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Trực quan hóa dữ liệu sức khỏe thời gian thực ứng dụng nền tảng mã nguồn mở Thingsboard

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TÓM TẮT

Trực quan hóa dữ liệu một chủ đề đầy thách thức và đang thu hút được sự quan tâm của cộng đồng khoa học và các nhà phát triển ứng dụng, đặc biệt là trong lĩnh vực chăm sóc sức khỏe. Với tính chất đa dạng và phức tạp của dữ liệu thu thập từ một lượng lớn các thiết bị cảm biến y sinh, việc biểu diễn dữ liệu một cách trực quan có vai trò hết sức quan trọng. Trên cơ sở ứng dụng nền tảng mã nguồn mở Thingsboard, bài báo này đề xuất giải pháp để trực quan hóa dữ liệu sức khỏe bệnh nhân theo thời gian thực, góp phần hỗ trợ người dùng và đội ngũ y bác sĩ theo dõi tình trạng sức khỏe của bệnh nhân và đưa ra các chẩn đoán phù hợp, kịp thời.

Từ khóa: *Trực quan hóa dữ liệu, chăm sóc sức khỏe từ xa, Thingsboard, IoT.*

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Real-time healthcare data visualisation using open-source platform Thingsboard

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ABSTRACT

Data visualisation is a challenging topic, attracting much attentions from the scientific community as well as application developers, especially in the healthcare domain. Due to a diverse and complex nature of data collected from a huge number of biomedical sensors, visual representation of data is of utmost importance. Based upon an open source platform namely Thingsboard, this paper proposes a solution to visualise healthcare data in real-time, thus allowing doctors, nurses and experts to monitor patients' health conditions and provide timely accurate diagnoses.

Keywords: *Data visualisation, remote healthcare, Thingsboard, IoT.*

1. INTRODUCTION

The rapid growth in the number of health sensing and monitoring devices, etc., has been generating a huge amount of data. According to IDC's prediction, by 2020, the data generated from healthcare applications can be up to 40 ZB.[1] Due to the diverse and complex nature of the collected data including biometric data, clinical symptoms, electronics health records (EHR) to MRI /CT diagnostic medical imaging data etc., the data visualisation is playing an ulmost important role.

Data visualisation is the process of converting data in numerical form (numerical data) into non-numerical data without reducing the entropy of the original data. In other words, *data visualisation is the main tool for creating images, diagrams, or animations to convey meaningful knowledge and messages to users, meeting specific tasks and requirements.* With the explosion of data, data visualisation is a challenging topic and attracting much attention from the scientific community and application developers as well.[2,3]

In the current context, the healthcare industry is looking for modern solutions to solve problems related to display, storage, data processing, and analysis. Especially, remote healthcare is actually getting a lot of benefits from technologies and data visualisation solutions. By using existing tools for visualizing health data, doctors and medical staffs can easily and remotely measure and monitor the patients' bio-physical parameters (e.g., heart rate, SpO2 - peripheral blood oxygen saturation, and ECG - Electrocardiogram), especially patients in remote areas, or disabled patients, elderly patients who are unable to move to medicare centers, resulting

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an improvement in the reliability of decision support systems.

In recent years, many studies in the area of medical data visualisation have been proposed. Liu et. al, proposed a data visualisation method to describe a relationship between heterogeneous data stored in databases using three types of data structure such as graph, tree, and graph-tree structure.[4] The authors in the study[2] used a graphical tool based on the GeoJSON (Geo Javascript Object Notation) standard to classify the patients' health data. These data were represented by using different colored circles. This method also deployed MongoDB database for storing the large amount of data. Based on a pre-defined and standardlised table of colors, doctors can diagnose the current health status of the patients.

Several research groups have been approaching a combination of technologies of web, mobile, and open-source platforms to develop medical data visualisation methods.[5-7] The authors in the study[5] introduce a multi-dimensional medical data display system from wearable devices on patients by combining smartphones and Web browser-based environments like the Google SDK, Android SDK, Google's IntelliJ. In this system, the collected data will be re-structured to visualise over time (e.g., hours, days, or months), or be interpolated and displayed through different shapes and colors. In the paper,[6] based on the application of virtual reality and the Internet, Xu et. al, propose a lightweight progressive coding architecture to visualize patients' medical data. The original images will be digitised, processed, and visualised to help doctors to provide patients with diagnoses.

To visualise data in IoT applications, selecting an appropriate platform plays a very important role.[2, 6 - 10] In the IoT architecture, IoT platform is responsible for performing main functions such as connecting IoT devices, collecting, monitoring, managing, and analysing data. In recent years, many commercial and open-source platforms have been released to meet the increasing demands of IoT applications. Notably, open-source platforms such as Thingsboard, ThingSpeak, Thingio, Site where, WSo2, Kaa IoT, DeviceHive, Zetta, and Blynk are attracting attention from researchers and application developers in IoT field in general and health sector in particular.[9, 10] Compared with the above open-source platforms, Thingsboard is considered as an effective platform to address the needs of data collection, processing, visualisation, and device management.[10]

The data visualisation methods in [2,6–8] have partially addressed the need to display medical data. However, there are some basic limitations in these methods as follows:

- Firstly, the methods have not met the need of representing data in real time [7] - an extremely important requirement in monitoring patient survival indicators, particular in patients in remote areas, or elderly/disabled patients;

- Secondly, the above solutions only provide measurement features, transfer patient health data through traditional communication methods such as LAN, and display locally on the patients' wearable device.[8] These systems still lack an integration of new technologies, which is a big challenge to develop large-scale data display systems;[6]

- Thirdly, end users such as clinicians, medical staffs, and researchers, etc., are usually not experts in the area of information technology and communications. However, the above solutions are still quite complicated for end-users.[2,6,7] In this context, it is necessary to deploy solutions with an easy-to-use interface in order to help them having quick captures of the patient's health status.

To address the above limitations, in this work, the authors will adopt the open-source Thingsboard platform and develop a system for monitoring and visualising patient health data in real-time. This system helps patients to understand their health conditions. More important, the system supports doctors and medical staffs to monitor the health status of patients and make appropriate diagnoses in timely fashion. The proposed system addresses the following basic requirements:

- Ability to monitor in real-time;

- Compatibility with a wide range of sensor devices from different manufacturers and data platforms;

- User-friendly interface;

- Being able to adapt to many different types of services, thus effectively deploying available resources.

- Ability to deploy at different scales such as: *(i)* on mobile devices of patients; *(ii)* in patients' homes (including people in remote and isolated areas, places where health care and medical facilities are scarce); *(iii)* at the doctor's office, and *(iv)* at health centers and hospitals.

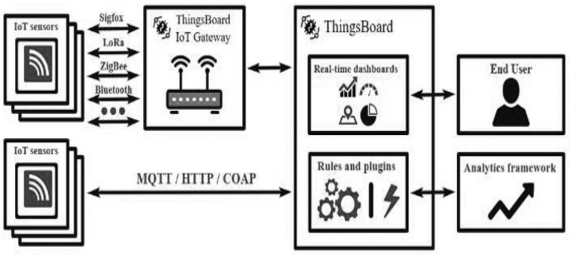


Figure 1. Open source platform hingsboard.[11]

The rest of the paper is organised as follows: Section 2 describes the open-source Thingsboard platform. Section 3 proposes a real-time monitoring and visualisation system for patient health data based on the Thingsboard platform. The results of the proposed system are illustrated in Section 4. The conclusion of the paper will be presented in section 5.

2. THINGSBOARD PLATFORM

2.1. Overview of Thingsboard

In recent years, the open-source Thingsboard platform is being considered as an effective solution for collecting, processing, visualising data, and managing devices for IoT applications. Thingsboard allows connecting devices through industry-standard IoT protocols such as MQTT (Message Queuing Telemetry Transport), CoAP (Constrained Application Protocol), and HTTP (HyperText Transfer Protocol). In addition, ThingsBoard allows an integration of devices connected to legacy and third-party systems with existing protocols. As depicted in Figure 1. Thingsboard includes some following basic features:

- *Remote data collection:* Thingsboard supports remote data collection and storage in a reliable way. Collected data can be accessed using custom websites or server-side APIs;

- *Data visualisation:* Thingsboard provides many utilities to visually display the collected data. Thingsboard also allows to create own gadgets like Google map widgets, real-time graphs, …;

- *Device management:* Thingsboard enables to register and manage the IoT devices. It allows monitoring of client-side device properties and server-side provisioning. Thingsboard also provides API for server-side applications to send RPC (Remote Procedure Calls) commands to devices and vice versa;

- *Dashboard: is used* to display data and control devices remotely in real- time;

- *Manage alerts:* Thingsboard introduces a tool to create and manage alerts related to entities in the system. In this context, Thingsboard allows to monitor real-time alarms and alarm propagation to the related entities hierarchy.

2.2. The basic communication protocols in Thingsboard

2.2.1. MQTT protocol

MQTT is a Publish-Subscribe messaging protocol. Because this protocol uses a low bandwidth, it is an ideal protocol for IoT applications. In a system using MQTT protocol, many clients connect to a server (i.e., in MQTT, the server is called MQTT Broker). Each client will register to follow the information channel (topic) or transmit its data to that information channel. This registration process is called "subscribe" and sending data of a client to the information channel is called "publishing". If there are data updates on the given channel (the data can come from different clients), the clients who have subscribed to this channel will receive the updated data.

2.2.2. CoAP (Constrained Application Protocol)

CoAP is a dedicated Internet application protocol for bound devices, as defined in RFC 7252. CoAP is designed to connect devices on the same bound network such as low power networks and lossy networks; or between devices and common nodes on the Internet, or between devices on different bounded networks connecting by the Internet.

CoAP is a service layer protocol designed for use in resource-restricted Internet devices, such as wireless sensor network nodes. CoAP is designed to be easily converted into HTTP in order to integrate with web applications and meet specific requirements such as multicast support, a very low overhead, and simplicity. Therefore, CoAP can be easily deployed in devices with small memory capacity and low power, especially applications in IoT, wireless sensors, and M2M (Machine-to-Machine). CoAP can run on most devices that support UDP (User Datagram Protocol) or similar UDP. To secure the data transmissions, CoAP uses Datagram Transport Layer Security (DTLS).

3. A REAL - TIME HEALTH DATA MONITORING AND VISUALISATION SYSTEM

3.1. System model

In this paper, we build up a real-time monitoring and visualisation system for patient health data combined with the open-source Thingsboard platform. The basic idea of this system is to collect basic bio-physical parameters such as heart rate, SpO2, and ECG. Supported by the Thingsboard platform, the collected data will be managed and visualised in real-time, thereby supporting for inspection and monitoring. The proposed system is illustrated in Figure 2 with some basic subsystems as follows:

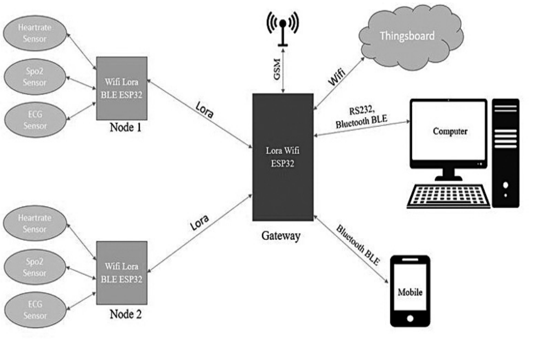


Figure 2. Proposed real-time health data monitoring and visualising system.

- *Sensing subsystem*: This subsystem includes some non-invasive sensors including MAX30100 [12] (i.e., to measure heart rate and SpO2), and AD8232 [13](i.e., to measure ECG). The detailed information of these sensors are as follows:

○ The MAX30100 module is a product of the Maxim cooperation, which uses the common optical measurement method today. This sensor allows an indirect and non-invasive measurement of oxygen saturation in peripheral blood and the patient's heart rate. The patients just wear the measurement device on their body. The device provides a measurement with a high accuracy, durability, and low noise;

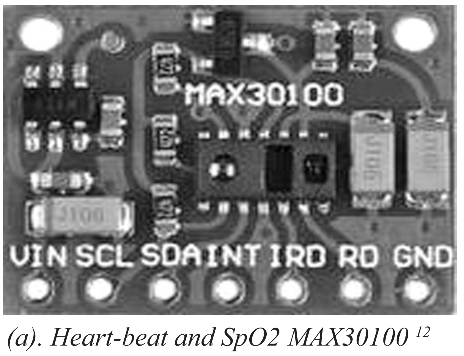
○ The AD8232 sensor is used to measure the electrical activity of the heart. This electrical activity can be graphed as an ECG electrocardiogram. This is a method of tracking activity, speed, and beat of the heart. When the heart is active, it will generate a variation in electric current. Here, ECG is a curve that records those changes and used for diagnosing various heart conditions.

- *Wireless and communication processing subsystem: This subsystem includes* microcontrollers and wireless transceivers in order to ensure the communications between the Gateway and Nodes using LoRa technology; or from the Gateway to the Thingsboard using WiFi:

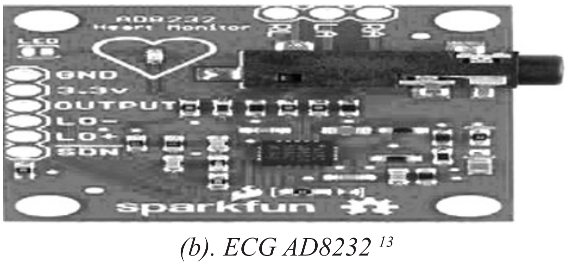
○ Heltec Wifi Lora 32 Kit is based on a combination of ESP32 chip; Tensilica LX6 processor, speed 240MHz, 520 KB SRAM; WiFi standard 802.11b/g/; two Bluetooth modes (traditional Bluetooth and Bluetooth BLE); and LoRa SX1278 chip. The LoRa SX1278 operates at frequency of 433MHz with the maximum distance of 5 km. The 0.96-inch OLED display is built-in; lithium battery charging circuit and UART CP2102 USB chip support development environment on Arduino;

○ Gateway requires relay communication between Node and server by using two wireless communication technologies of LoRa and WiFi. ESP32 module is chosen because its synchronous design and programming is similar to Arduino. ESP32 chip is used as a powerful microcontroller and integrated WiFi interface, which meets the requirements of the proposed system.

- *Display subsystem* uses a 0.96-inch OLED screen to display measured parameters from the sensing subsystem and the status of peripheral devices. At the same time, the sensed data is also visualised on the Thingsboard platform.



(a). Heart-beat and SpO2 MAX30100 [12]



(b). ECG AD8232 [13]

Figure 3. Sensing devices.

Table 1. SpO2 reference table [14]

SpO2 (%)	Meaning	Warning
97 - 99	Oxygen in the blood – good	
94 - 96	Medium blood oxygen	Need more oxygen to breathe
90 - 93	Low blood oxygen	Need to be monitored promptly
< 90	Extremely low blood oxygen	Emergency

Table 2. Heart-beat reference table by age (beats/minute). [15]

Age	Awake Mode	Sleep Mode
< 3 months	85 - 200	80 - 160
3 months - 2	100 - 190	75 - 160
2 - 10	60 - 140	60 - 90
> 10	60 - 100	50 - 90

3.2. Monitoring and alerting the patient's health status

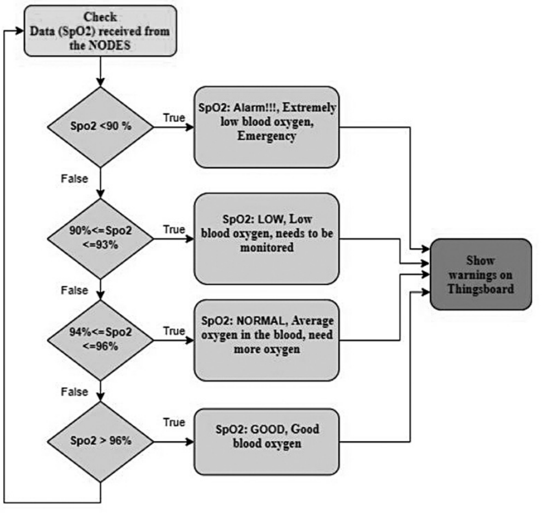


Figure 4. SpO2 level monitoring algorithm

The most important content of the paper is to generate alerts based on the patient health data collected by the sensing subsystem as described in section 3.1. In particular, this paper also develops a SpO2 level alert function as shown in Table 1. The warnings displayed on the dashboard of Thingsboard platform will help the medical team to capture the patient's status timely. The SpO2 monitoring algorithm illustrated in Figure 4 has four levels: Level 1 - ALARM (Emergency), Level 2 - LOW (Low), Level 3 - NORMAL (Normal), and level 4 - GOOD (Good).

3.3. Connecting with Thingsboard

In this paper, the authors collect three types of data as described in section 3.1 and send them to Thingsboard using MQTT protocol. It is a publish /subscribe (message) messaging protocol, uses low bandwidth, has high reliability, and is capable of operating under unstable transmission conditions. In this case, many station nodes (Client) connect to an MQTT Broker. Each client will subscribe to several channels, such as "/client1/channel1", "/client1/channel2", called "subscribe". Each client will receive data when any other station sends data to the registered channel. When a client sends data to that channel, it's called "publish".

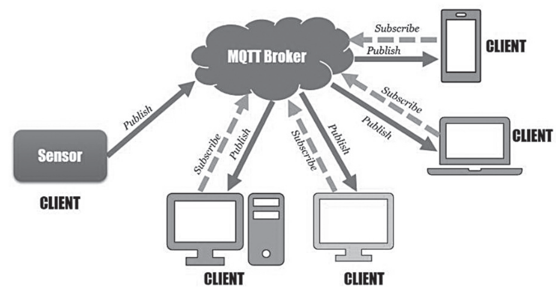


Figure 5. MQTT Broker[16]

4. RESULTS

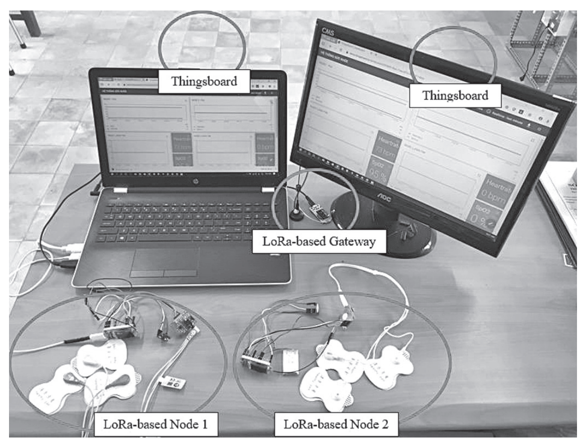


Figure 6. A testbed of the real-time health data monitoring and visualisation system.

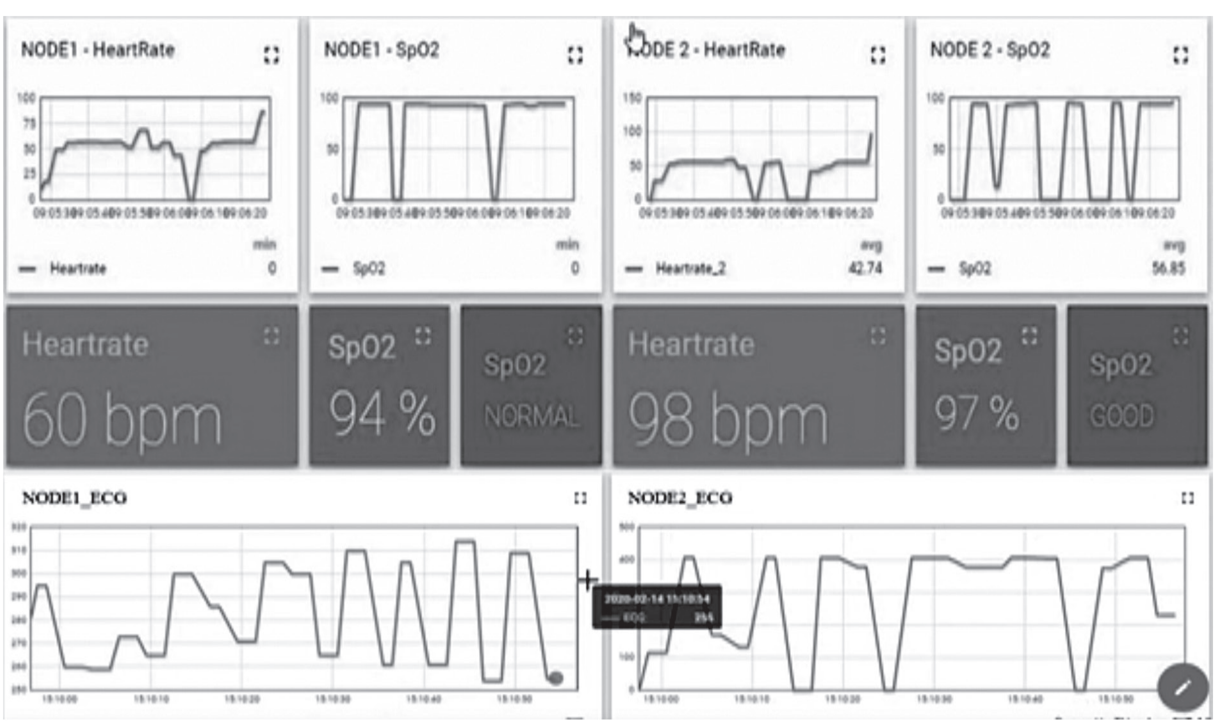


Figure 7. Visualising health data in real-time with Thingsboard platform.

In this work, the authors develop an experimental testbed of the real-time health data monitoring and visualisation system as shown in Figure 6. The testbed consists of two nodes (NODE) and a Gateway using LoRa technology:

- Each NODE will integrate two types of sensors MAX30100 and AD8232. The nodes are mounted on the different patients: a 30-year-old male patient lying on a bed (i.e., NODE 1 is powered by using a grid power) and a 38-year-old male patient wearing a device (i.e., NODE 2 is powered by a battery) moves within a 300m radius of the Gateway.

- Gateway is responsible for collecting data from NODE 1 and 2. At the same time, the Gateway will forward data to Thingsboard for further processing and display.

Patients' health data will be visualised on the Thingsboard's dashboard in real-timeas depicted in Figure 7. Heart rate, SpO2, and ECG values of each patient are displayed in two basic forms: graph and numerical. Figure 8 shows a piece of ECG signal extracted from NODE 1.

As shown Figure 7, the warning function (i.e., based on the SpO2 indicator) has been integrated into the dashboard. If SpO2 values respectively measured from NODEs 1 and 2 are 94% (NORMAL) and 97% (GOOD), doctors can diagnose the patient's condition and suggest a solution for patients to breathe more oxygen. Clearly, the real-time data visualisation plays an important role in supporting clinicians to monitor patients' health status and provide suitable diagnoses a timely.

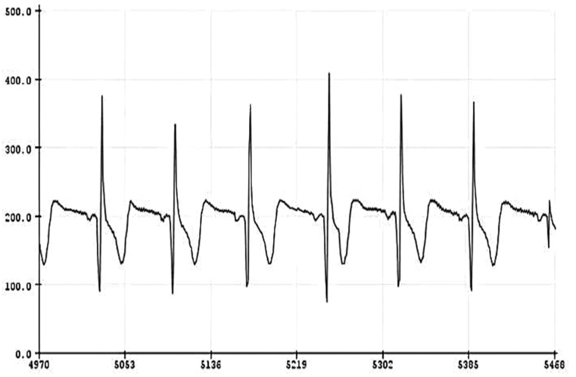


Figure 8. Extracting ECG signal from NODE 1.

5. CONCLUSION

This paper built a model for monitoring and visualizing patient health data in real-time based on the open-source Thingsboard platform. The proposed system is expected to assist doctors, medical staffs to monitor the patients' health status. The results of the paper show that Thingsboard is suitable platform for data visualisation in real-time. More important, the results also confirm the importance of data visualisation in the domain of healthcare.

Based on the preliminary results of the paper, the authors will integrate more sensors and build up new systems with more functionalities, especially data analysis supported byartificial intelligence (AI). New integrations can improve the ability of healthcare for people in the future.

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