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Public Health and Safety on Close Contact Proximity Detection for COVID-19 and Alert via IoT

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ABSTRACT

Social distancing among people is vital in minimizing spread of COVID-19 within community and can be effective in flattening the outbreak. This research work focuses on developing a close contact proximity detection system among smartphone users, particularly of COVID-19 patient, using Bluetooth signal to identify and analyze close contact proximity and social distancing from other anonymous smartphone user in their surrounding. The system aims to alert user if the social distancing is breached. The methodology rely on the Radio Signal Strength Indicator (RSSI) signal to analyze and estimate the proximity distance and duration of the individual's exposure to other peoples in surrounding area. An overlap zone of 1-meter is used to indicate detection of closed contact proximity between users. Furthermore, the collected data can be utilized for contact tracing that enabling health officials to identify the closed contact of infected patient systematically and rapidly covering people who may be anonymous or not directly known to the COVID-19 patient. Encouraging results have been obtained for the closed contact proximity detection within the mobile apps. Furthermore, the performance of system for close contact proximity detection has shown that indoor locations have a more robust signal distribution compared to outdoor locations.

Keywords: COVID-19 patient; close contact proximity detection system; social distancing; bluetooth signal

INTRODUCTION

COVID-19 has become a serious threat to human life. Millions humans have died and over 20 million people have been infected. Difference countries have responded to Covid-19 initial outbreak in various ways, leading to widely different outcomes (Hernandez et al. 2020). Some countries carefully examined all patients with symptoms, and traced their past contacts when an infected case was identified. This approach was taken because government needed to manually trace individuals who tested positive, and the method was not very effective. Some of patients did not comply write the rules and regulations on self-quarantines at home for 14 days (Hernandez et al. 2020). Government worldwide are now utilizing social media to communicate and control the spread of COVID-19. A more selective isolation measure directed at finding the person most likely to be infected by close contact tracing. It manually check up on closed contact of new COVID-19 infected patients was tinted consuming. The contact tracing was proposed with the ability as one of the solution to identify, track and update the close contacts of the infected patients (Ng et al. 2020).

Here, smartphone surveillance might seem like a good solution to control and track the spread of Covid-19 using Bluetooth with RSSI signal and Beacon technology (Kumar et al. 2020). It can help track on social distancing advance and enable contact tracing for Covid-19 patients. Bluetooth technology can be a valuable tool in detecting social distancing compliance and tracing contacts (Chunche et al. 2020). It operates write in a short distances and can transmit data between devices, making it a versatile wireless system technology. Bluetooth finds applications in devices such as printers, wireless headsets, and wireless mouse and it is designed to connect phones or other portable devices seamlessly. Bluetooth based proximity detection occults when the mobile devices are in the close proximity to each other, both indoors or outdoors. This technology void the potential to serve as a platform for proximity detection and user data privacy is safeguarded as Bluetooth requires user permission for data requests (Newman 2014). Next, it accuracy can be further improved through the fusion of several technologies. As the result, Bluetooth was the potential to become an alternative for indoor positioning. There are many radio technologies alternatively in the market nowadays, such as Wireless Local Area Network (WLAN) and Bluetooth which have features suitable for indoor and outdoor positioning. Beacon technology is another option that can be used for proximity close contact detection. It relies on Bluetooth Low Energy (BLE) to send out messages and widely used for apps and devices, including beacons for the Internet of Things. Current proximity-based BLE beacon applications that can only provide coarse-grained distance estimation indicating close, immediate and far distances (Pei et al. 2010). The RSSI is a standard measure for positioning and widely support by mobile devices with BLE (Ahmad et al. 2020).

The Internet of Things (IoT) can be integrated into the system for preventing and controlling epidemics. A Cloud integrated IoT platform that can be utilized to alert about social distancing breaches and regulate COVID-19 in a systematic and intelligent manner. Therefore, social and technical approaches have been implemented throughout the world to control the spread of the virus and prevent infection resurgence. Contact tracing based on IoT technology is among the technological measures used in several countries. IoT has found applications in various fields such as the oil and gas (Soh et al. 2109a), utilities consumptions (Soh et al. 2109b) medical, commercial and industrial, transportation, and environmental nature, existing numerous advantages over systems that lack internet access. As a monitoring system, IoT is relevant tracking COVID-19 cases, allowing early infection discovery, leading to less intrusive treatment an efficient spread control. It can be effective not only in flattening the curve of the outbreak, but also facilitating a safe return people to public life once a community is on the downward side of the curve.

Therefore, this paper propose a Close Contact Proximity Detection (CCPD) using Bluetooth signal on smartphones integrated with IoT for alerts is presented. This mobile apps can be used for social distancing and potentially extended for contact tracing. The CCPD will track every phone within a certain range of a person surroundings. If that person encounters another user within a 1-meter radius proximity, the CCPD will alert them about a possible close contact in their surroundings. The paper is structured as follows: the next section will explain the proposed system and methodology followed by results analysis and discussions. Finally the paper will be concluded in the final section.

RESEARCH METHODOLOGY

The working principle and catalyst of this research work is the extensive usage of smartphone among the people around the world which enhanced the tracking of people based on their smartphone location. The CCPD using Bluetooth signal on smart phone for social distancing alert and contact tracing app are an innovative system that based on the Bluetooth Low Energy (BLE) BLE and IoT technology. The BLE has been chosen along with Beacon technology. Beacon relies on BLE to alert user. These technologies can be effective for close contact tracing on smartphone (Li et al. 2018). The IoT platform is used to monitor and collect the identification, RSSI and Distance data from participating smartphone users. Then, the event notification and respective alert is invoked based on the collected data in real-time if 1-meter radius social distancing is breached. In determining the distance between smartphone users and collect identity of them the RSSI has been calculated and observed. The practical usage of RSSI depends on properties of radio signals such as their frequency or time frequency characteristics. However, the fluctuations within the RSSI make it difficult to measure the RSSI signal with an explicit distance due to the nature of radio frequency signal (Alam et al. 2016). From Figure 1, it shows the system architecture that has been implement in this research work, there are several BLE devices (B1, B2, B3, B4) within the radius of user current location and a device as beacon devices(N) that will scan all the signal from nearby BLE devices within the radius.

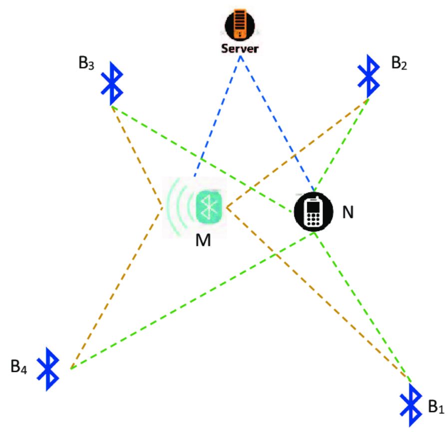


FIGURE 1. CCPD architecture framework

After all the data measured has been collected, the data will be sent and analyzed to the server, PC of user has been indicated as a server in this research work. The collected measurement is based RSSI between devices with distance. RSSI is an estimated measure of power level that a Radio Frequency is receiving from an access point. It is also the strength on the beacon's signal as seen on the receiving devices. The important parameter in this measurement are RSSI value in -dBm with transmission power which usually range between -59dB to -65dB (Du et al. 2017). The expected value of the distance based on RSSI signal is set as RSSI signal will be calculated through a distance that has been set less than 1-meter between the nearby devices as shown in the formula:

$$Ratio\ Distance = \frac{RSSI}{txPower} \tag{1}$$

where txPower in (1) is assume -59dBm, in range between -59 to -65dBm which represent measured transmission power is a read-only, factory-calibrated constant that indicates the estimated RSSI at a distance of 1 meter from the beacon.

It may be used in conjunction with RSSI to estimate the distance between the device and the beacon. However due to external factors that influence radio waves signal such as interference, diffraction or absorption the RSSI values tend to fluctuate. Hence the RSSI signal will be more unstable if the devices are kept away from each other. In creating the map of the CCPD App, the Haversine formula has been used. The two locations on a sphere and their longitudes and latitudes calculated by the Haversine formula and get the distance between them (Chunche et al. 2020).

In this research work, there are several devices with BLE, applications and software used. Scanning the Bluetooth and RSSI signals are the main purposes of contact tracing in this research work. The CCPD system is started with random devices at a certain place on enable mode Bluetooth then, the BLE device starts scanning nearby devices with Bluetooth but if the BLE devices do not enable Bluetooth the system will stop there. After scanning the nearby BLE devices, the data of RSSI and the radius between the user BLE devices are collected. The circle of radius between users within 1 meter is recorded. If the circle of radius is overlapped between users, then the color of center circle is changed to orange, the data of the social distancing breached is updated and the user in that radius will be declared as a "close contact". After that, the data is stored and evaluated in the server (PC/laptop), and also all data of the device ID, radius and RSSI values is sent to Ubidots IoT platform. The IoT Cloud event manager sent a notification alert on the mobile app and e-mail about the close contact detected nearby within his/her location. However, if the circle of radius is not overlapped which indicates no close contact with the user within his/her surrounding radius. The CCPD operation is repeated by scanning back the nearby BLE devices.

The proposed solution for this CCPD research work to determine a close contact between the users and breaching of 1-meter social distancing by using the Zoning Method on Map (Circle in Circle). The concept can be illustrated as a circle inside a circle where the outer circle will be the foreign BLE device and the inner circle will be the user device location. The concept of a circle inside a circle will be used since most BLE devices did not advertise their location so this method seems to be the most suitable method to implement the contact tracing app using this concept.

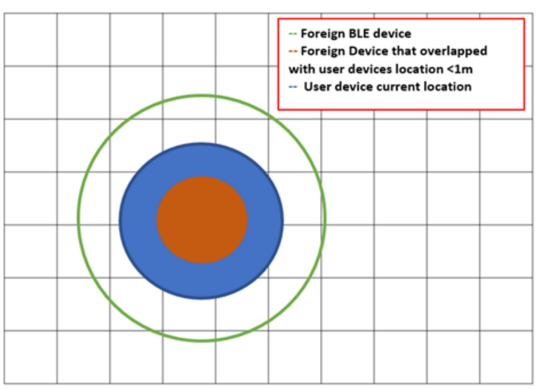


FIGURE 2. Zoning Method of CCPD System

Based on Figure 2, the zoning method has been applied for this research work to track the data of close contact and at once measured the distance based on the RSSI signal from the random BLE devices near to the user location. There are three different types of zoning circles with different colours, each circle representing the different BLE devices. The green circle indicates the random foreign BLE devices and the circle were not in the radius between the user location. The next circle is a blue circle that acts as the user device's current location when the outer circle zone overlaps with the inner circle zone, the inner circle zone will display orange color where it indicating that there is close contact between the zone within the radius less than 1- meter. This is because the user will be alerted there was a danger or close contact within the parameter of the user's current location. In this research, the hardware used to scan nearby devices with BLE and the device that acts as the cloud server for the research work are Redmi 9 Smartphone and Huawei Matte book D15 respectively. The map template has been created using Here Tracking App map web view to display the location where the process takes place and the few data function were added to enable updated data from Android application. A web view on the Android application will be used to display the map where the location and radius will be injected using JavaScript injection to the web view. Then, the Android application has been created by using React-Native, an Android application needs to be created where using react native can ease the task of creating native Android application where it uses HTML, CSS and JS. The uses of these three (3) elements makes it easier to create a mobile application compare to create it by using native developing language. Thus, react native is cross-platform and can create Android app, iOS and web development using a single platform with minimal changes to the codes (Bay et al., 2020). For the calculation of measurement RSSI vs Distance as in equation (1), the Python 3.9 software has been used to create formula and send the data to the cloud server. The Python code will consist of Flask server where it will listen POST request from the Android application. The Android application will submit the data when the distance between the user and BLE device are too close. The contact between the user and BLE device zone will trigger an event to submit the data to the server. The Python code will be used to store data from the application and log the data into an Excel file in the server which is a PC/ laptop that has been indicating as a server in this research work. The IoT technology also is in used, which is Ubidots platform. The Ubidots also will listen for the POST request in Python from the app and store the data in webserver then notify the user.

RESULTS AND DISCUSSION

In this section, it is explained the results of research work on a working CCPD system. First, the Map layout of the Tracing app categories of a CCPD system. Then, analysis and discussion of the signal attenuation of a Bluetooth signal versus the distance radius in an outdoor and indoor area and lastly, on interfacing of measured close contact data to Ubidots dashboard and event notification to user when there is a closed contact detected in his/her surrounding area.

MAP LAYOUT OF CCPD

It can be observed from the map layout in Figure 3(a) below that the mapping for the user's current location has been set up in the Tracing App based on the user's BLE devices. The marker on the map indicates the user's device location and the circle zone for the user's location is originally blue. While Bluetooth is still in disabled mode, this layout will appear on the user's screen to begin scanning other BLE devices based on the RSSI signal. RSSI signal. Figure 3(b) depicts the Tracing App's map layout after the user device has enabled Bluetooth, with other random BLE devices appearing on the screen. BLE needs to be configured to scan for nearby BLE devices. The green circle represents foreign BLE devices that have an RSSI signal and are close to the user's device's current location. In Figure 3(c), the map layout has displayed the user marker and its circle has been overlapped with other random BLE devices after scanning the RSSI signal within a radius less than 1 meter. The colour of user's device current location circle will change to orange. The warning also appeared to trigger the user that there is close contact detected. The RSSI signal will be scanned and displayed only when the other foreign BLE device is within the 1-meter radius of the user device's current location. Upon having contact between the zone, the BLE device ID, RSSI signal and distance will be logged and submitted to the cloud server. The BLE device circle will start to be added when the user's device location is detected. Then it will be removed after 2 seconds where it will then repeat to update its distance or radius on the map. This is to indicate the BLE device location with delayed time to show better indication on the map. The user location will be set to run every 1000 ms to ensure the user location is updated on the map.

(a) (b) (c)

FIGURE 3. Map layout of Tracing app for (a) before scanning BLE devices, (b) the random BLE devices appeared, (c) random BLE devices detected near user

BLUETOOTH SIGNAL ATTENUATION AND DISTANCE

To provide a baseline for collected measurements of received RSSI signal strength vs distance, the measurement of the two parameters has been taken with the same height and position between each location (indoor and outdoor). There are several smartphones with BLE signal have been used to perform this experiment which are Redmi 9 as a user's current location for scanning RSSI signal and collect data from other BLE devices, iPhone 11 and Redmi 6A act as a BLE devices nearby the user's current location. The collected measurement of the signal strength with the distance is varied by spacing between the devices. The position of the devices has been fixed for at least 2 minutes for the distances. There are many measurement data has been logged at the cloud server as the measurement for the system using RSSI signal, where it tends to fluctuate as the signal can rise and fall each second. This is because the radio wave signal of RSSI can be easily disrupted (Chunche et al. 2020). The distance for the devices that can scan RSSI signal also has been fixed within 1 meter only to avoid any useless data logged to the cloud server. Table 1 shows that the RSSI signal strength with its distribution based on the range of RSSI signal received. The good RSSI signal was within the range of -30 to -70 dBm, while within the range of -80 to -90 dBm the distribution of signal was not good and tends to be an unusable signal. Table 2 tabulates the measured RSSI and distance for indoor location whereas Table 3 tabulate the measured RSSI and distance for an outdoor location for the Redmi 6A and the iPhone 11 smartphone respectively. Each model recorded the different measured data as shown in Table 2 and Table 3. Data measured from Table 2 and Table 3 is retrieved and analysed from Excel file that has been stored in the PC as the server. From data in both tables, Table 2 and Table 3 show the same distance that has been placed with the different data of received strength signal, it can be seen that the indoor location has a better signal distribution compared to the outdoor location.

TABLE 1. The RSSI signal strength with its distribution.

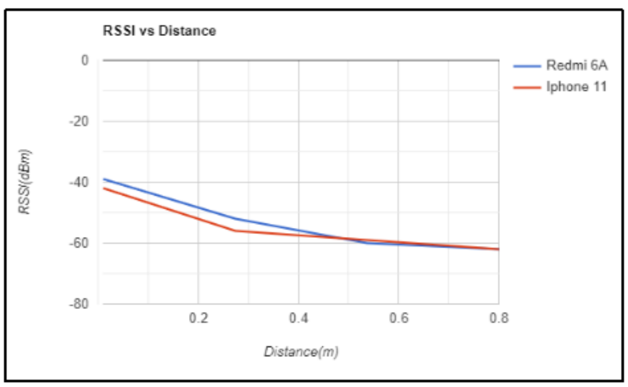
Signal Strength	Distribution
-30dBm	Amazing
-67dBm	Very Good
-70dBm	Good
-80dBm	Not Good
-90dBm	Unusable

TABLE 2. The measured data of RSSI and distance for indoor location.

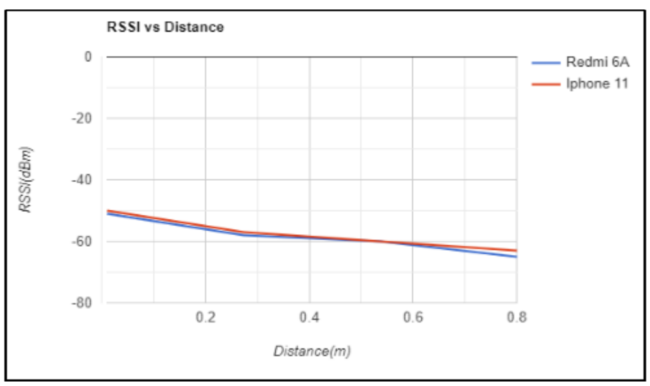
Devices	Parameter	
	Distance(m)	RSSI(dBM)
Redmi 6A	0.01	-39
	0.23	-52
	0.45	-60
	0.62	-62
IPhone 11	0.04	-42
	0.23	-56
	038	-59
	0.62	-62

TABLE 3. The measured data of RSSI and distance for outdoor location.

Devices	Parameter	
	Distance(m)	RSSI(dBM)
Redmi 6A	0.01	-51
	0.23	-58
	0.45	-60
	0.62	-65
IPhone 11	0.04	-50
	0.23	-57
	038	-60
	0.62	-63



(a)



(b)

FIGURE 4. The Measured RSSI (dBm) vs Distance(m) (a) indoor location, (b) outdoor location

The solid line in Figure 4(a) depicts the line graph resulting from the measured RSSI vs distance for the pair of BLE devices, Redmi 6A and iPhone 11, which were placed in an indoor location (living room in a house. As expected, the measured data shows that the RSSI decreases steadily with increasing distance. Figure 4(b) depicts the measurement received signal strength (RSSI) with distance taken in an open space of outdoor location at the same height and position as an indoor location, with the solid line for each device steadily decreasing in relation to its RSSI and distance. However, the distribution RSSI signal has a lower range than the indoor location distribution signal. Because the received signal strength is affected by transmit power and other factors, the expected measured received signal strength may vary depending on the smartphone model (Chen et al. 2018). As can be seen in Table 1, a good distribution signal of RSSI falls somewhere in the range of -30 to -67 dBm. The entirety of the data to be measured was obtained with a remarkable signal distribution. When there is less space between the devices, there is a greater chance that the signal will be distributed. The process of signal propagation indoors is more difficult than when it is carried out outside. The received signal can also change depending on the behaviours of the user who placed the devices; when the place is narrower, the measured received signal will be increasing because of the blocks that are in the place such as walls, furniture, and other things (Chai & Du et al. 2016). It has been demonstrated that when the measured received signal in an indoor location is compared to an outdoor location, the indoor location has a better signal distribution.

INTERFACE TO UBIDOTS IoT CLOUD

Ubidots is an IoT platform that enables innovators and industries to test IoT projects and scale them into production (Jahmudah et al. 2021). Any system that is connected to the internet can have its data uploaded to the cloud using the Ubidots platform. The configuration will then issue warnings and take actions based on the data in real time. It will also activate the value of the data through the use of visual tools. Any location in the world with internet access can view the most recent data that was generated by the system that was put into place. In this CCPD research project, the measured parameter data will be uploaded to the cloud using internet connectivity via a Wi Fi module through wireless communication. These parameters can be accessed via a URL/website on the Ubidots Dashboard. These parameters can be accessed via a URL/website on the Ubidots Dashboard. When the Ubidots detect POST requests from the Tracing App, all data will be automatically sent to the webserver when a proper connection is established with the server devices layout, as shown in Figure 5.

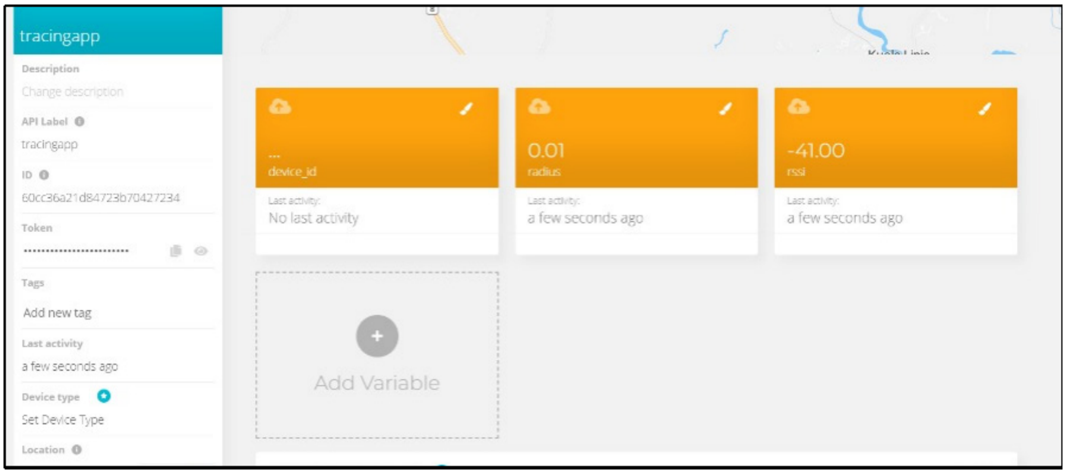


FIGURE 5. Data for radius and RSSI displayed at tracingapp devices layout

(a) (b) (c)

FIGURE 6. Ubidots (a) Graph of measured RSSI, (b) Graph of measured Distance, (c) Notification from Ubidots that alert user via e-mail

The RSSI and Distance data that were measured have both been updated in the device layout of Ubidots respectively. This is due to the fact that the Tracing App is constantly scanning other BLE devices, which ensures that the data is always continuously logged. Repeatedly sending data to the internet through the use of Wi-Fi occurs at regular and predictable intervals of time. In addition, the line graph of RSSI and distance results was displayed on the dashboard of the Ubidots device simultaneously with the data that was updated in the Ubidots device, as can be seen in Figure 6(a) and 6(b). Afterwards, the data that was sensed will be saved in the cloud. The analysis of the parameter and the purposes of continuous monitoring are both possible uses for the data that is stored in the cloud. Figure 6(c) demonstrates that whenever the data is triggered, the user will be notified by Ubidots via user e-mail that there was a close contact within the user parameter.

CONCLUSION

Bluetooth technology has been widely used in personal area network communication as an existing wireless infrastructure. Bluetooth-based proximity methods have also been investigated in recent years. This research highlights an inquiry-based Bluetooth for social distancing and contact tracing solution using RSSI signal distributions in order to advance a practical Bluetooth tracking social distancing among smartphone users and close contact for COVID-19 with adequate accuracy in indoor and outdoor location. The test results have shown that social distancing monitoring via Bluetooth based on RSSI signal has been successfully implemented via mobile app. The experiment data of the measured received signal with varying distance is always dependent on the position or location of the BLE devices. The RSSI data has also steadily decreased as the distance between smartphone users has increased. The data that has been gathered and saved on the server can subsequently be used by the authority for the purpose of tracing the user's contact history. The development of contact tracing is also difficult because of concerns over identification privacy, but if it is ever put into practise, it will be of great benefit to society. The future recommendation is that the development of the tracing app system can continue to develop and improve by adding some features of flexibility where the apps can be downloaded in all platforms and also with the tightening of security so that the user's privacy will not be invaded.

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DECLARATION OF COMPETING INTEREST

None

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