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Use of Smartphone-based Contact Tracing Technology during COVID-19 Outbreak

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ABSTRACT: Tracing and controlling the widespread of infectious diseases such as current COVID-19 is very crucial to manage. One common measure taken to control the spread is to detect the infected individuals and trace their prior contacts so as to then selectively isolate any individuals likely to have been infected with COVID-19. These contacts are traced using mobile platforms such as Smartphone or Smartwatches, which can continuously collect their live locations and contacts of their owners by using their positioning and communication technologies, such as GPS, Cellular phone networks, Wi-Fi, and Bluetooth. This paper evaluates the use of these technologies and determines the impact of contact tracing accuracy on the spread and control of infectious diseases such as COVID-19. This paper also explains that in order to control the widespread of COVID-19 disease, the contact tracing technology must be very precise, contacts must be traced very quickly, and a significant percentage of the population must use the Smartphone or Smartwatches and must have a contact tracing application installed in it. These strict requirements make Smartphone-based contact tracing effective at the spread of the infection during the second outbreak of the virus. However, considering a second-wave of COVID-19, where a significant portion of the population will have gained immunity against COVID-19, or in combination with some other more precautionary measures, Smartphone-based contact tracing could be extremely useful.

KEYWORDS: COVID-19, Mobile platforms, Smartphone, Cellular phone networks, Contact Tracing.

I. INTRODUCTION

The current COVID-19 pandemic has resulted a major threat to our human society and way of life. Till date, hundreds of thousands of people around the world have died, and millions got infected. Most of the countries have taken severe precautionary measures, such as quarantines, nationwide lockdowns and social distancing, which continue to impact the population of countries dramatically. They started checking anyone with possible COVID-19 symptoms and when a case of infection was detected, their contacts were traced in order to detect new cases. The use of mobile tracing (mobile communication) was instrumental to accomplishing this task, and the pandemic was controlled without taking further steps [1]. Other countries, however, despite taking some measures after the initial outbreak such as quarantining infected people or checking their direct contacts only, did not manage to control the outbreak and eventually had to take further measures, such as lockdowns and social distancing. In addition to that, the impact on the world economy is still hard to predict. This paper focuses on how contact tracing impacts the control and spread of the COVID-19 disease. The comparison of several contact tracing technologies and the relative methods for obtaining the contacts are also mentioned. Therefore, This paper contributes significantly to a better understanding of the advantages and limitations of mobile contact tracing applications, particularly when applied to such extreme scenarios as COVID-19.

II. LITERATURE SURVEY

Detecting and controlling the infectious diseases is common when public health is considered. Through the use of new technologies such as internet-based patient surveillance, remote sensing, disease mapping, telecommunications and use of mobile phones, these infectious diseases can be detected, prevented and controlled. Other methods for detection and tracing of contacts uses wireless sensor network technologies, such as Wi-Fi, Bluetooth and ZigBee. One of the recent experiment in this was performed by Marcel Salathé [2]. They obtained high-resolution data of contacts on one day at a high school in America, which made it possible to reconstruct the relevant social network model from a perspective of an infectious disease transmission.

Authors Rosanna Mastrandrea and Alain Barrat [3] also used sensors to detect contacts between students and compared the results with contacts obtained from personal diaries. Further, the authors have compared how an infectious disease was spread using two different contact networks (i.e. from sensors and diaries), which showed a significant difference in their results.

Recent years have seen an increasing interest in the efficiency of contact tracing in pandemics. Contact tracing is a very useful measure which has a primary focus on potential new infectious cases. Contact tracing has proven to be a highly successful strategy when the number of cases is low, or at the early stages of an outbreak, or especially when the disease may be asymptomatic but still vulnerable to spread the infection, as it provides the only means by which such individuals responsible for spreading the disease can be easily identified [4]. Other studies evaluate the main factor in making an outbreak of this disease controllable [5], [6].

Some recent studies are specifically based on COVID-19 pandemic. Author Luca Ferretti and others [7] claims that isolating the patient and its contact tracing which is currently practised is not beneficial in prevention of COVID-19 spread. This is mostly due to a large number of asymptomatic infected individuals that remain undetected and then they contribute to the spread of the disease. Thus, they have proposed the use of mobile applications to trace previous contacts, showing mathematically that spread can be contained even when not all the population uses the mobile application, although the required portion is significantly high. Author Joel Hellewell [8] drawn a similar conclusion through his mentioned model. That is, in most of the scenario, high amount of contact tracing and patient isolation are sufficient to control the new outbreak of COVID-19 within next 3 months of spread, or even when 70-80% of the total contacts are tracked. Thereby, these procedures make Smartphone-based contact tracing far from being a realistic solution.

One of the recent attempts of using mobile phones to estimate contacts was the FluPhone application developed at Cambridge University [9]. The application used Bluetooth and other wireless signals as a proxy for estimating physical contacts and asked users to report Flu like symptoms in order to track the risk of disease. For COVID-19, the Government of Singapore have developed the Trace-Together mobile Application for allowing a better contact tracing in response to the COVID-19 spread in Singapore. It is depended on Bluetooth and had already been used to control disease spread [10]. Other similar applications, which also focusing on privacy issues, are the Pan-European Privacy Preserving Proximity Tracing (PEPP-PT) [11] and SafePaths [12], [13]. Finally, at last, Google and Apple have teamed up to developed similar solutions into the iOS and Android operating systems. They integrated it into the operating systems as the proposed solutions were more beneficial, and more importantly, they were user-friendly.

Gathering the personal information, even for health application purposes, have specific challenges when it comes to securing ethical principles and personal privacy issues [14]. Finally, the analysis of personal information can be explained if it can be beneficial to public health. This paper therefore explains how smart device contact tracing technology can reduce the spread of infectious disease like current COVID-19 and the associated cost for medical measures. To evaluate these contact tracing technologies, it is necessary to consider the contacts individually. Additionally, as an example, we use a real scenario to evaluate these contact tracing technologies.

III. WHAT IS CONTACT TRACING ?

Contact tracing is the process of identifying, assessing, and managing people who have been exposed to a specific disease to prevent onward transmission. When systematically applied, contact tracing will break the chains of transmission of an infectious disease and is thus an essential public health tool for controlling infectious disease outbreaks. Contact tracing for COVID-19 requires identifying persons who may have been exposed to COVID-19 and following them up daily for 14 days from the last point of exposure [15].

Critical elements of the implementation of contact tracing are community engagement and public support, careful planning and consideration of local contexts, communities, and cultures, a workforce of trained contact tracers and supervisors logistics support to contact tracing teams and a system to collect, compile, and analyse data in real-time.

For contact tracing to be precisely effective, countries must have adequate capacity to test suspect cases in a timely manner. Where this is not possible, testing [16] and contact tracing strategies may instead focus on specific high-risk settings with vulnerable individuals, such as hospitals, nursing homes, or other closed settings (e.g. dormitories).

When countries have passed the peak period of transmission and number of cases are decreasing, and particularly when strict public health and social measures are being adjusted, rapid identification of cases and contact tracing are very helpful to maintain low levels of transmission and rapidly identify and break new transmission chains.

IV. METHODS OF TRACING THE CONTACTS

Basically, contacts are obtained manually through conducting personal interviews, during which the patient is asked to remember prior contacts or any locations that he/she had visited during pandemic. This approach is widely used for specific kinds of diseases (particularly transmitted ones) where the contacts are easy to remember. For most infectious diseases, like in the current COVID-19 situation, however, personal interviews provide very poor tracing response of visited locations and prior contacts.

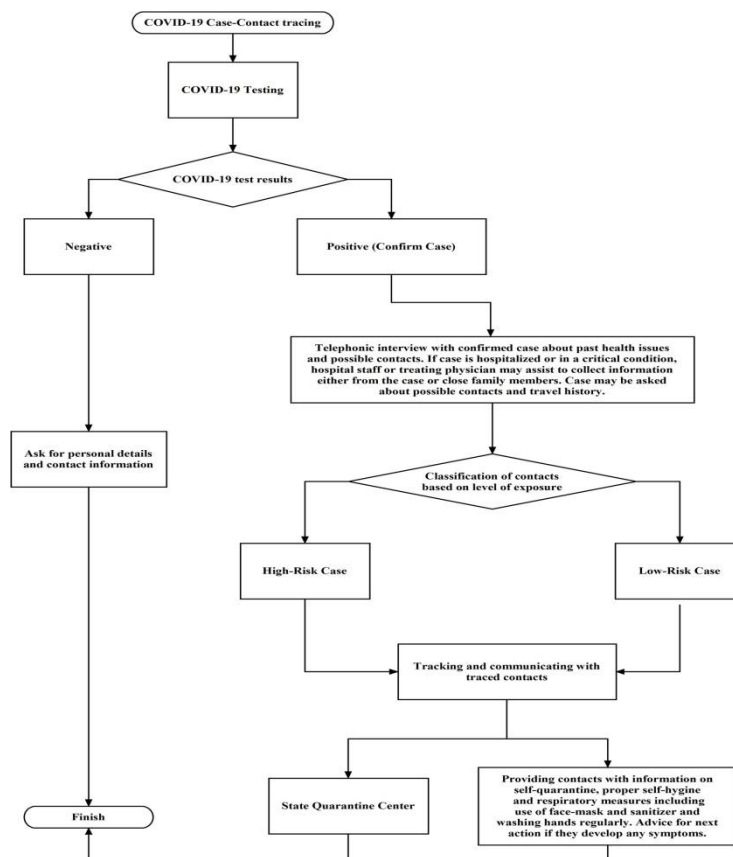


Figure 1: COVID-19 Contact Tracing Procedure Flowchart.

A. Mobile Contact Tracing

Mobile contact tracing technology is actually based on the idea of tracking contacts by using some of the latest communication technologies. In this, we mention the ability of four different technologies to obtain a significant data of contacts.

1. **Cell:** The mobile phone network is distributed over large areas called cells. Telecommunication service providers can determine the location of connected phones depending on which cell the mobile phone is connected. Division of a city into small cells allows extensive frequency reuse across the entire city, so that millions of people can use cell phones simultaneously [17]. Cell phones operate within cells, and they switch cells as they move around a city. Cells give cell phones a network range. Someone using a cell phone can drive over a long distance and maintain a conversation for entire time because of the network approach. Each cell has a base station that contains of a tower and a small building containing the radio equipment.

2. **Wi-Fi:** The Wi-Fi works on the same principal as other wireless devices. It uses radio frequencies to send signals between connected devices. The radio frequencies are completely different from cell phones, car radios, and transistor radios. For example, a typical car stereo receives frequencies in Kilohertz and Megahertz range whereas Wi-Fi transmits and receives data in the Gigahertz range. A Wi-Fi hotspot is created by installing an access point to an internet connection [18]. Then that access point transmits a wireless signal over a short distance. It typically covers around 300 feet. When a Wi-Fi enabled device such as a mobile phone detects a hotspot, then the device is then connected to that network wirelessly.
3. **GPS:** The GPS (Global Positioning System) is a satellite-based navigation system. It provides time and location-based information to a GPS receiver, located anywhere on or near the earth's surface [19]. A GPS operates independently of the user's internet connection or mobile network signal. The range of tracing is about 10 to 15 meters outdoors, although indoors the precision for detection is severely reduced, making this a restriction because most infectious contact takes place at indoors.
4. **Bluetooth:** Bluetooth uses short-range to link two devices together. The standards of Bluetooth specifies a uniform structure for communication between a wide range of devices with minimal user effort. So, another way to look at Bluetooth is that it is a robust, simple and economical technology that offers wireless access to Local Area Networks, mobile phone networks, the Internet and so much more [20]. Bluetooth is the most suitable technology because it allows tracers to detect contacts within a range of 2-3 meters [21]. These contacts are considered as a contacts capable of passing the infection from one person to the another.

B. Remote health monitoring and wearable sensors

In many countries, even with high standards of healthcare like in Denmark, United Kingdom or in United States of America, the healthcare systems have trouble handling the large number of patients [22]. The severity of the disease, which at first affects the human respiratory tract, varies from mild or asymptomatic to critical [23]. patients are usually receive treatment on that basis. Those who are severely ill are hospitalized as they may require external life support system and intensive care, while those with mild symptoms are home quarantined, considering their condition may not get worse after they get infected [24]. These prevents the countries healthcare systems from being overloaded.

In this age of technology, the progress in wearable technology, embedded systems, IoT and telemedicine, makes remote health monitoring of patients to check if their symptoms gets worse. This kind of monitoring is very much important for vulnerable age groups, i.e. for people aged above 60 years and/or with pre-existing health issues like cardiovascular or respiratory disorders [25]. Also, patients with Non-COVID-19 and Non-emergency health issues can be monitored remotely, which can reduce the chance of cross-infection.

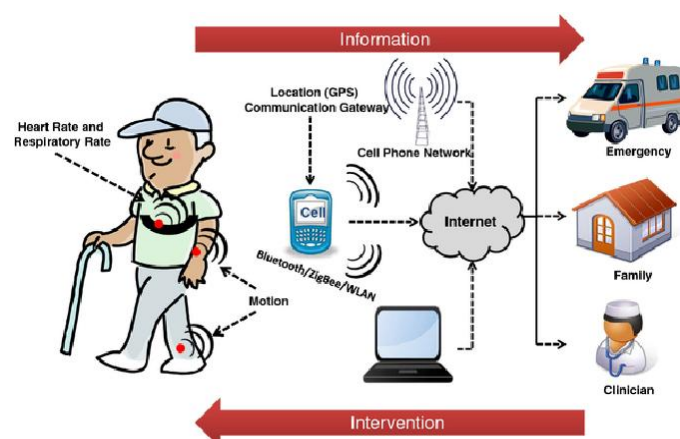


Figure 2: Picture showing Remote health monitoring system based on wearable sensors [26].

V. PRIVACY, SECURITY AND DATA MANAGEMENT

One of the major issues in any tracing application is privacy, security and management of the data that is collected. Since contact tracing technologies use location and personal information of users, there arises important privacy concerns. In the absence of a particular vaccine for COVID-19, countries around the world have used this contact

tracing technology to limit the spread of COVID-19, for assisting healthcare units to trace individuals and limit community spread, and to relax nationwide lockdown restrictions. There is a race in development of contact tracing mobile applications and in the last few months, and around 45 such apps have been launched worldwide in over 25 countries.

A. Action Mechanism

The contact tracing applications require constant access to a person's location history through GPS. The user has to type information such as name, age, gender, mobile number, profession, travel history etc. Bluetooth range is considered as proximity sensor and helps to alert a user if there is a possibility of contact with another user who is infected in that range. Many of these applications globally work on the centralized model which effectively means that the location details and the collected personal data by the application into a central database rather than storing locally on the user's phone. This database is most likely to be controlled by the country's government or the local health body raising serious questions on the data transparency and the principles of Cybersecurity to stop misuse of this data for any unintended purpose [27].

B. Progress of other countries and data privacy issues

The infection of COVID-19 was first identified in Wuhan, China and has resulted in the current worldwide pandemic. China was amongst the first few countries to develop these applications for its population and this played an important role in the control of spread and to lift regional lockdowns in the country. Despite questions being raised on the functionality of these application, countries such as Taiwan, Korea and Hong Kong have successfully used this mobile applications to keep monitoring people in quarantine resulted in limiting the outbreak. In Singapore and Australia, users can request the government for deleting their personal data stored on servers.

In Poland, the official contract tracing application is subjected to a debate on privacy and surveillance issue when number of problems are detected. A security issue in Qatar's COVID-19 contact tracing application have risked the personal data of more than one million people before it was fixed. Gulf countries such as UAE, Bahrain and Saudi Arabia have made the use of the applications mandatory by issuing warnings in terms for violations which has led to severe backlash from regulators and activists. US has no contract tracing plan yet for its citizens but many of the states have announced their own methods of tracing in the form of applications working on the Bluetooth technology or by simply sending survey questionnaires via text or email to gather information from the people to track the infection.

However, amongst the privacy issues in contact tracing applications, many countries are taking appropriate measures. Europe follows one of the strict privacy regulations in the world. Switzerland developed the world's first contact tracing application built on the API platform developed by Apple and Google together which follows a decentralized approach. UK is conducting trials to develop a second application which is based on this Apple-Google API and will be UK's first application is based on the centralized model. Austria, Germany, Ireland and Italy are also working on building apps using the Apple-Google API platform [27].

On 2nd April of 2020, India's official COVID-19 tracing application, Aarogya Setu, was launched. It is an open-source application. This application is aimed at the initiatives of the Government of India, particularly by the Department of Health, in proactive reaching out to and informing the users of the application regarding risks, syndrome mapping and relevant advisories regarding the containment of COVID-19. After that it has witnessed 120 million downloads till May 29th, making it the most downloaded contact tracing application in the world and the seventh most downloaded application worldwide in April crossing Netflix. It is available in 12 languages on Android, iOS and KaiOS platforms. It uses Smartphone's GPS and Bluetooth features to track the COVID-19 infection. The application has helped to predict COVID-19 virus hotspots, traced many individuals and alerted citizens of India of possible infections. The data that the Aarogya Setu application collected is divided into four categories- contact, location, self-assessment and demography and is stored and managed on the government servers. The collected user's data is deleted from the government server after a maximum of 60 days and the information stored on phone is deleted in 30 days [28].

C. Conflict between public health and information privacy policy

Citizens and social activists in many countries have mentioned concerns that governments can use this health crisis for surveillance and may violate their fundamental rights. A recent research by experts in John Hopkins University suggested that the privacy issues should not affect the public health goals and other fundamental values.

Eventually, this situation can also be observed with a different point of view. Many countries in the world are dealing with current health crisis and in these challenging times there are some extent of conflicts between regulations and measures to deal with health, financial and humanitarian challenges brought by COVID-19 pandemic. Issues related to individuals privacy may impact the ability to gather personal information which is required for a successful contact tracing. Country Governments, technical organizations and local health bodies should contribute to data transparency and increase trust for the efficacy of the applications amongst people. Releasing the application source code of the contact tracing applications were done by United Kingdom, India and other countries as a first step in that direction. This could go a longer way in setting standards for using personal data for dealing with health crisis amongst people.

VI. DATA TRANSPARENCY

There is always a genuine public concern about the type of information which is being collected from the user's Smartphone and its usage by various third-party applications. There are two essential approaches to achieve the data transparency. The first option is to make the source code of the application open. Publicly releasing the application source code improves the data transparency and trust in the system, as the implemented privacy and security features can be scrutinised by the researchers and academic community. This includes the publication of both the application and the server-side code, as they together form the tracing system. Although this could be the preferred option, but public release of source code does not ensure security. Many risks and complications may arise from system configurations and the use of a system that is not readily observable from the source code analysis.

A better option would be to ensure that the code is subjected to periodic review and trusted third-party audits to verify the functionalities against documented features to ensure that all future versions are compliant with the specifications on privacy and security. While transparency is a key to wider adoption by the end-users, it is essential to note that ultimately a degree of trust is required in the use of any mobile application. This includes trusting the developers, the independent test and verification team, the operators and owners of the service, and importantly, the companies providing essential infrastructure such as the mobile phone operating systems [29].

VII. CONCLUSION

The current COVID-19 pandemic has a continuous effect on the way of life of everyone. The Smartphone-based contact tracing applications are likely to play an important role in assisting health authorities quickly to identify individuals that may have been exposed to the disease. The imminent interest and adoption of tracing application technology will improve the tracing capability of health authorities; however, as this paper highlighted, it is not a final solution. These applications still face many issues from users, data protection agencies, and researchers [30]. The main issues are related to the user data management, potentially non-trivial false positive and negative instances, and the security and privacy issues of these applications. Additionally, this paper has focused on the privacy and security issues. Security attacks could be possibly performed on user's privacy. This paper also describes some other user's issues regarding connectivity, compatibility, consent withdrawal, and data transparency. Finally, there are some of the near and long term future research directions.

VIII. FUTURE PROJECTIONS

This paper therefore contributes significantly a better understanding of advantages and limitations of Smartphone-based contact tracing applications, particularly when applied to such scenarios as COVID-19 pandemic. Some of the most important results are:

- Rapid contact tracing is extremely important for quickly isolating potentially infected individuals, particularly for a disease such as COVID-19, with a high reproduction rate and low detection rate. This analysis is in agreement with some recent results found in papers [7], [8], although the present methodology differs substantially from the one which is used previously.
- Smartphone-based contact tracing accuracy mainly effects the actual number of quarantined persons, as it allows for a greater selectivity when quarantining citizens, by reducing the personal inconveniences and economical costs of these drastic measures. However, this accuracy has no significant impact on reducing the final number of infected individuals.

- Smartphone-based contact tracing, when adopted during the first outbreak, can only be effective when a fast and high-precision contact tracing technology is used, and when a significant proportion (i.e. more than 80%) of the total population uses the Smartphone and Smartphone applications. These requirements make it unlikely to be a feasible solution on its own.
- Fortunately, for future outbreaks, and under the condition that at least 20-30% of individuals gain immunisation or that the reproductive rate gets reduced by some other more strict social distancing measures, Smartphone-based contact tracing can be very effective, even when only a portion of the population is willing to use it (i.e. less than 60%).

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