Monitoring Self-isolation Patient of COVID-19 with Internet of Things

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***Abstract*—Internet of Things (IoT) application can be used in health care service to monitor patients remotely. During the COVID-19 pandemic, infected people with no symptoms must isolate theirself to keep the virus from spreading. Medical devices connected to internet can be used for physiological measurement such as heart rates, blood oxygen saturation and body temperature and send the measurement result to a server. Remote monitoring can also reduce patient visit to hospital and therefore reduce workload of medical staff. In this research we propose a monitoring system for COVID-19 patients in self-isolation to monitor physiological data like SpO_2 and heart rate together with location information of the patients. We have developed IoT-based health monitoring system with wireless body sensor networks and a gateway that can be used for data acquisition and transmission. The system also employed an application server that can be used for data storage, analytics, and visualization. The prototype of the monitoring system used home pulse oximeter for measuring SpO_2 and heart rate and an Android application working as IoT gateway to collect data from sensor and adding location information before sending the data to server. In server, an open source Elasticsearch Logstash Kibana (ELK) stack popular for logging and indexing large data continuously process incoming data so that medical staff can explore and visualize measurement results of patients and their location in a dashboard. That way they can monitor patient's condition trying to recover themselves in self-isolation at any time and take preventive actions as necessary.**

Keywords—COVID-19, Elasticsearch, Internet of Things

I. Introduction

In March 2020, the World Health Organization (WHO) announced the spread of the COVID-19 virus as a pandemic, which means that its spread has reached the entire world and the number of infected patients is increasing rapidly. Many efforts have been done to identify potential COVID-19 patients by tracing contacts which lead to patient isolation and therefore contributes to slow down the spread of the virus [1].

Internet of Things (IoT) is a technology that can be used to help when infected people needed to be quarantined. Patients can have proper monitoring system to do physiological measurements like blood pressure, heart beat and glucose level remotely. Therefore the implementation of this technology can improve the efficiency of medical staff by reducing their workload significantly. This technology will help to capture the real-time data and other necessary information from various location of the infected patient [2]. Additionally, the availability of location information will also make it easier not only for doctors and paramedics to determine the course of action, but also to help patients perform actions independently if needed. Therefore, it is necessary to process and present good patient location data together with sensor measurement results in a single dashboard. The Elasticsearch, Logstash and Kibana (ELK) application is a technology that works very well in collecting large amounts of log data and other data from various sources and displaying it in graphs and maps. This study aims to develop a system that can display the results of recording the conditions and locations of various patients in real time using the ELK application for the needs of COVID-19 patient treatment.

This document proposes a COVID-19 patient monitoring system that would collect real-time symptom data from wearable sensor technology. In order to quickly identify potential coronavirus cases from this real-time data, this document proposes the use of the open source ELK stack. This monitoring system can be implemented with an IoT infrastructure that will monitor infected patients while in self-isolation, as well as the treatment response of patients recovering from the virus. These systems can also contribute to understanding the nature of viruses and infected people by collecting, analyzing and archiving relevant data.

In [3] shows that a number of portable medical devices can be used to monitor the conditions needed in monitoring patients. In this design a number of portable medical devices are linked to a server application that allows doctors and medical personnel to remotely perform real-time monitoring. With this application, doctors and medical personnel can make a diagnosis not only from the patient's condition at one time but from all the time as long as the medical device is used.

Wearable sensor devices, especially those based on IoT, can be used for observation and data recording at home and at work for a longer duration when compared to observations made during laboratory visits. This enormous data collection when analyzed and presented with a visual that is easy for health workers to understand has the potential to help improve the quality of health services and reduce costs [4]. In the study of [4], also described the architecture of a remote health monitoring system that has data acquisition components, data transmission components, and servers that function as data storage, analytics, and visualization. Fortunately, these components are available not only on existing IoT platforms but also on other application stacks such as Elasticsearch Logstash Kibana (ELK). Although it is not specifically built as an IoT platform, ELK has a very good reputation for the capabilities needed, especially in health monitoring systems. For this reason, research is needed that can prove this capability so that it can be an alternative in implementing IoT in health care services.

IoT has a large market potential with one of its application domains being in the health sector. The use of IoT in the health sector includes remote management, remote diagnosis, remote patient monitoring and tracking, and tracking of medical assets [5]. Other research showed that health monitoring system has developed rapidly, and an intelligent system had been proposed to monitor the current health condition of patients. The system could track and monitor patients and facilitate management of patient health. Thus more effective medical services can be provided in a timely manner [6].

In [7] it was also concluded that the implementation of real-time location systems allows the hospital to achieve its goals, such as increasing efficiency, increasing patient satisfaction and reducing time and costs. This study is in line with [8] where a health monitoring system has been developed to monitor the physiological parameters of the patient and send these data along with the details of their location to be monitored by the doctor on duty.

The health monitoring system has become a human need today. In [9] an electronic health registration system that was cheap, lightweight, energy efficient and has a centralized system had been developed. With this portable form, patients can keep records of health parameters during the trip. Meanwhile, centralized data storage is used with the Internet of Things.

Elasticsearch Logstash Kibana (ELK) are three applications which, although they can be used separately, are commonly used as an integrated solution which is called the Elastic Stack [10]. Elasticsearch provides functions to store, index data for the needs of large-scale data search and query in real time as required in a monitoring and analytics application in [11]. The Logstash application can continuously retrieve and collect data from multiple sources and send it to Elasticsearch for storage and indexing. Kibana which is designed as a data visualization platform can be used to display data stored and indexed in Elasticsearch. As needed in IoT development, ELK supports vertical and horizontal scale development. Thus the IoT system using ELK can be developed easily and cheaply [10].

In [12] it is stated that the ELK stack is the main choice in implementing the monitoring infrastructure because it is open source, provides the required features and is relatively easy to configure and use. In this study, the ELK stack was used to provide a monitoring interface for a number of data. Research [13] has also resulted in confirmation that the technology can meet the need for the development of a solid monitoring system.

II. System Overview

A. Proposed Architecture

Research in [3] showed that an IoT-based system can be built to monitor patients by having number on sensors on a patient, an IoT gateway, and a server application. The information service application will aggregate sensor data from patients and can be integrated with authentication and authorization services and is connected to a user database that stores user health data. The server application can also provide analysis and visualization for the collected data.

Based on these references, a system architecture design is made which can be seen in Fig. 1. A location tracking system that uses this architectural design can obtain data from a number of sensors in the patient's body and then send the measurement data through the IoT gateway. The sensor, which can consist of several measurement devices, is connected to an Android device that acts as an IoT gateway through a Bluetooth Low Energy (BLE) serial connection which can always be active without consuming large amounts of electrical power. Apart from being a gateway for Android devices, it is also needed to complement the sensor data to be sent, namely by adding patient information according to the context of the location where the patient location coordinate data is obtained from the Location API available in the Android operating system.

B. Wireless Body Sensor Networks

Measurement of blood oxygen or SpO_2 levels is one of the measurement points that must be carried out in routine examination procedures for a self-isolation patient of COVID-19. Measuring SpO_2 at home can be used for early detection of "silent hypoxemia" in COVID-19 patients [14].

The data from the SpO_2 measurement results in this study were obtained from direct measurements using a home pulse oximeter as part of the wireless body sensor networks (WBSN). In addition, the location data that is sent along is obtained from an Android device that has GPS and Location API. The Android device, which acts as a gateway, will also add a patient ID before sending it to the server. This patient ID is needed to authenticate and differentiate the ownership of incoming data between one patient and the others.

The pulse oximeter used in this system can transmit data via BLE or Bluetooth Low Energy. Unlike classic Bluetooth, BLE has several advantages such as lower energy usage and can stay connected even though it uses less energy when not transmitting data. Devices that use BLE can also be connected to several connections at once, thus selecting a number of devices that can communicate via BLE is the right choice to build a wireless body network as recommended [7].

The concept of BLE connection is different from classic Bluetooth in that a device wishing to share data via BLE can activate one or more services in which it can consist of several characteristics or data category. Similar to the publish-subscribe concept contained in the message broker application, applications that want to get data from sensor devices that use BLE can register first so that when the data is available, the data will be sent directly to the data subscriber or the central device.

The sensor device can send multiple data as an array of bytes with specific order so a number of data can be sent at once to other devices or applications that require that data. Fig. 2 shows an illustration of a data packet sent via BLE that contains sensor measurement data for SpO_2, heart rate, and temperature in specific order.

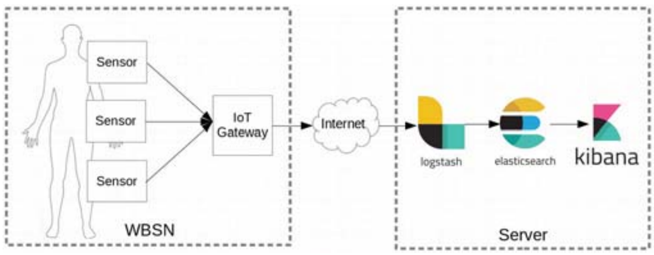

Fig.1. System Architecture

SpO_2	Heart Rate	Temperature

Fig.2. Sensor Data Model

C. IoT Gateway

After the data is received from the sensor and collected on Android, the mobile application will send the data to server together with patient ID and location coordinates. The delivery process can take place in real time or delayed according to the availability of the internet connection. Application on Android devices connect to application on the server using HTTP or HTTPS connection. The data is transmitted as a payload of the HTTP request with Content-Type application/x-www-form-urlencoded. The flow chart in Fig. 3 shows how data is collected in WBSN and then transferred between the nodes.

D. Elasticsearch Logstash Kibana (ELK) Stack

The data received on the server is then transferred by Logstash into Elasticsearch to be indexed and displayed on the Kibana dashboard. Elasticsearch is a document oriented database which is non-relational and optimized for search and retrieval. Each document consist of measurement values, location information, and patient information needed for exploration and visualization in Kibana. This Kibana application has a feature that allows administrators to manage data and personalize the dashboard. Administrators can make navigation menu settings according to user roles, select data to be displayed according to the index pattern and determine the type of visualization to be used.

The whole stack of this patient monitoring system that has been developed is implemented into a server that will receive patient ID, patient measurement results, and patient location. Applications that are on this server will also manage the data received and then display it with the appropriate visualization that can show the location and status of patients. Fig. 4 shows a deployment diagram that illustrates how the components in this system are positioned and related to each other.

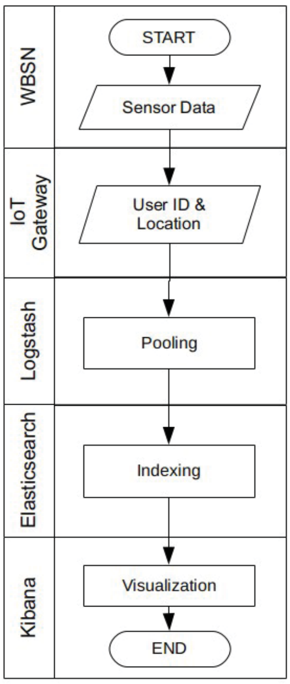

Fig.3. Application flow chart

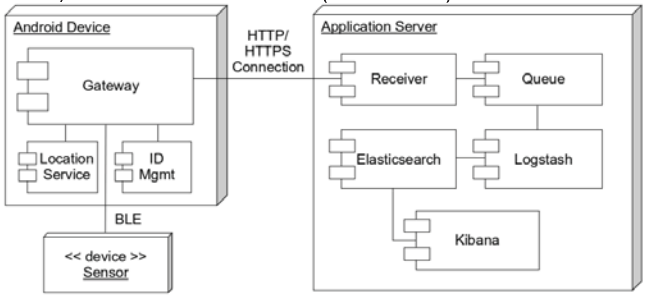

Fig.4. Deployment diagram

In Fig. 4 we can see the main components of the system in the form of sensor devices, Android devices in which there is an IoT gateway, and a server consisting of data receiving applications, Logstash, Elasticsearch and Kibana for data visualization.

III. Result and Discussion

The implementation and testing of this system is carried out by installing the Elasticsearch, Logstash and Kibana stack version 7.7.0 on a Linux-based OS and an IoT gateway application on the Android platform with OS version 5.1.1. The home pulse oximeter uses a JPD-500G which is available in the market. The range of SpO2 measurement of the device is 70%-99% and has ±2% accuracy while the range of pulse rate measurement is 35bpm-250bpm and has ±2bpm of accuracy. The fingertip sensor is connected to the IoT gateway using a Bluetooth connection and send the measured values every 5 seconds.

Fig. 5 shows the pulse oximeter used in this research and the mobile application acting as an IoT gateway sending the data to server. The mobile application user interface can show the list of connected devices and the measurement values from the medical device. The distance between the the pulse oximeter and Android device during testing is less than 2 meters or similar with the distance of a patient and a bedside monitoring device. We compared the values read on the device against the values received by the server and showed no difference or 100% accuracy for data transmission while the average response time of data transmission is 389.492 ms. The sample of measurement data was taken from five different persons using the home pulse oximeter connected to the gateway.

Fig.5. Testing the connection of pulse oximeter and IoT gateway using Bluetooth Low Energy

Fig. 6 shows an example of test results where after the sensor data has been successfully received and indexed in Elasticsearch, the data is displayed as a location point on a digital map in Kibana together with identification data or patient ID from where the sensor data comes from. In addition, the data that has been indexed can also be explored by displaying it as a Discovery table in the Kibana application as shown in Fig. 7 or can be visualized as time series as shown in Fig. 8. Users can customize the tables and the map to fit their needs. They can choose which sensor data must be displayed for better visibility on monitoring their patients.

IV. Conclusion

From this study it can be concluded that an IoT-based patient monitoring system can be developed to monitor COVID-19 patients who are doing self-isolation at home. The developed system is designed to monitor patient's physiological parameters such as heart rate and blood oxygen saturation level. The system is capable to acquire data from a home pulse oximeter and transmit the data together with location information to a server to be monitored by medical staffs.

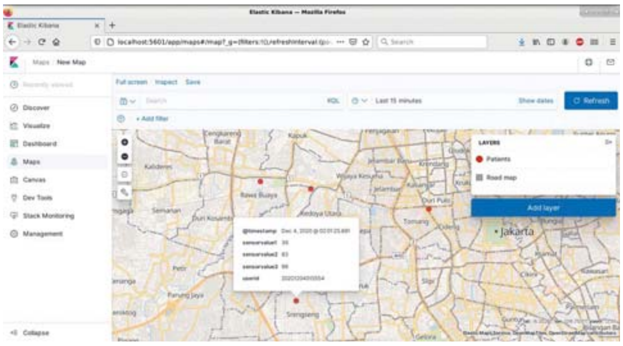

Fig.6. Example of Kibana dashboard for monitoring patient physiological data and location

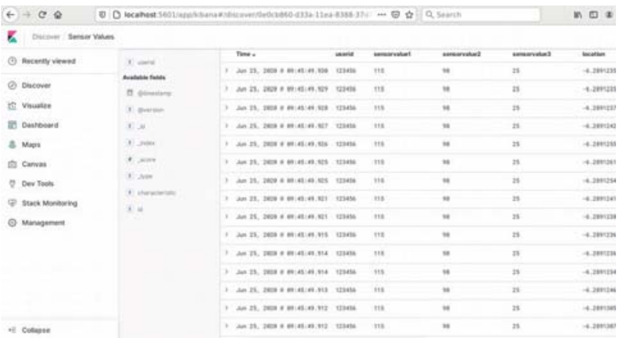

Fig.7. Example of Kibana Discovery page for exploring patient physiological data

Fig.8. Example of Kibana visualization showing measurement result of a patient over time

The proposed system integrates a wireless sensor with a smartphone application acts as an IoT gateway where the sensor can collect user's physiological parameter and the Android application connects to the internet to send the data to the server after adding patient's ID and location coordinates. The system was built using open source stack consisted of Elasticsearch for data storing and indexing, Logstash transfer the data to Elasticsearch and Kibana to provide a dashboard that can display patient condition data and the location where the patient is located. The sensor used for testing was a home pulse oximeter available in the market and the connection between the sensor device and IoT gateway uses Bluetooth standard communication protocol.

Employing the proposed system for self-isolation patient of COVID-19 could help the medical staff to obtain the physiological parameter required for monitoring the patient. Makes it easier for patients to report their condition without having to go out from home so that health care providers can immediately provide services according to the patient's condition, for example pick up the patient when SpO2 is low to prevent hypoxemia.

The future work of this study will cover more detailed work of the system, such as development of alert system and recommendation system based on the collected data and to use more features in ELK to provide more capabilities. Performance analysis will also be performed more thoroughly to find the limitation of the system by using multiple devices and more patients. Therefore this technology will be more helpful to support quality supervision with real-time information.

References

[1] C. Sandeepa, C. Moremada, N. Dissanayaka, T. Gamage, dan M. Liyanage, "Social Interaction Tracking and Patient Prediction System for Potential COVID-19 Patients," in *2020 IEEE 3rd 5G World Forum, 5GWF 2020 - Conference Proceedings*, 2020.

[2] R. P. Singh, M. Javaid, A. Haleem, dan R. Suman, "Internet of things (IoT) applications to fight against COVID-19 pandemic," *Diabetes Metab. Syndr. Clin. Res. Rev.*, 2020.

[3] T. M. Kadarina dan R. Priambodo, "Preliminary design of Internet of Things (IoT) application for supporting mother and child health program in Indonesia," in *2017 International Conference on Broadband Communication, Wireless Sensors and Powering (BCWSP)*, 2017, hal. 1–6.

[4] M. Hassanalieragh *et al.*, "Health Monitoring and Management Using Internet-of-Things (IoT) Sensing with Cloud-Based Processing: Opportunities and Challenges," in *Proceedings - 2015 IEEE International Conference on Services Computing, SCC 2015*, 2015.

[5] O. B. Sezer, E. Dogdu, dan A. M. Ozbayoglu, "Context-Aware Computing, Learning, and Big Data in Internet of Things: A Survey," *IEEE Internet of Things Journal*, vol. 5, no. 1. hal. 1–27, 2018.

[6] K. Aziz, S. Tarapiah, S. H. Ismail, dan S. Atalla, "Smart real-time healthcare monitoring and tracking system using GSM/GPS technologies," in *2016 3rd MEC International Conference on Big Data and Smart City, ICBDSC 2016*, 2016.

[7] L. Gholamhosseini, F. Sadoughi, dan A. Safaei, "Hospital real-time location system (A practical approach in healthcare): A narrative review article," *Iranian Journal of Public Health*. 2019.

[8] M. Manas, A. Sinha, S. Sharma, dan M. R. Mahboob, "A novel approach for IoT based wearable health monitoring and messaging system," *J. Ambient Intell. Humaniz. Comput.*, 2019.

[9] F. Shanin *et al.*, "Portable and Centralised E-Health Record System for Patient Monitoring Using Internet of Things(IoT)," in *2018 International CET Conference on Control, Communication, and Computing, IC4 2018*, 2018.

[10] M. Bajer, "Building an IoT Data Hub with Elasticsearch, Logstash and Kibana," in *2017 5th International Conference on Future Internet of Things and Cloud Workshops (FiCloudW)*, 2017, hal. 63–68.

[11] N. Shah, D. Willick, dan V. Mago, “A framework for social media data analytics using Elasticsearch and Kibana,” *Wirel. Networks*, Des 2018.

[12] S. Bagnasco, D. Berzano, A. Guarise, S. Lusso, M. Masera, dan S. Vallero, “Monitoring of IaaS and scientific applications on the Cloud using the Elasticsearch ecosystem,” in *Journal of Physics: Conference Series*, 2015.

[13] V.-A. Zamfir, M. Carabas, C. Carabas, dan N. Tapus, “Systems Monitoring and Big Data Analysis Using the Elasticsearch System,” in *2019 22nd International Conference on Control Systems and Computer Science (CSCS)*, 2019, hal. 188–193.

[14] R. Jouffroy, D. Jost, dan B. Prunet, “Prehospital pulse oximetry: A red flag for early detection of silent hypoxemia in COVID-19 patients,” *Critical Care*. 2020.