Chapter 26
NodeMCU Based Monitoring System for Individuals with Covid-19 Self-quarantined Order

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Abstract One of the factors that contributes to the increased number of Covid-19 cases in Malaysia is according to the authorities that Covid-19 patients, persons under investigation (PUI) and persons under surveillance (PUS) had deliberately left their home quarantine without valid reason and permission. There were irresponsible people who act selfishly by cutting their quarantine wrist tags provided by the Ministry of Health (MOH) and casually left their quarantine zone. The authorities are having a hard time to track down these irresponsible people especially among those who are ordered for self-quarantined at homes. These challenges had inspired for this work to propose a monitoring system to notify and remind respective individuals if they left the permissible area. The developed system could also update the authorities when these individuals continuously defy orders to return to their quarantine area. Through prototype testing, the proposed system offers an acceptable battery consumption since its tracking device consumed an average 150 mAh for a whole day operation. It is anticipated that this system could be an effective technology tool to ensure the quarantine session is undergone perfectly by these individuals and thus, combating the spread of deadly Covid-19 virus in the country.

Keywords Covid-19 · Self-quarantined · Contagious disease control · Internet of things (IoT)

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26.1 Introduction

An initiative called a movement control order (MCO) had been implemented by the Malaysian government on all 14 states starting on 18th March 2020 to restrain the contagious and deadly Covid-19 virus from spreading. During the early MCO implementation, Malaysia is seen to successfully control the active cases reported daily. Thus, the government started to allow several economics sectors and social activities to be operated as usual in several stages through implementations of conditional movement control order (CMCO) and recovery movement control order (RMCO). Unfortunately, the active Covid-19 cases reported daily started to increase again starting from September 2020 with reported cases entering 4-digit values. Since then, Malaysia is struggling to flatten the reported statistics and sadly, the highest statistics were reported on 29th May 2021 with 9020 cases [1]. Many factors contribute to the increasing number of Covid-19 cases in Malaysia, as discussed in [2]. Due to a shortage of medical facilities at the available hospitals and quarantine centers, Ministry of Health (MOH) Malaysia could no longer isolate Covid-19 patients with no symptoms shown at hospitals nor quarantine centers for meticulous quarantine observation.

Alternatively, MOH will perform a thorough assessment to all infected individuals and decide who are eligible for self-quarantined at their homes only. Once a person is diagnosed with Covid-19, their traveling history will be investigated for close contact tracing. According to MOH, there are two types of close contacts namely persons under investigation (PUI) and persons under surveillance (PUS). PUI is referring to symptomatic close contact who will be screened for Covid-19. Conversely, PUS refers to asymptomatic close contact who will not be screened for Covid-19 but is required for self-quarantined until the PUI Covid-19 test result is released. Note that PUI or PUS who are tested positive with Covid-19 will be brought to hospitals or quarantine center for observations if their health condition deteriorates. However, those who obtained negative results during the first screening are still compulsory to undergo 14 days home-quarantined as they will need to perform the second screening on the 13th day. PUI or PUS will be released from self-quarantined order if both screening tests are confirmed to be negative.

Undergoing home-quarantined order may sound easy. Yet, it requires individual's strong will, upright attitude and accountability to perform several guidelines set by MOH without being monitored by them. Sadly, polices and MOH had testified several cases involving people disobeying the home quarantine order. Offenders were traveling in public with quarantine tags still on their wrists. There were also offenders who cut and removed their quarantine tags before traveling elsewhere. For example, MOH had confirmed that 63 quarantine wrist tags were found without proper disposal and thus, police need to track the wrist tag owner as they might be infecting others with this contagious virus [3]. Based on the highlighted issues, there is a need for an electronic tracking device to be fitted on Covid-19 patients, PUI and PUS to monitor their movements if they break the quarantine rules [4, 5].

In [6], a telemedicine system was developed based on a WeChat application to monitor the health progress of home-quarantined patients. The patients will need to self-assess their conditions and update them to a multidisciplinary team stored on a cloud service. The self-assess update is very useful for medical staff identifying the disease progression for appropriate and timely treatment decisions. On the contrary, a geofencing technology-based was developed in [7] with an integration of smartphone application in the iPhone Operating Software (iOS). This system is able to notify the authorities if the quarantine wristband is cut or removed by the wearer. Users are given 15 s to validate their current location if they leave their quarantine zone. Aside from that, a wearable bracelet prototype was developed in [8] to monitor a patient's blood oxygenation and body temperature. The recorded data is connected to geo-localization in which the sanitary authorities will easily identify close contact of the wearer.

Although the telemedicine system in [6] is hassle-free as it requires only the smartphone application, it may not effectively trace the locality of a person with Covid-19 self-quarantined order mainly when the patients left their smartphone and travel to somewhere else. Nevertheless, the system proposed in [7] will drain the user's smartphone battery consumption for its operation since it requires the integration of WiFi, Bluetooth and global positioning system (GPS) assistance to identify the wearer's locality. Moreover, only iOS smartphones can be supported in which this approach may not cover other smartphone users. Having said that, the close contact tracing method proposed in [8] may not be effective at all if the person with Covid-19 light symptoms purposely left their wearable bracelet when outing. As of now, Malaysian authorities had made it compulsory for all its citizens and those staying in the country to use *MySejahtera* application or manual details writing upon entering any premises. Thus, close contact tracing for newly infected people could be easily identified by the authorities.

Based on the above discussion, there is still room for improvement in having an effective and efficient monitoring system. In this work, a prototype of monitoring system is proposed to offer an acceptable battery consumption throughout the quarantine period and straightforward system deployment for individuals with Covid-19 self-quarantined order at their homes.

26.2 System Description

In this section, the proposed monitoring system is described in detail. It consists of two devices called parental device (refer Fig. 26.1) and tracker device (refer Fig. 26.2a). The parental device is used to transmit and receive data to and from the tracker device to ensure the tracker device is always connected to WiFi and in online mode. Basically, the parental device will be accountable to alert the users if they leave the permissible self-quarantined area. It will also notify the authorities if they fail to return to the quarantine area or purposely remove the tracker device from their wrist. Meanwhile, the tracker device will update the latest user's locality

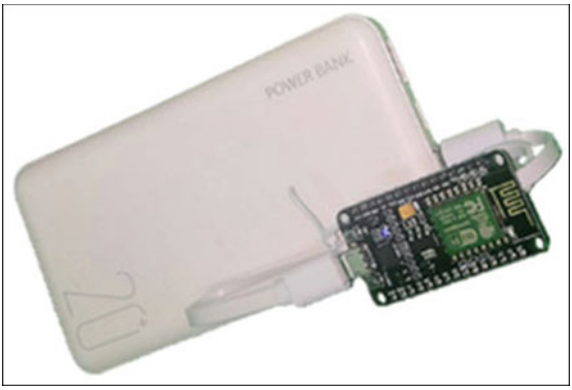

Fig. 26.1 Parental device of the proposed monitoring system

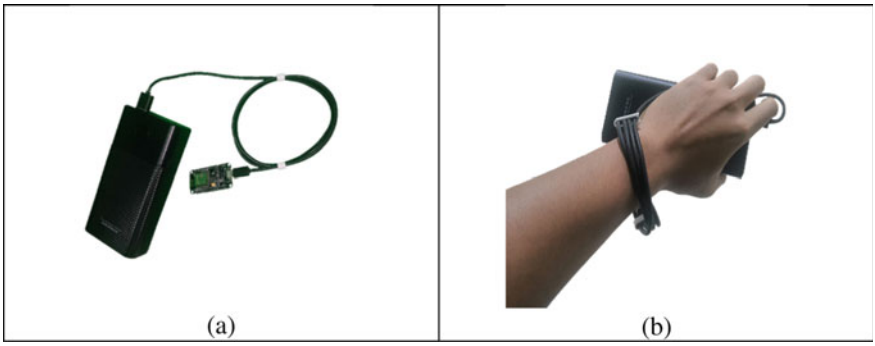

Fig. 26.2 **a** Tracker device of the proposed monitoring system **b** when it is placed on the user's wrist

information throughout the self-quarantined order (i.e., 14 days). The tracker device must be worn on the user's wrist, as portrayed in Fig. 26.2b.

This proposed monitoring system requires two units of NodeMCU ESP8266 (each for the respective parental and tracker devices), user's existing smartphone and Google Firebase. The NodeMCU at the tracker device is programmed to retrieve the user's latest location from the built-in GPS module in the user's smartphone. An open-source platform called Blynk mobile application in the user's smartphone is used to send the acquired location information from the built-in GPS module to the NodeMCU microcontroller in the tracker device. The latest locality information provided by the Blynk application helps the microcontroller in the tracker device to perform (i) the distance calculation from the quarantine zone and (ii) make a declaration on the user's locality status. These two pieces of information will be updated in Google Firebase.

The Google Firebase serves as the real-time database to keep the user's records reported from the tracker device. Thus, the NodeMCU microcontroller in the parental device will track the reported information in Google Firebase to (i) send

an alert/reminder messages to the users if they are about to leave the permissible self-quarantined area and (ii) to notify the authorities if the users fail to return to the quarantine zone. Note that, the quarantine zone (i.e., user's home location) can only be set/registered by the authorities in the Google Firebase to avoid the user from changing their quarantine zone details. The system operational flow is described as follows.

Upon system initialization, the parental device transmits a signal to the tracker device until the tracker device is confirmed to receive the signal. When the tracker device receives the transmitted signal from the parental device, it updates the user's current distance from the quarantine zone and locality status onto the Google Firebase. The parental device will continuously monitor such information updated in the Google Firebase to identify if any person with Covid-19 self-quarantined order has breached the quarantine procedures. In this proposed system, Telegram application is used as a medium for users to receive automatic reminder messages on their locality status.

There are three locality statuses in this monitoring system: green zone, yellow zone and red zone. A user is declared to be in a green zone when they are located within 10 m from the quarantine point set by the authorities in the Google Firebase. Nevertheless, a user will be declared to be in a yellow zone if they are located within 20 m but exceeding 10 m from the quarantine area. Red zone will be updated as user's locality status if they travel beyond 20 m from the quarantine area. Reminder messages will only be sent to the users if they are declared in yellow and red zones.

Besides monitoring the user's locality status, the parental device could also track if the tracker device experiences network disconnection or system damage. For actual system implementation, the tracker device will be designed as an electronic wristband and will be fitted according to the user's wrist size. Hence, the wristband will not be easily removed by adding a system detection on trials made to remove the electronic wristband. However, if the wristband is cut, it is impossible to reconnect back due to wiring damage. Therefore, the users could not stop the parental device from submitting several reminder messages to put on the wristband back. Consequently, the authorities will know that there is an event where the user totally removed the wristband.

The system operation will continuously perform the reporting of user's locality status in real-time, although no quarantine violation is detected. Therefore, the system shall be designed with an acceptable battery consumption to ensure the tracker device withstands 14 days of operation without recharging it. Recall that Figs. 26.1 and 26.2 show the proposed system prototypes in which both parental and tracker devices seem bulky due to the powerbanks capacities are 20,000 mAh and 30,000 mAh, respectively. These huge powerbank capacities are purposely chosen for prototype functionality testing to evaluate the battery discharging rate when operating the devices. It is observed that the powerbank battery used on the tracker device depleted only 1% from a fully charged 30,000 mAh in two days. Hence, Eqs. (26.1) till (26.3) show that the tracker device requires at least 2100 mAh supply to withstand 14 days of operation.

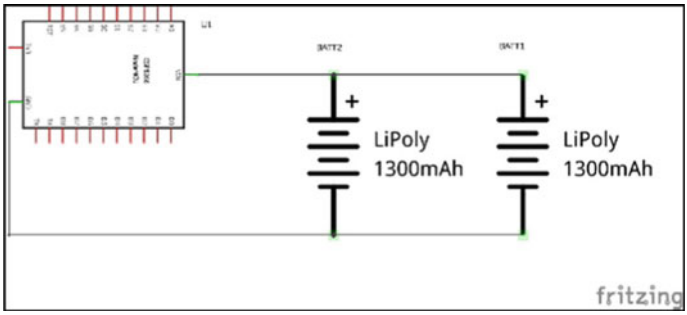

Fig. 26.3 Circuitry diagram for battery supply on the proposed system

$$\frac{1}{100} \times 30{,}000\,\text{mAh} = 300\,\text{mAh for 2 days} \tag{26.1}$$

$$\text{Average 1 day battery consumption} = \frac{300\,\text{mAh}}{2\ \text{days}} = 150\,\text{mAh} \tag{26.2}$$

$$\text{Average 14 days battery consumption} = 150\,\text{mAh} \times 14\ \text{days} = 2100\,\text{mAh} \tag{26.3}$$

Based on the above calculations, the power source for the tracker device will be replaced with a Li-Poly battery with a capacity of at least 2100 mAh. With the replacement of the Li-Poly battery of specific capacity, the battery supply size could be reduced to its minimal size. Thus, it ensures the users are comfortable when applying the tracker device on their wrist throughout the self-quarantined period.

Figure 26.3 shows the circuitry diagram for battery supply on the proposed tracker device, constructed in Fritzing software. Since Fritzing software has a 1300 mAh Li-Poly battery unit only, the tracker device is powered up with 2600 mAh Li-Poly batteries. However, in the actual system deployment, it is targeted to use 2800 mAh Li-Poly battery to withstand 14 days of system operation.

26.3 Results and Discussion

Experimental measurements have been carried out to assess the capabilities of the proposed system prototype to monitor the user's locality status during self-quarantined order. A house location of a test subject with a coordinate 3.102188, 101.551506 was chosen and updated in the Google Firebase. The test subject distance from the quarantine coordinate can be calculated using Eq. (26.4). Note that in the theoretical calculation, 10 m in the Google Map equals a value of 0.000100 in the Google Firebase.

Fig. 26.4 Real-time database recorded in Google Firebase for green zone status

$$\text{Distance from quarantine coordinate} = \sqrt{(\text{homelatitude} - \text{userlatitude})^2 + (\text{homelongitude} - \text{userlongitude})^2} \quad (26.4)$$

Figure 26.4 displays the real-time database recorded in the Google Firebase when the tracker device detected the test subject within the green zone (i.e., within 10 m from the quarantine coordinate). From Eqs. (26.5) and (26.6), it is confirmed that the distance calculation performed by the tracker device prior to locality status reporting on the Google Firebase is correct. Other than that, the state value "1" shown in Fig. 26.4 indicates that the active communication between parental device and tracking device via internet connectivity.

$$\text{Distance from quarantine coordinate} = \sqrt{(3.102188 - 3.102170)^2 + (101.551506 - 101.55152)^2} = 0.000023 \quad (26.5)$$

$$\therefore 0.000023 \equiv 2.3\,\text{m} \quad (26.6)$$

The test subject was then performed an active movement from the quarantine coordinate. As soon as the tracker device detects the test subject distance from the quarantine coordinate to be in the range of 10–20 m, the Google Firebase will get a real-time update stating that the test subject has entered the Yellow Zone. Hence, the user needs to be reminded by the parental device to return to its quarantined station. Figure 26.5 displays the database update when the test subject has entered the yellow zone and Fig. 26.7a shows the notification message sent to the user smartphone via Telegram application when yellow zone is detected. The calculations shown in Eqs. (26.7) and (26.8) confirm the proposed system correctly measured the distance calculation.

Fig. 26.5 Real-time database recorded in Google Firebase for yellow zone status

Distance from quarantine coordinate

$$= \sqrt{(3.102188 - 3.102078)^2 + (101.551506 - 101.55152)^2} = 0.00011 \quad (26.7)$$

$$\therefore 0.00011 \equiv 11\,\text{m} \quad (26.8)$$

Last but not least, Fig. 26.6 displays the real-time database recorded in Google Firebase in an event when the test subject left the quarantine coordinate for more than 20 m. From Eqs. (26.9) and (26.10), it is confirmed that the test subject has traveled for 21 m from the quarantine coordinate and red zone was declared. Therefore, a notification message in Fig. 26.7b was sent to the user's smartphone. The parental device will keep sending the notification messages to the user for every 10–12 s if the Google Firebase still receives red zone status from the tracker device. If the red zone status remains in a specific duration set by the authorities, the police will be able to track down the user's latest location based on the Google Map link attached herewith the notification message if the person defies orders to return to his/her quarantine

Fig. 26.6 Real-time database recorded in Google Firebase for red zone status

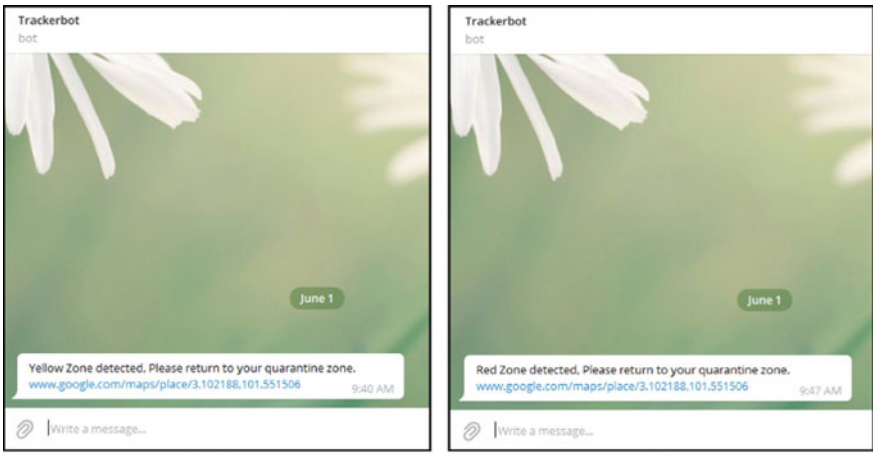

Fig. 26.7 Notification message sent by parental device via Telegram application when **a** yellow zone and **b** red zone are detected

area. Besides that, the police may also make visits to the home-quarantined premises when there is no response reported from the tracker device.

$$\text{Distance from quarantine coordinate} = \sqrt{(3.102188 - 3.101978)^2 + (101.551506 - 101.55152)^2} = 0.00021 \quad (26.9)$$

$$\therefore 0.00021 \equiv 21\,\text{m} \quad (26.10)$$

26.4 Conclusion

In this work, a prototype of monitoring system for individuals with Covid-19 self-quarantined order is proposed. The obtained results run by the prototype measurements demonstrated that the proposed system could be a solid starting point for an actual system implementation of a monitoring system for individuals with Covid-19 self-quarantined order in Malaysia. The system deployment is realistic and straightforward because it requires only a programmed microcontroller unit at both parental and user end, integrated with sophisticated and accurate GPS reading from the user's existing smartphone. Besides, the proposed system has realized the industrial revolution 4.0 (IR4.0) in combating the spread of the deadly Covid-19 virus in a country. This is achieved by using the internet of things (IoT) concept for a device-to-device communication and to manage the real-time data in a cloud database.

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References

1. Hirschmann R (2021) COVID-19 number of daily cases Malaysia 2021. Statista. https://www.statista.com/aboutus/our-research-commitment/1956/r-hirschmann. Accessed 1 July 2021
2. Rampal L, Liew BS (2021) Malaysia's third COVID-19 wave—a paradigm shift required. Med J Malaysia 76(1):1–4
3. Saiful AM, Amir AH, Hafidzul HMN (2020) Covid-19: Polis buru 63 pemakai 'wristband' keluar rumah [METROTV]. Harian Metro. https://www.hmetro.com.my/utama/2020/07/602475/covid-19-polis-buru-63-pemakai-wristband-keluar-rumah-metrotv. Accessed 1 July 2021
4. Sharifah MA, Takiyuddin (2021) Electronic tracking devices only for selected PUI, PUS patients. New Straits Times. https://www.nst.com.my/news/nation/2021/03/671709/takiyuddin-electronic-tracking-devices-only-selected-pui-pus-patients. Accessed 4 July 2021
5. Veena B (2021) Tracking devices could turn the tide. New Straits Time. https://www.nst.com.my/news/nation/2021/03/671744/tracking-devices-could-turn-tide. Accessed 4 July 2021
6. Xu H, Huang S, Qiu C et al (2020) Monitoring and management of home-quarantined patients with COVID-19 using a WeChat-based telemedicine system: retrospective cohort study. J Med Internet Res. https://doi.org/10.2196/19514
7. Hui M (2021) Hong Kong is using tracker wristbands to geofence people under coronavirus quarantine. Quartz. https://qz.com/1822215/hong-kong-uses-tracking-wristbands-for-coronavirus-quarantine. Accessed 4 July 2021
8. Manekiya M, Donelli M (2021) Monitoring the Covid-19 diffusion by combining wearable biosensors and smartphones. Prog Electromagn Res M 100:13–21