Development of IoT-based Health Monitoring System using Blynk

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1. Introduction

The leading cause of death in Malaysia is heart disease. According to the data of the World Health Organization (WHO) published in May 2014, the rate of coronary heart disease deaths in Malaysia has reached 23.10% of total deaths [1]. The Department of Statistic Malaysia stated that the statistic of death caused by heart disease in Malaysia was 13.9% which higher than the death caused by accident [2]. Heart disease occurs when the abnormalities level of fats (lipids) accumulates to forms plague in a coronary artery and narrowing the arteries. At the same time, it reduce the oxygen-rich blood flow to the heart and leads to heart attack, stroke or even death [3]. The most common sign of coronary artery diseases is chest pain or angina which caused discomfort, heaviness, and pressure in the chest [4]. The other symptoms included shortness of breath, palpitations or irregular heartbeats and faster heartbeat [5]. Furthermore, the common risk factors of heart disease are high Body Mass Index (BMI), obesity, diabetes, smoking, and high blood pressure. Heart diseases are often thought to be an adult person's problem but it can happen to anyone regardless of gender and age [6].

Nowadays, healthcare services have great and advance facilities in monitoring health. For instance, electrocardiogram (ECG) and pulse rate sensor are devices for monitoring heart rate and oxygen level. However, a person who suffers from heart disease may collapse anytime in public, deserted places, or during driving. The worst case is the heart disease patient dies without anyone notice [7]. One of the best steps is to provide continuous health monitoring that perhaps able to save their lives whenever their conditions need medical attention. In the era of Industrial Revolution 4.0 (IR4.0), exploiting the Internet of Things (IoT) platform in providing better and smart services [8][9], especially in healthcare is the key idea of this work.

In this work, the authors have been developing a health monitoring device to measure pulse rate and locate the patient's location. Then, these data are transferred to a cloud server namely *Blynk* as the IoT platform. Therefore, this paper presents the development of the proposed health monitoring system using IoT application. Furthermore, the experimental results are also discussed.

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2. Methodology

2.1 Proposed Architecture of IoT-based Health Monitoring System

Figure 1 illustrates an overview of the proposed IoT-based health monitoring system. The proposed system comprises of a health monitoring device and *Blynk* app that able to monitor the user's pulse rate and locate their location.

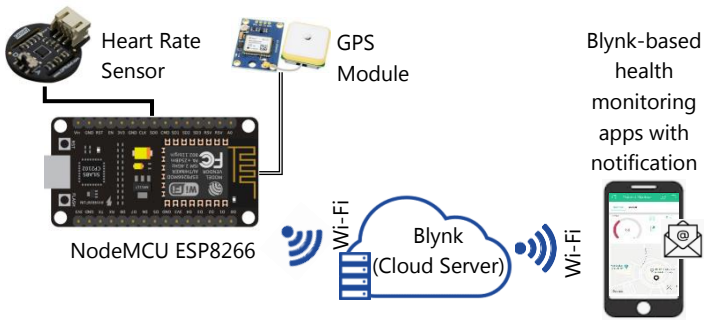


Figure 1: Proposed architecture of health monitoring system with *Blynk* as IoT platform

In this work, the health monitoring device measures pulse rate and locate current location. The pulse rate is measured using a heart rate sensor SEN0203 manufactured by DFRobot. The sensor measures the pulse rate through changes of blood flow through an index finger using photoplethysmography (PPG) technique [10]. Whilst, locate the user's location is performed by using a GPS module GY-NEO6MV2 with antenna MWC 2.5. The module provides real-time data of the user's location in terms of latitude and longitude. The NodeMCU ESP8266 has a built-in Wi-Fi module feature act as a microcontroller. These data are processed and transmitted by a microcontroller to an IoT platform called *Blynk* via Wi-Fi network. A caregiver can monitor and view the data via an Android or iOS smartphone with *Blynk* app. Furthermore, the caregiver receive an alert in the form of an email if the pulse rate reading is abnormal.

2.2 Prototype Hardware Design

Figure 2 shows the actual circuit of the prototype. A physical connection between the heart rate sensor, GPS module and the microcontroller is shown in Table 1.

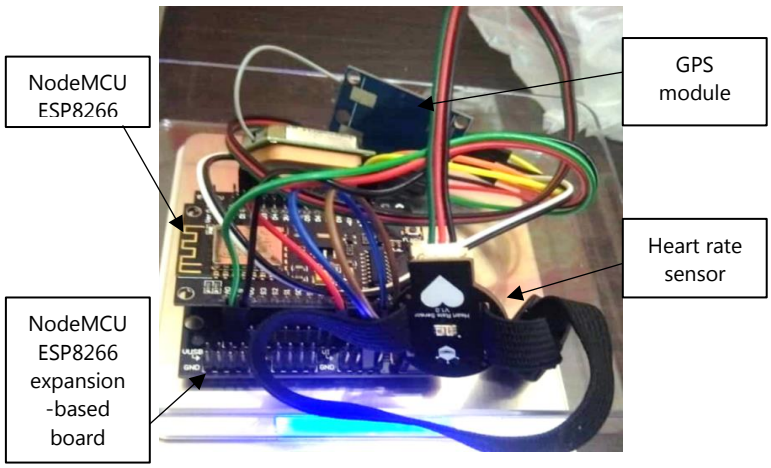


Figure 2: Actual circuit of health monitoring device

The microcontroller is programmed using *Arduino IDE* software to receive the data from the heart rate sensor and the GPS module. Then, these data are stream to the cloud server, *Blynk* via microcontroller wirelessly. The heart rate data, as well as the latitude and longitude of GPS, are displayed via the *Blynk* app that was installed in the user's mobile phone.

Table 1: Connection between GPS module, heart rate sensor and NodeMCU ESP8266

GPS module Pin	Heartbeat sensor Pin	NodeMCU ESP8266 Pin
VCC	VCC	3V
GND	GND	GND
RX	-	Digital 2
TX	-	Digital 1
-	Signal Output	Analog 0

2.3 Blynk as IoT Platform

The IoT platform is used as a medium to store monitoring data and also provide the notification. In this work, *Blynk* platform is used to support the IoT application in the proposed health monitoring system. The *Blynk* app in the user's smartphone provides a graphical user interface (GUI) of the system. The GUI is designed to have two (2) tabs; the *monitor* and *report* as shown in Figure 3. The *monitor* page allows the user to view uploaded data. When the abnormal heart rate is detected, the system pushed a notification to the caregiver via the email. This notification is configured in an *eventor* widget to set the events of the system. As shown in Figure 4, in this work, the caregiver have been receive a notification when the heart rate is below 60 bpm or over 120 bpm.

Whilst the *report* allows the user to save the heart rate data in the form of a report. As shown in Figure 5, the *report* widget is configured and customised the data in *CSV* format in which the user able to view the tabulated data using spreadsheet software.

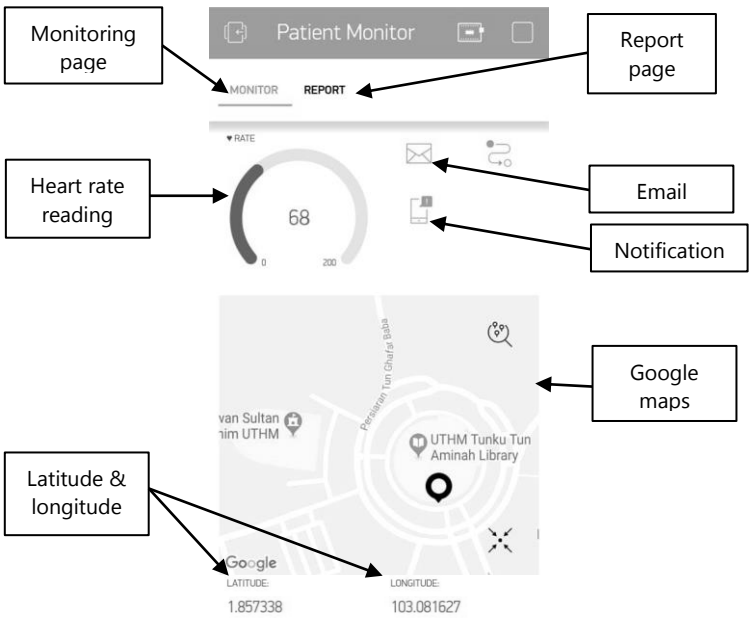


Figure 3: GUI of *Blynk* app

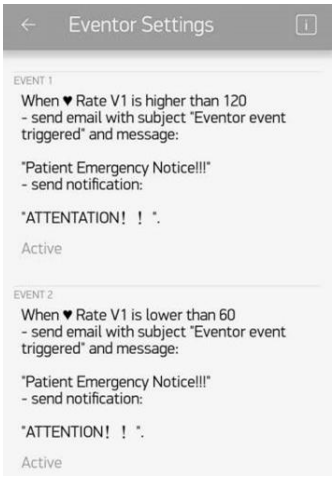


Figure 4: The setting of *eventor*

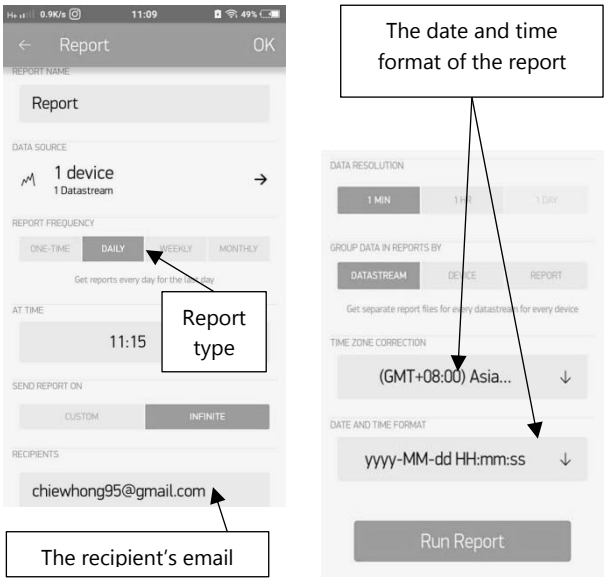


Figure 5: Configuration of *report*

3. Results and Discussions

3.1 IoT-based Health Monitoring System

Figure 6 shows the photo of the developed IoT-based health monitoring system that consists of a health monitoring device and *Blynk*-based monitoring app. The device is installed in a transparent box with dimension of 11.4 cm (length) x 11.4 cm (width) x 5.1 cm (height). The overall weight of the device without the battery is approximately 65g as shown in the photo of Figure 7.

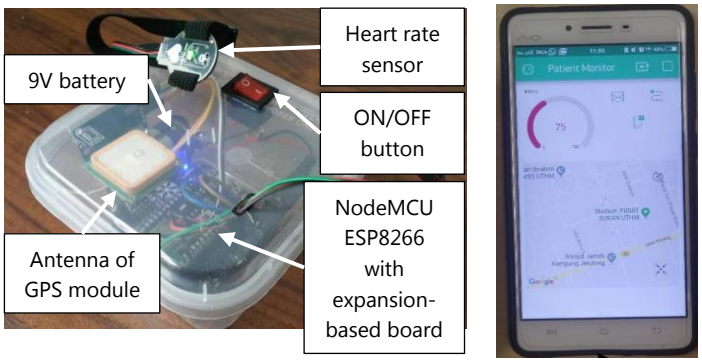


Figure 6: Health monitoring device (left) and its *Blynk*-app (right)

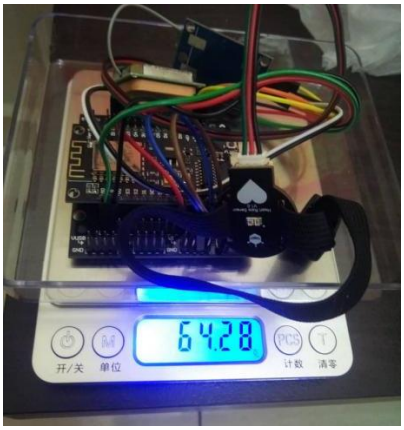


Figure 7: The weight of the health monitoring device

This device is powered by 9-volt lithium-ion battery and operates by switching the ON/OFF button. Once the button is switched ON the heart rate sensor and GPS module takes pulse rate measurement and locates the user's location, respectively before sending the data to the *Blynk* cloud server. As shown in Figure 6, the data can be viewed on the user's smartphone via *Blynk* app.

3.2 Experimental Results

This section is divided into three (3) experiments: heart rate measurement, GPS tracking and monitoring and notifying experiments.

Heart rate measurement experiment: This experiment is carried out by obtaining the heart rate data from the proposed device and commercial device, *drFrei*. The setup of the experiment is photographed in the Figure 8.

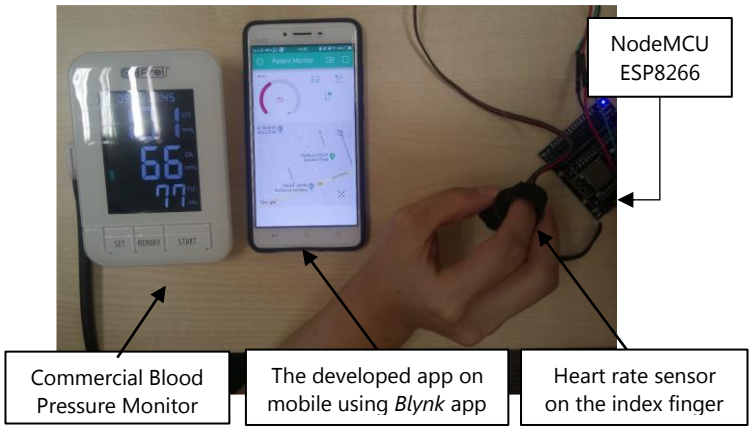


Figure 8: The experimental setup for heart rate measurement

The root means squared error (RMSE) is used to quantify the difference between the predicted and measured heart rate. The RMSE is calculated as Equation (1):

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(p-m)^2}{n}} \qquad (1)$$

where *p, m* and *n* represent the predicted value, measured value and number of samples, respectively. The collected data from two (2) healthy female for resting on the chair condition is taken three times and tabulated in Table 2. The RMSE for both subjects is approximately 3 bpm.

Table 2: RMSE between predicted (commercial device) and measured (proposed device)

Subject#	Commercial device (bpm)	Proposed device (bpm)	Approx. RMSE (bpm)
S01	72	78	3.9
	80	81	
	74	77	
S02	77	75	3.2
	69	74	
	73	74	

GPS tracking experiment. Figure 9 shows the GUI of the health monitoring system on the user's smartphone via *Blynk* app. When the health monitoring device is turned on, the GPS module locates its current location and streamed the data to the *Blynk* cloud server. The location is then updated to the lower screen of the *Blynk* app that shows the google maps with latitude and longitude information.

Monitoring and notifying experiment. For monitoring purposes, the *Blynk* app able to display the real-time data in the form of a chart as shown in Figure 10. This real-time data can be saved by sending the data in *CSV* format to the recipient's email as shown in Figure 11.

The notification feature is also added in the system to alert the caregiver via email as shown in Figure 12. This notification feature is activated when the abnormal heart rate is detected.

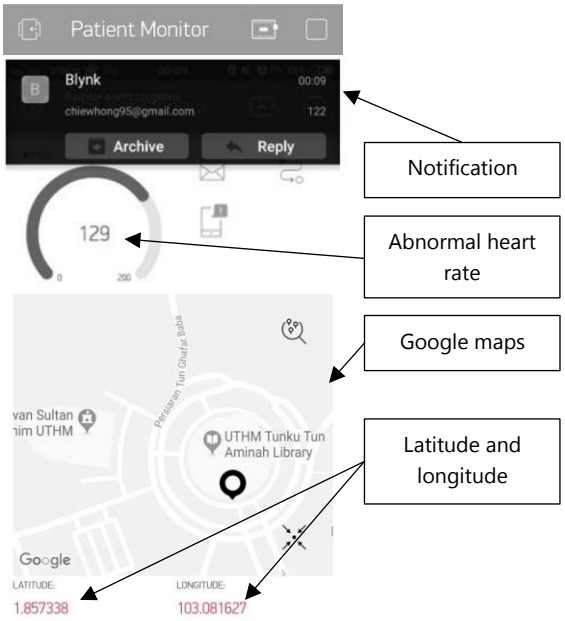


Figure 9: Pop-up notification when abnormal heart rate detected

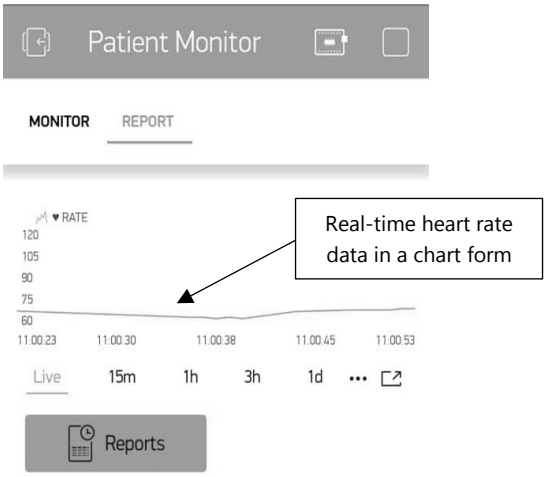
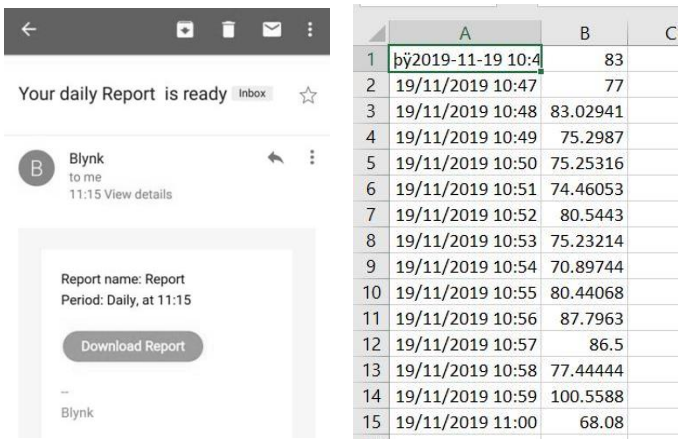


Figure 10: The chart of the real-time heart rate data



(a) (b)

Figure 11: (a) Email of daily report and; (b) data stored viewed in a spreadsheet

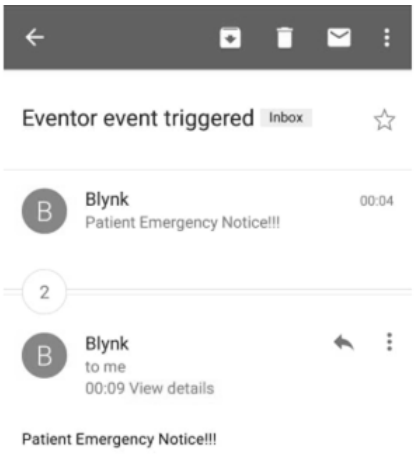


Figure 12: Email notification

4. Conclusion and Recommendation

In conclusion, a prototype of an IoT based health monitoring for measuring the heart rate and locating user's location has been successfully developed. Also, the developed device able to upload the data in the *Blynk* cloud server and notify the caregiver when abnormal heart rate was detected. The data can be viewed via the *Blynk* app in the user's smartphone. However, placement of the heart rate sensor that limited in the finger is one of the limitations of this work. Furthermore, the small size of the subject was recruited to test the performance of the developed device. As for future work, the placement of the heart rate sensor to the other part of the body to measure accurate heart rate are considered. Suitable size of subjects should be recruited ranges from healthy non-athlete to athletes. Lastly, the finishing of the hardware should be taken into consideration as a wearable device.

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