Pulse Oximeter SpO2 - Heart-Rate Sensor (MAX30102)," [Online]. Available: https://store.fut-electronics.com/collections/medical/products/pulse-oximeter-spo2-heart-rate-sensor-max30100.

[30] "DS18B20 Programmable Resolution 1-Wire Digital Thermometer," [Online]. Available: https://cdn.shopify.com/s/files/1/0672/9409/files/DS18B20.pdf?645