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Android Based Digital Contact Tracing and Health Monitoring System for Covid 19 Pandemic

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Abstract: The World Health Organization has declared the SARS Covid 19 virus as a global pandemic due to its exponential transmission throughout the world. They have advised people to keep safe distances, to wash hands frequently, to wear a proper mask, and to get vaccinated at the earliest. They have also introduced new guidelines to adhere to the new normal. Despite these recommendations, public health system capacities have been exhausted in many countries and has caused deaths due to limited access to health care facilities. To reduce the number of deaths, WHO has further encouraged countries to implement home quarantine programs for people who are exposed to Covid 19 or have been a first contact of a Covid 19 patient. The purpose of this paper is to describe the development of an android-based application to monitor, track and advise the general public on various aspects of Covid 19 pandemic. This system mainly consists of an analytic dashboard that consists of latest statistics of Covid 19 pandemic, a health care monitoring system that can interact in real-time with health care authorities, an awareness platform to provide time-to-time updates on the latest guidelines provided by the health care authorities and also a Covid 19 contact tracing mechanism based on the google map. This system was tested with the help of randomly selected staff members and students of the Faculty of Engineering, University of Peradeniya.

Keywords: Covid 19, Android Application, Contact Tracing

1. Introduction

Covid 19 has become a global pandemic since the beginning of 2020 with its exponential spreading through airborne particles and droplets. Also, this virus is capable of easily creating variants that are deadlier than previous variants thus increasing the number of positive cases throughout the world. With the increasing number of cases, it is hard to treat such a large number of patients by the public health system and causes exhausting stress to health care workers [1]. This has led to patients who have severe symptoms not getting properly treated due to the increase in number of patients in hospitals and health care centers. As a result, it causes the total number of deaths around the world to gradually increase. Since this is a trade-off between health system capacity and the number of patients, it is important to classify patients depending on their symptoms. This will enable health care workers to focus on patients with severe and critical symptoms thus reducing the number of deaths. But patients who have no symptoms, mild symptoms, or moderate symptoms also need to be monitored from time to time because their symptoms might worsen [2]. So, it is important to have a system to monitor people who are being isolated due to Covid 19 exposure. This paper is mai nly based on the development of an android based application that can be used to advise, monitor, contact trace via google maps and inform the general community by providing safety guidelines from time to time depending on the situation.

2. Literature Review

Using mobile based applications as a solution for current challenges and problems is a current trend which has powerful impact on changing people's lives. There have been many studies conducted to help health care workers combat this Covid 19 pandemic using mobile applications.

Bouabida et al. (2021) has done a study in Canada to evaluate capacity and contribution of platforms which are used to monitor Covid 19 infected patients remotely [3]. The first platform is based on telecare phone call mechanism

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(Telecare Covid) and the second one is based on They have contacted a cross-sectional study on the patients who have been monitored remotely by using the above two platforms. They have found that both platforms have a similar overall satisfactory level of quality and safety. This study shows that, since the Care Simple Covid platform is based on a mobile application, it can support more interaction with patient care teams rather than phone call-based Telecare Covid system. Finally, they have suggested to develop these monitoring systems based on patient-centered approach to improve user friendliness and efficiency of these remote platforms.

Ranajoy et al. (2020) has done a study based on developing an android application to inform its users about different zones depending on the risk of Covid 19 contamination within India [4]. They have used Google Maps to show the identified areas depending on the data feed of the configured Google Firebase cloud storage.

Liz et al. (2021) have conducted a study based on the people's perspective and acceptance of the National Health Service Covid 19 app in the United Kingdom [5]. They have used an online survey on a sample of the UK population. They have employed the extended Technology Acceptance Model for this survey. More than half of the sample has downloaded the application and yet, the app has not been deleted from their devices. People have responded that the common reason for downloading the app is to help NHS to protect people. About one-third of the sample is not using the app claiming uncertainty of their privacy protection. Also, depending on the social groups, the attitude toward the app has drastically changed. They have concluded that the authorities need more work done for encouraging social groups towards digital tracing applications.

telemonitoring application (Care Simple Covid). Hanson et al. (2020) conducted a study to scope the evidence based on mobile applications that were developed in response to Covid 19 [6]. They have followed the instructions of PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analysis) as the main framework of their study. This mobile application was selected based on the most frequently visited online news articles published in 19 different countries within a defined time interval. They have categorized these applications depending on the purpose, application development organization, platform and technologies used in data collection. To improve their application usage, they have suggested having more government influence and rules and regulations to ensure people's trust.

The main drawback with the above mentioned systems is that they don't cover the whole patient monitoring, contact tracing, general public advising, and real time statistic feeding as a single system. The newly proposed system in this study is capable of covering all the aspects mentioned above as an end to end service provider.

3. Methodology

The system consists of an android application, a spring boot backend server, a Google Firebase cloud storage, and a RabbitMQ broker service as shown in Figure 1. All the user interactions are handled by the android application. Since almost all mobile phones can access the Google Play Store, people can easily download the application without any cost [8].

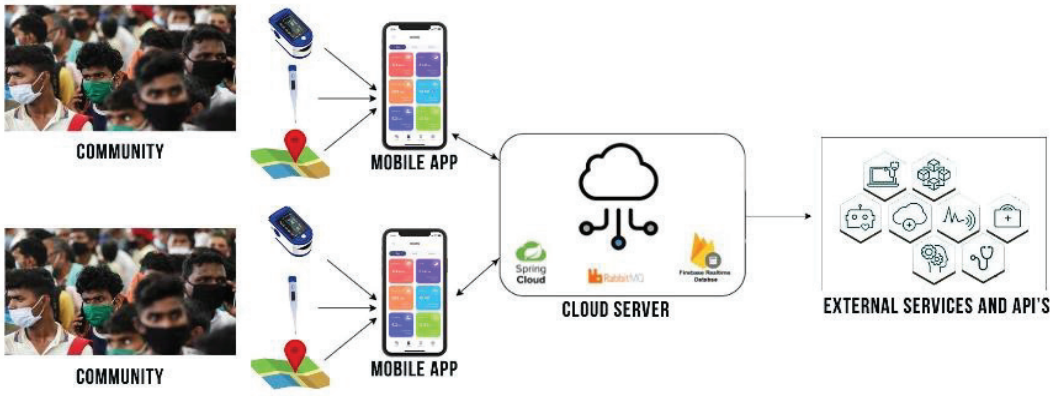

Figure 1 - System Architecture

The Spring Boot cloud server is the main processing unit that handles database management, user input data processing, and exposing processed data to external services and other data processing-related activities of the system. Google Firebase cloud storage is the main data storage of the system. The AMQP (Advanced Message Queue Protocol) based RabbitMQ message broker service is used to store and queue real-time user input readings.

3.1 Android Application

This app consists of six main components as shown in Figure 2.

- Login Screen
- User Registration Screen
- Summary Dashboard
- Incident Report Screen
- Risk Assessment and Evaluation Screen
- Contact Tracing Google Map

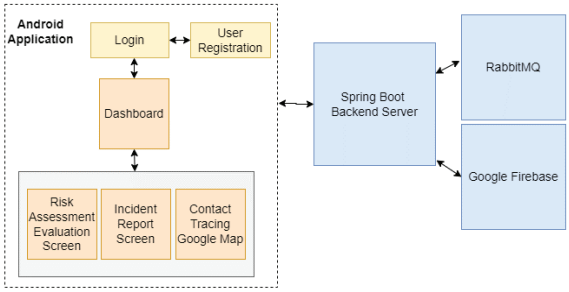

Figure 2 - System Overview-Android Application

The User Registration screen is used to get the required information of the user which requires one-time submission only (This information can be updated later if required). Users need to enter their contact details, information of the closest medical center, police station, and also contact details of the regional health officer. Also, we can identify different user roles such as general users, health care officials, etc. This information can be used to locate the user, in case of emergency situations and inform the necessary authorities to take immediate actions.

Once the user has successfully registered with his/her information, they can use the email and password used in the registration process to log in to the application. This step is required to protect the user's privacy and also to differentiate the users based on their credentials.

After the submission of credentials, the system will automatically generate an authentication token and send it back to the user's mobile phone. For the rest of its data communication, the android application will automatically send that generated token back to the cloud server in order to maintain security. This will ensure data security between the user and the system.

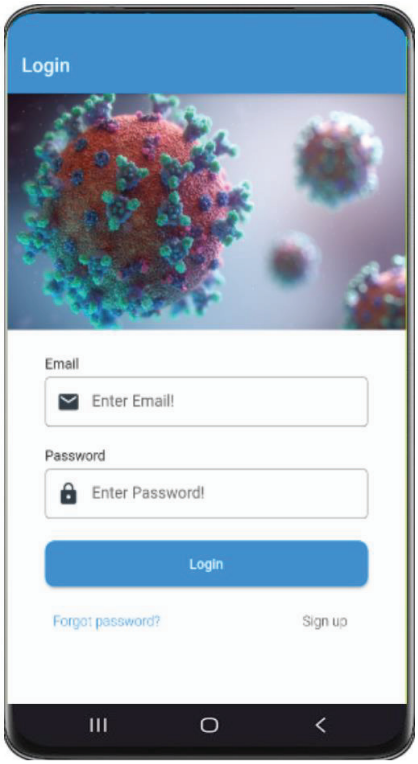

Figure 3 - Login Screen

Once the user successfully login with his/her credentials, the user will be directed to the summary dashboard page. This page contains guidelines and advice provided by health care authorities about the current Covid 19 situation.

This page will periodically update with the latest statistics of the Covid 19 data such as the total number of confirmed cases, the total number of deaths, the total number of new cases etc. from the Health Promotion Bureau Sri Lanka [10]. This page also provides an interface to report daily temperature readings, SpO2 level readings, and other health related parameters of the user. This data is useful in monitoring the patient remotely and providing necessary advice in real-time.

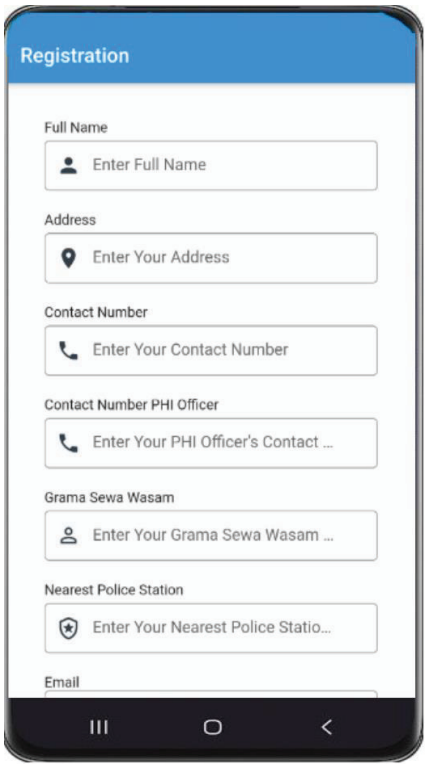

Figure 4 - Registration Page

The Incident Report Screen can be used by people who have been tested positive or who have been a first contact for Covid 19. The user needs to provide his/her personal details, vaccination details, nature of first contact (days of contact, days of last contact), and other useful details related to the severity of exposure to the virus. People can also report their past traveling history by selecting all the places and locations from Google Map together with the timestamp so that other people and health service authorities can easily trace subsequent contacts with less effort and resources. Since the system only considers those data points as a location with a timestamp (These data will not be correlated with the user and also there is no real-time location-based user tracking) their privacy can be ensured.

All the data submitted from the Incident Report Screen will be evaluated by authorized health officers and necessary decisions and actions taken accordingly. Once a user submits his/her information from the Incident Report Screen, it will be notified to a medical officer or a public health inspector (PHI) who is registered and knows the community. Then they can take a decision based on the information. Thereafter the officer is able to provide his/her feedback to the person who has submitted details from the Incident Report Screen.

The traveling history entered in the Incident Report Screen of Covid 19 infected people and people who have had close contacts are shown by using Google Maps in the Contact Tracing Google Map screen. This map can be used to identify high-risk areas and low risk areas. This will enable health authorities to clearly identify high-risk areas depending on the timestamp and to carry out further action to prevent the virus spreading further. Even the user is able to verify whether he/she has been exposed to the virus by considering the timestamps and the locations that they have visited. With that information, they can do self-isolation by themselves in order to prevent further spreading of the virus without any health authority involvement.

3.2 Spring Model-View-Controller (MVC) Backend Server

This is the main processing unit of the system. All the data provided from app users are processed here. This server uses spring MVC architecture to handle REST APIs (Representational State Transfer Application Programming Interface) as shown in Figure 5. A REST API is an application programming interface which can interact with web services based on RESTful architecture. These REST APIs can provide much better deal of flexibility rather than other protocols which are being used in web-based communication.

This MVC architecture consists of controllers for handling all HTTP (Hyper Text Transfer Protocol) requests and responses, service layers for implementing corresponding business logic, repository classes for extending database related CRUD operations, and models that contain the data of the application. This server handles user authentication, user information verification, database connections, process user inputs (Temperature Readings, SpO2 level Readings, Past Traveling Information, etc.), communication with health service end points, and takes care of all other processing related tasks [11].

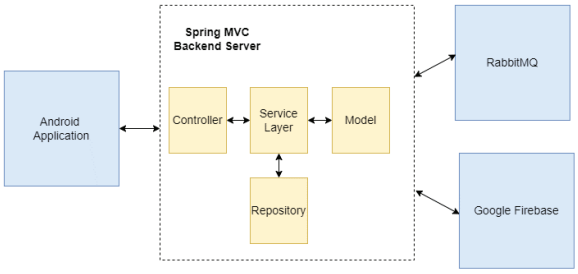

Figure 5 - System Overview - Spring MVC Backend

3.3 Google Firebase Cloud Storage

This is the cloud storage where all the data related to users are stored securely. The Spring MVC backend server will store all the data from the user-side and real time data from other services within this cloud storage. The back-end server will use, update, delete these stored data accordingly [12]. There are several important advantages for using Google Firebase as the main cloud storage in this system.

- Data Security: Firebase requires Google sign-in and two factor authentication to access cloud database.
- Firebase Cloud Messaging for Cross-Platform: From the Firebase cloud console, we can easily enable automatic push notifications to all the users without any additional programming effort.
- No SQL Support: Google Fire Store is a No SQL real time storage. This will make sure to store any kind of unstructured data related to an end-to-end system. Even though this cloud storage is a real time storage, it allows us to work without an internet connectivity and once the connectivity is back, it automatically syncs with the cached data.

The communication between the server and the database will be authorized by using a JavaScript Object Notation-based Web Token (JWT) generated from the Firebase cloud storage.

3.4 Advanced Message Queue Protocol based RabbitMQ (AMQP)

AMQP is a publisher-consumer based protocol to handle light weight messages. Once the android user publishes data related to temperature, SpO2 or any other reading and geo location related information, the consumers can consume these data from the intermediate AMQP message broker (We use RabbitMQ) as shown in Figure 6. This broker service can manage these lightweight messages between message publisher and message consumers while providing many advantages. Here the main consumer is the Spring Boot Backend server [13]. Also, these data can be consumed by any other service as well. There are several advantages in using RabbitMQ as the intermediate AMQP Message Broker.

- Scalable and Flexible: when the number of messages increases from the publisher side, it automatically creates parallel queues and handle them by itself.
- Guaranteed Delivery: RabbitMQ guarantees 100% delivery to its consumers even with the connection failures.

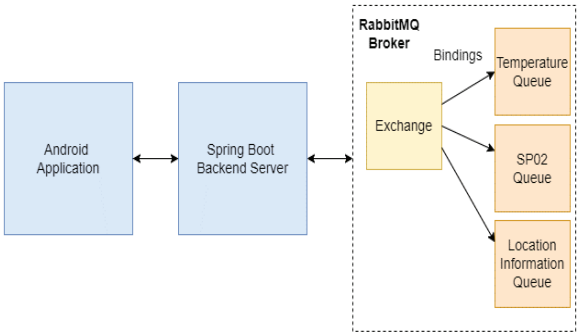

Figure 6 - System Overview - RabbitMQ Broker

4. Results

Once the user downloads and installs the application, the user will be directed to the login page as shown in Figure 3. User can use his/her credentials to log in to the system. If the user logs in to the application for the first time, they need to tap the sign-up button. Then the user will be directed to the Registration page as shown in Figure 4. Here the user needs to enter the full name, address, contact number, gramasewaka division, regional public health officer's contact number, closest police station contact number, email, and a password. The email and password can be used to log in to the system as their user credentials. The other information is used to inform relevant authorities in case of emergencies.

After successfully logging in to the system by entering the user's credentials, the user will then be directed to the summary dashboard as shown in Figure 7. On the top of the dashboard, users can see the important advice given as a news slider by the healthcare authorities from time to time. By tapping the right plus mark, the user can enter his/her current temperature, SpO2, and other useful readings into the system.

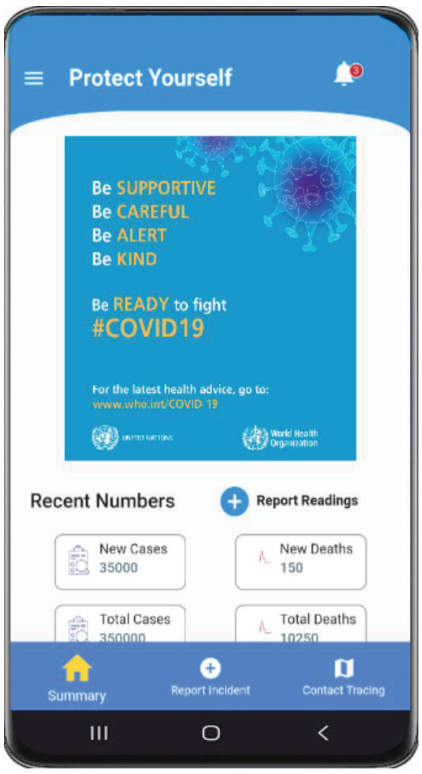

Figure 7 - Summary Dashboard

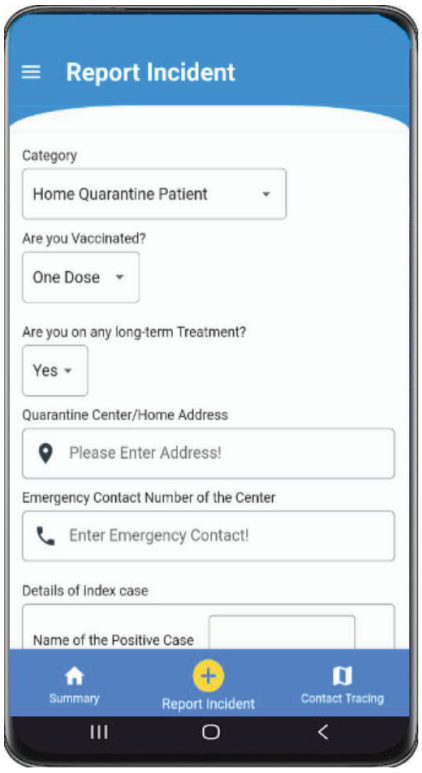

Figure 8 - Report Incident Screen

By tapping the Report Incident button on the bottom menu, the user will be directed to the Report Incident screen as shown in Figure 8. Here, if the user has been tested positive or identified as a close contact can submit his/her information to the system.

After successfully submitting the information on the Report Incident page, these data will be notified to a registered health officer as shown in Figure 9. This is a summary of the information so that the officer can make decisions based on user details.

These health officers can evaluate details and report their feedback from the screen as shown in Figure 10. With this feedback, the patient can take immediate actions to prevent further spreading of the virus and to make sure to have necessary treatments for himself/herself rather than waiting for health officers to visit.

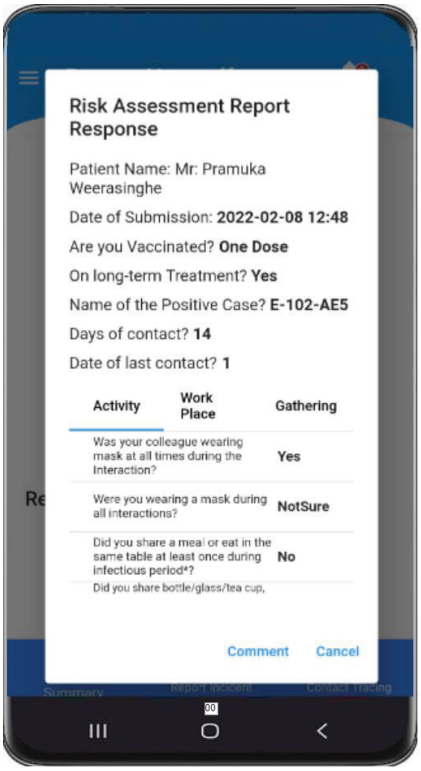

Figure 9 - Risk Assessment Report Response Screen

For contact tracing, users can access the tracing map as shown in Figure 11 by tapping the right-most button from the bottom menu. They can pick a specific date and a time duration from the date and time pickers from the bottom and check whether they have been exposed to a Covid 19 infected person at any place by tapping the search button. Then all the places exposed to Covid 19 infected people will be shown as red circles on the map within the time duration selected.

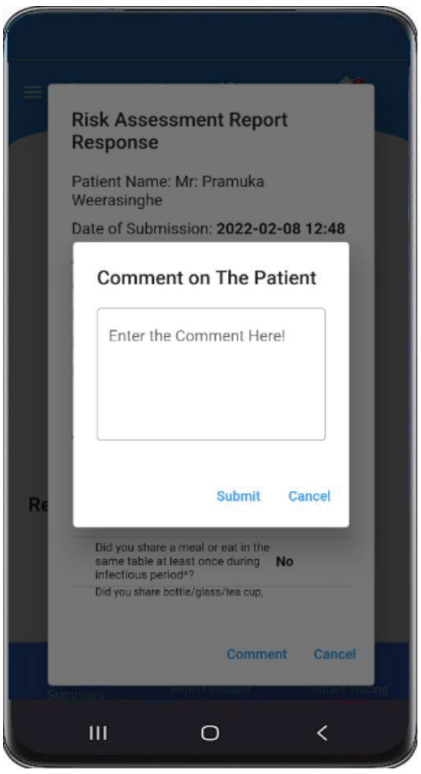

Figure 10 - Health Officials Feedback Screen

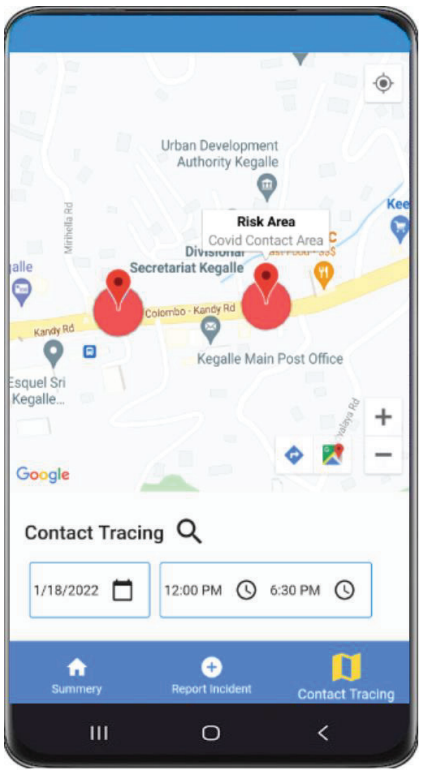

Figure 11 - Contact Tracing Google Map

All data coming from different users are handled by the cloud server by queuing, storing, processing, and exposing them to external APIs. Finally, these processed data are exposed as external APIs, so that other third-party applications and organizations can use that information to trace contacts, inform healthcare services and also conduct further studies.

The android application was tested with randomly selected staff members and students (sample size 50) of the Faculty of Engineering, University of Peradeniya.

As shown in Table 1, the following details are a summary of the data submitted by test users between 1st of April 2022 to 4th of April 2022.

Table 1 - Answers for the Questionnaire – Repeat Incident Page

Question	Yes	No	Not Sure
Was your colleague wearing mask at all times during the interaction?	12	32	6
Were you wearing a mask during all interactions?	15	35	0
Did you share a meal or eat at the same table at least once?	39	11	0
Did you share items at least once during the infectious period?	50	0	0
Did you share same transport?	31	15	4
Did you share the room while you are working?	47	3	0
Are you on any long-term treatment?	13	37	0
Are you vaccinated?	50	0	0

Table 2 – Past Traveling Histories – Contact Tracing Google Map

Date (MM/DD/ YYYY)	Duration (HH:MM)	Expected No of Pin Points on the map	Actual No of Pin Points on the map
04/01/2022	08:00 – 09:00	11	11
04/01/2022	12:00 – 13:00	21	21
04/01/2022	15:00 – 16:00	23	23
04/02/2022	08:00 – 09:00	39	39
04/02/2022	12:00 – 13:00	42	41
04/03/2022	08:00 – 08:30	45	44
04/03/2022	14:00 – 14:15	47	45
04/04/2022	07:00 – 07:15	31	31
04/04/2022	10:00 – 10:30	36	36
04/04/2022	18:00 – 18:30	37	37

With the collected sample data on the submitted traveling histories, the system was able to show the infected areas depending on the date and time duration selected with above 95% accuracy as shown in Table 2.

5. Discussion and Conclusions

Currently, there are many different systems being used to fight against Covid 19 pandemic. But most of them are based on real-time user tracking. Hence the users might hesitate to use such applications due to the privacy issues and the drastic battery drain. Moreover, there is no system that can monitor, track, advise the general public and feed real-time statistics of the Covid 19 pandemic.

The main goal of this system is to overcome the drawbacks of current available systems and provide an end to end service for the users. This system can be used as an information storage space for its users (Personal details, Emergency contacts, etc.). Once the system detects abnormalities related to the user's health, it can automatically inform relevant authorities in order to ensure their safety. This system can also be used as an awareness platform for health and safety. This will help users who have been exposed to the Covid 19 virus to verify to themselves the risk of being infected using the contact tracing page.

This contact tracing mechanism is not complex as tracing them does not require any additional tracing devices. This will simplify the way of contact tracing due to its simplicity. The external exposed APIs can be used by any kind of third-party application for various purposes. With the enormous amount of data, this system helps to reduce the effort and time for other researchers and application developers to obtain data related to the pandemic situation. By using these contact tracing details of close contacts and Covid 19 infected people, we can identify deferent levels of contacts (First contact, second contact, third contact, etc.) depending on each case as shown in Figure 12.

With the test data, the system was able to locate infected areas with above 95% accuracy. This is due to the size of the sample and the current algorithms of data processing. Once the system incorporates thousands of users, these algorithms may need to be updated in order to achieve higher accuracies and fast response times.

As for further development, this application can be used as a people awareness government health service platform for any kind of pandemic situation. This contact tracing mechanism can be improved so that all the relevant authorities and services can easily access these data for their analysis.

Currently, the healthcare officers (Doctors, Phi Officers, etc..) provide feedback to the registered users based on the submitted readings and answers received from the mobile application. As a future improvement, we can develop a machine learning-based model to predict early diagnosis results to support officers to make required decisions.

The health status monitoring system can be improved to monitor each and every user's health without taking them to healthcare centers. These data can be used to identify the nature of spreading of the virus and analyze symptoms against time. Many third-party applications and systems can be integrated with this system to face any kind of health threat without implementing new systems and

platforms. Also, this system can be further developed to fight against any kind of infectious disease rather than Covid 19 pandemic.

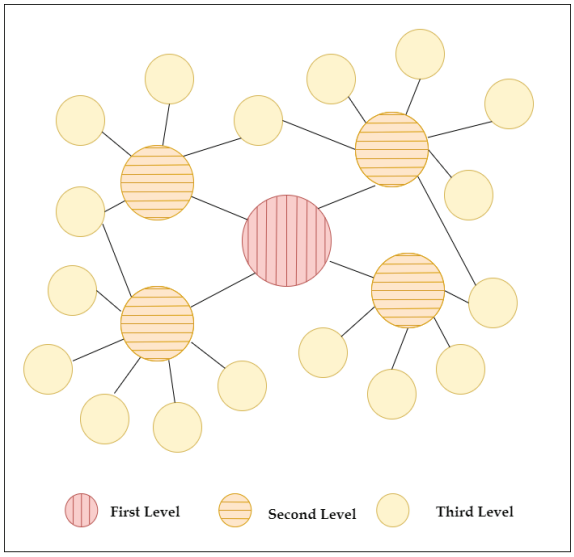

Figure 12 - Contact Tracing Diagram

References

1. Dadras, O., Alinaghi, S. A. S., Karimi, A. et al. Effects of COVID-19 Prevention Procedures on Other Common Infections: A Systematic Review. Eur J Med Res 26, 67 (2021). https://doi.org/10.1186/s40001-021-00539-1.

2. Lotfi, M., Hamblin, M. R., & Rezaei, N. (2020). COVID-19: Transmission, Prevention, and Potential Therapeutic Opportunities. Clin Chim Acta; International Journal of Clinical Chemistry, 508, 254–266. https://doi.org/10.1016/j.cca.2020.05.044.

3. Bouabida, Khayreddine & Malas, Kathy & Talbot, Annie & Desrosiers, Marie-Ève & Lavoie, Frédéric & Lebouche, Bertrand & Taguemout, Melissa & Rafie, Edmond & Lessard, David & Pomey, Marie-Pascale. (2021). Remote Patient Monitoring Program for COVID-19 Patients Following Hospital Discharge: A Cross-Sectional Study. Frontiers in Digital Health. 3. 721044. 10.3389/fdgth.2021.721044.

4. Mallik, R., Hazarika, A. P., Ghosh Dastidar, S., Sing, D., & Bandyopadhyay, R. (2020). Development of an Android Application for Viewing Covid-19 Containment Zones and Monitoring Violators Who are Trespassing into It Using Firebase and Geofencing. Transactions of the Indian National Academy of Engineering, 1–17. Advance online publication.

5. Dowthwaite, L., Fischer, J., Perez Vallejos, E., Portillo, V., Nichele, E., Goulden, M., McAuley, D., Public Adoption of and Trust in the NHS COVID-19 Contact Tracing App in the United Kingdom: Quantitative Online Survey Study. J Med Internet Res. 2021 Sep 17;23(9):e 29085. doi: 10.2196/29085. PMID: 34406960; PMCID: PMC8451731.

6. Singh J. L, H., Couch, D., & Yap, K. (2020). Mobile Health Apps that Help with COVID-19 Management: Scoping Review. JMIR Nursing, 3(1), e20596. https://doi.org/10.2196/20596.

7. Singh, R. P., Mohd Javaid, Abid Haleem, Rajiv Suman, Internet of Things (IoT) Applications to Fight Against COVID-19 Pandemic, Diabetes & Metabolic Syndrome: Clinical Research & Reviews, Volume 14, Issue 4, 2020, Pages 521-524, ISSN 1871-4021, https://doi.org/10.1016/j.dsx.2020.04.041.1.

8. Liu, J. and Yu, J., "Research on Development of Android Applications," 2011 4th International Conference on Intelligent Networks and Intelligent Systems, 2011, pp. 69-72, doi: 10.1109/ICINIS.2011.40.

9. Neumann, A. & Laranjeiro, N. & Bernardino, J. (2021). An Analysis of Public REST Web Service APIs. IEEE Transactions on Services Computing. 14. 957-970. 10.1109/TSC.2018.2847344.

10. https://www.hpb.health.gov.lk/en/api-documentation

11. Suryotrisongko, H., Jayanto, D. P, Tjahyanto, A., Design and Development of Backend Application for Public Complaint Systems Using Microservice Spring Boot, Procedia Computer Science, Volume 124, 2017, Pages 736-743, ISSN 1877-0509, https://doi.org/10.1016/j.procs.2017.12.212.

12. Khawas, C. & Shah, P. (2018). Application of Firebase in Android App Development-A Study. International Journal of Computer Applications. 179. 49-53. 10.5120/ijca2018917200.

13. Dixit, S., & Madhu, M., (2019). Distributing Messages using Rabbitmq with Advanced Message Exchanges. Int. J. Res. Stud. Computer. Sci. Eng., 6(2), 24-28.