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Contact-Tracing Approaches to Fight Covid-19 Pandemic: Limits and Ethical Challenges

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***Abstract*— COVID-19 pandemic is the largest worldwide sanitary and economical crisis of modern time. According to the World Health Organization (WHO), the new corona virus is spreading rapidly from person to person through contact transmission. To fight the COVID-19 outbreak, a number of strategies have been implemented at the population level, such as social distancing, testing and contact tracing. In this work, we focus on contact tracing, which is considered an effective public health measure to control the spread of this disease by identifying and tracking potential persons who may have been in contact with a COVID-19 infected person. To this end, we review various approaches and existing contact tracing applications used by various governments around the world to monitor and control the spread of this disease. Then, we discuss the limits and ethical issues of such digital contact tracing solutions.**

Keywords*— *COVID-19, contact tracing, pandemic, positioning, surveillance.

I. INTRODUCTION

Nowadays, the widespread and high transmission rates of COVID-19 are the main risk factors that led the World Health Organization (WHO) to declare this disease as a public health emergency of international concern.

For centuries, infectious diseases have been considered a major threat for humanity and can destroy entire populations. Therefore, understanding the disease remains the only way to control and limit its spread. In this context, modeling has been widely used to understand the spread of diseases and to determine the best strategies required to reduce their impacts [1].

Within the context of the current health crisis, several modeling studies have been carried out to understand the nature and characteristics of COVID-19 disease. These investigations show that the process of identifying susceptible individuals will help to control the pandemic spread, especially now as many countries around the world are moving towards the lifting of containment.

In fact, the purpose of contact tracing is to control the spread of a contagious disease [3] and it was commonly used as an ancient procedure and an indispensable step in the strategy to fight previous epidemics such as Ebola and Tuberculosis [4]. To this end, many governments around the world rely on contact tracing methods to monitor and limit the spread of the COVID-19 pandemic [2]. Furthermore, the WHO organization has recommended it as one of important population-wide strategies to tackle against COVID-19.

Obviously, Contact tracing can be performed manually, by human tracers, who interview the infected persons about all their recent contacts and then follow them [5]. However, this traditional method is not very effective in identifying all susceptible contacts as it is based on the memory of the infected persons, who cannot remember all individuals who have been in close contact with them during the period where they were potentially infectious (up to 14 days). Moreover, it is also impossible to trace potential contacts that have in close contact with the infected person in public transport or public spaces. Therefore, the study [6] shows that the use of technological applications, carefully designed, can help make the contact tracing process more efficient.

In this context, several countries around the world use -or debate- different approaches of contact tracing on mobile apps to control the COVID-19 outbreak dissemination. In fact, the key to ongoing containment of the pandemic in Singapore and several provinces in China is the use of contact tracing app that help to limit the number of their initial outbreaks [7]–[9] by identifying many new cases, often before symptom-onset which decrease significantly the likelihood of sustained transmission [10], [11]. Moreover, such solutions were also effective to reduce the spread of the disease in China and South Korea during the widespread transmission period [8], [12], [13] even if the diversity of technical solutions proposed for contact tracing has solicited a debate on their practical effectiveness and ethical issues. In this survey, we present a review of all contact tracing approaches used by different countries to tackle against the COVID-19 pandemic. Then, we discuss the limits and issues encountered by governments while deploying such solutions on mobile applications.

The paper is organized as follows: Section 2 gives basic concepts related to the contact tracing. In Section 3, we describe different approaches of contact tracing and their limitations. Section 4 presents an overview of some existing mobile applications serving to trace the disease dissemination. In sections 5 and 6, we introduce some ethical challenges. Then, we discuss issues that can limit the effectiveness and efficiency of these applications. Finally, the section 7 gives conclusions and identifies future works.

II. CONTACT TRACING

A. Principe

Contact tracing allows identifying each person in close contact with someone infected with a virus, such as COVID-19. The aim is to control the pandemic spread by breaking the chains of transmission of infection [14].

In contact tracing process, a contact is a person who has experienced any of the following cases during the two days

before and the 14 days after the onset of symptoms of a probable or confirmed case [15]:

- Face-to-face contact with a probable or confirmed case within one meter and for more than 15 minutes.
- Direct physical contact with a probable or confirmed case.
- Direct care for a patient with probable or confirmed COVID-19 disease without using proper personal protective equipment.
- Other situations as indicated by risk assessment of situations. For example, exposure in closed environments such as classrooms, places of worship, hospital waiting rooms, and shared Transport.

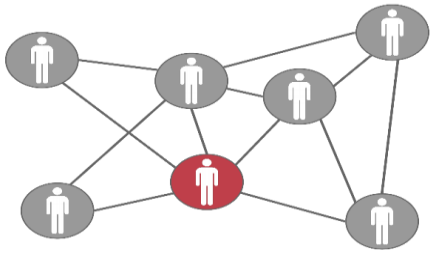

Fig. 1. Contact tracing overview

B. Procedure

According to [15], the monitoring process of the contact tracing follows four basic steps:

- **Contact identification:** For each confirmed COVID-19 infection, contacts are identified either by the traditional strategy through asking about the persons' activities and those of the people around them, or by the technology strategy using the mobile applications of contact tracing.
- **Contact listing:** refers of all people who have contact with the infected person. The objective is to inform each listed contact about their contact status.
- **Contact follow-up:** In order to control the symptoms and test signs of infection, a regular process of follow-up should be conducted with all contacts in order to receive early care if symptoms develop and send them all information about prevention of the disease and the action that will follow such as quarantine or isolation, if it is a high risk contact, either at home or in hospital.
- **Contact discharge:** In this step, contacts will be removed from the follow-up list if they met one of the following criteria:
  - ✓ If the contact finishes 14 days of follow-up without any COVID-19 symptoms.
  - ✓ The contact confirmed as an infected person and moved to a case list.
  - ✓ If the health authorities' investigation confirms that the person is non-contact.

III. CONTACT TRACING APPROACHES

Due to the actual health crisis related to COVID-19, the health authorities commonly used different techniques to trace the movement of infected persons and identify their contacts. In this section, we present a brief description of different approaches of contact tracing as well as some limitations of each case.

A. Self-assessment surveys

The first approach is the self-assessment surveys which is a traditional method to generate a list of close contacts, who they might have infected, during the past 2 weeks based on the interviews between health professionals and the infected persons [5].

Limits: The major limitation of this method is that the results are imprecise and unreliable. In fact, the results are based only on the memory of the person interviewed, and thus it is very difficult to determine whether a contact was important enough to be considered a random contact or a case to be analyzed. Moreover, the process is very slow which can take several days to reach out to all persons who is in close contact with an infected person.

B. Cell tower location data

Cell tower is a technology method used to track the position of a mobile phone using the signal emitted by the cell phone to the nearest cell tower. Once the cell phone is connected to a cell tower, Wireless carriers collect and store the information about cell phone's location. Using this information, the carrier can gives an approximate location of the mobile phone[16].

***Limits*:** This approach is not precise enough and provides poorer results as compared to other approaches such as GPS or Bluetooth because it is not very informative to determine how two phone are close to each other and thus to predict the possible infections.

C. Global Positioning System (GPS)

Modern mobile phones embed a satellite-based radio navigation system (called GPS) which operates based on the leverage of wireless network of a mobile's operator. In the case of a pandemic, the GPS system can be used to trace recent path of an infected person, inform the population of areas at risk, and finally to identify recent contacts in close to the infected person[5].

***Limits*:** The geo location data may be not operate or lack of precision in some confined spaces (supermarkets, metro), because the GPS uses the cellular network and the precision depends on the strength of the signal between the mobile phone and the cell tower**.**

D. Bluetooth

According to this method, users must install a mobile application and activate the "bluetooth mode" on their phone. Then, whenever two phones with the application installed are in close proximity to each other, they will exchange their encrypted contact information. This data can identify the mobile phone and by measuring the strength of the signal between two phones, Bluetooth can help to establish if there has been contact between two people based on the calculated approximate distance. A history of all devices of people who have been in contact with the person is stored in the phone. No personal identification data is required and no geographic location information is recorded [5].

***Limits*:** To effectively identify "contact" subjects, a high number of users in the population must use the contact tracing application. According to [17], such application will be effective if it is by about 60% of the population. This goal

is still difficult to achieve and requires a broad awareness campaign.

E. *QR codes:*

QR Code (Quick Response) is a two-dimensional barcode that can store data information [18]. In the current health crisis, several countries use this technology to track the spread of the COVID-19 disease. This new approach uses a specific application to scan the QR code of each person at the entrances buildings such as hospitals or restaurants. The approach can be combined with physical temperature testing equipment or thermal imaging cameras to track the person' movement on public transport [19].

***Limits*:** This approach restricts the movement of the population as government authorities compel them to scan their QR code at every entrance to stores, subways and other public buildings [16].

F. *Credit card / public transit card*

Some countries, such as Singapore and South Korea, are using the credit card as well as the public transit card to track the healthy and infected individuals' movement in public spaces [17]. In the case of credit cards, the bank records all information about a transaction, including the location, at each payment or withdrawal by credit card. This information is used to track the movements of their customers whereas; the public transit card is used when a public transit subscriber validates the card at a bus or at a subway terminal. In this case, the positions at the entrance to the network as well as the positions of the connections are recorded by the transit operator.

Limits: These approaches are very limited, since they reconstruct quite partially the itinerary of tracked persons. Moreover, they require the consent of the individuals prior to the backtracking process.

G. *Videos Surveillance*

Videos surveillance, controlled by human or an artificial intelligence program, can help to identify the contacts of an infected person by distinguishing people's faces within the public space.

***Limits*:** This approach presents some limitations. In fact, if the observation of videos is made by humans, the task will be long and complex. However, if the observation is made by an artificial intelligence program, the major issue is the lack of algorithms' performance regarding the automatic identification.

TABLE I. SUMMARIZATION

Digital approach	Investigation	Limitations
Self-assessment surveys	Traditional contact tracing method based on the interviews of infected persons by health professionals	• imprecise and unreliable results • slow process
Cell tower location data	Track the position of a mobile phone using the signal emitted by the nearest cell tower	Not very informative to predict the possible infections.
GPS	Determine location and time information of a mobile phone	Lack of precision in some confined spaces.
Bluetooth	Detect phones with the application installed	Require a high number of users for efficiency
QR codes	Track individuals' movement in public spaces	Restricts the movement of people
Credit card / Public transit card	Track the person' movement on public spaces and transport	Reconstruct partially the itinerary of tracked persons
Surveillance videos	Identify contacts of an infected person by detecting people's faces	• Complex task • Lack of performance

IV. CONTACT TRACING APPS TO FIGHT COVID-19

According to the WHO organization, the lifting of containment measures may trigger a new wave of COVID-19 infections. In this context, several contact tracing applications have been deployed throughout the world in order to track and limit the disease spread and thus giving people back their mobility and keeping them safe. In this section, we provide a brief presentation of some existing contact tracing applications used in many countries to tackle against COVID-19 pandemic.

A. *Exposure Notifications*

The two American compatriots Apple and Google have joined their efforts to develop "Exposure Notifications"[20] . The application uses Bluetooth technology on mobile devices to help authorities to trace the COVID-19 dissemination. The proposed application is a two-phase solution that aims to allow infected people who know they are infected to share this information with others persons on the one hand, and to alert individuals who have crossed their paths on the other hand. Hence, the application defines two user roles:

- Affected user: When a user has a confirmed or potential exposure to COVID-19, the framework identifies them as affected and shares their diagnosis keys to alert other users to potential exposure.
- Potentially exposed user: To assign a user the potentially exposed role, the framework determines whether a set of temporary exposure keys indicate proximity to an affected user. If so, the app can retrieve additional information such as date and duration from the framework.

B. *TraceTogether*

TraceTogether is a mobile application developed by Singapore's Government Technology to support the existing efforts to fight COVID-19 pandemic by adopting a community-driven approach of contact tracing. The application is based on Bluetooth technology to track the disease spread. Indeed, while mobile phones with TraceTogether application are close to each other, they exchange information anonymously about their proximity via Bluetooth. The application store this information securely on the mobile, and only the Ministry of Health can access data if a user is diagnosed by covid-19 infection [21]. Moreover, to determine if two persons are in close contact, TraceTogether estimates:

- The approximate distance between them by measuring the signal strength between their mobiles using signal strength indicator (RSSI) values, and
- The approximate duration by interpolating between successive communications.

C. CoviFight:

CoviFight app is a solution developed by a team of German and Indian software developers. It is a 3-tier solution with a user's app, a provider's app, and an official portal .The system aims to:

- Alert users to the risks the virus' contamination if they were in contact with an infected person within the past three weeks. To this end, the solution uses machine learning and social networking analysis
- Identify the public place or the transport mode that needs sterilization.
- Inform the medical system accurately about the spread of infection.
- Generate a map with hotspots for what places have virus traces so that people can prevent travel to and from these places and authorities can sterilize or lockdown these places efficiently rather than having a complete lockdown of a country.

D. COVI-ID:

South African's government launched COVI-ID" a contact tracing application to support the authorities' efforts to stop the spread of COVID-19.

Therefore, COVI-ID is used to track the movement of citizens and to follow the respect of precautionary measures taken to fight COVID-19 through the use of a simple QR Code generated for each user. In order to enable users to receive their health status from medical professionals and to control their personal information, the application use the self-sovereign identity (SSI). Therefore, only the user can control how the government uses their personal and sensitive data.

E. Rakning C-19:

Rakning C-19 is an Icelandic application, which is based on the GPS localization. Nearly 40% of Icelanders are using Rakning C-19. The application tracks users' GPS data to compile a record of where they have been. Then, it analyses the movements of individuals and in case of infection or suspected infection, the application compares itineraries to those of infected persons.

Once the application is configured, it runs in background and records the phone's position several times per hour. The data is stored locally on the phone and only data from the last 14 days is stored. Older data is deleted.

F. Wiqaytna:

Wiqaytna is a voluntary application based on Bluetooth technology and used by Moroccan authorities for notification of exposure to the "COVID-19". The application notifies users if another user who was nearby during the last 21 days is confirmed positive to "COVID-19".

In fact, a random crypto-identifier is generated and associated with users' mobile phone number after registration. The mobile phone number and the identifier are then stored encrypted in a secure server. Afterwards, all identifiers of the mobile phones in its proximity will be stored for a period of 21 days, which corresponds to the average incubation period of the virus. Finally, all data especially the phone number will be archived anonymously at the end of the pandemic

V. ETHICAL CHALLENGES OF DIGITAL CONTACT TRACING

Despite their efficacy to limit and control the spread of the COVID-19 pandemic, several ethical concerns have been raised regarding the deployment of the various contact tracing methods discussed above. In what follows, we present some ethical challenges of digital contact tracing:

The first challenge is related to the ability to access COVID-19 testing results as the wide availability of such results is a crucial component for these apps to work. In fact, even if contact-tracing apps rely on users to report if they were tested positive, users should not be able to report that they are COVID-19 positive without an independent verification (test results). In this context, anonymous aggregate data may be shared with governments and researchers within the limits of applicable laws and regulations

On the other hand, given that digital contact-tracing will only be successful when enough people participate, any obligatory measure will be resisted. Therefore, voluntary consent should be preserved on each step of digital contact-tracing implementation including decisions to :(download the app, leave the app operating in background, leave the app, share contact logs when testing positive for COVID-19, react to the app's alerts,... etc.). Therefore, measures to override consent and privacy rights in the name of surveillance by sharing data in a way that was not specified in terms of service may feed a climate of distrust, particularly in places where citizens have a lower level of trust in their governments.

Regarding privacy and data security risks, Digital contact-tracing comes with several privacy and security risks. In fact, carriers of COVID-19 face a significant privacy risk as they can be identified by a set of location data needed to alert their potential contacts. Moreover, multiple protections against data loss and unauthorized access are needed to ensure data security. In this context, effective database management, including encryption and automated backup procedures, needs to be implemented.

Finally, decisions on the implementation of mobile contact tracing should be taken in a transparent manner to encourage the participation of all stakeholders. Public officials should disclose the reasons why they are implementing such contact tracing application and the guarantees involved in that operation to ensure equity, accuracy and lack of partiality .

VI. DISCUSSION

Obviously, digital contact tracing approaches play a strategic role to control the spread of epidemic such as COVID-19. Nevertheless, several challenges can limit their effectiveness and efficiency. Based on the recent data and reporting around the world, we can summarize these issues as follows:

- A significant percentage of the population in the world, and especially in poor countries, cannot access to the Internet or do not have modern smart phones. As such,

contact identification remains challenging particularly in public spaces and digital contact tracing cannot replace the need for rigorous contact identification and listing.

- Due to the lack of signal especially in some spaces such as metro, the contact tracing apps may have some measurement error that can influence the effectiveness of the apps in identifying contacts as the precision depends mainly on the strength of the signal between the mobile phone and the cell tower for example**.**
- As the potential of a contact tracing application varies with the square of the fraction of users in a population. The success of a strategy to implement mobile contact tracing to identify infected contacts will depend on the degree of adoption and participation of the population.
- To tackle transparency issue, the application should be developed using an open-source approach, enabling independent experts to access and evaluate the algorithms.
- As far as privacy and data protection concerns, mobile contact-tracing users may face privacy risks by allowing third-parties such as health insurance companies to access their data. Moreover, local businesses can be impacted when they are identified as places visited by a COVID 19 carrier. One way to maintain both privacy and security at the same time is to allow data to be encrypted and stored on users' phones. The information is then shared upon request or when users test positive.

VII. CONCLUSION

Digital contact tracing is one of the most strategies used in the current health crisis to control the spread of COVID-19 disease. The use of digital solutions in such context can improve the efficiency of early identification of infected cases and guarantee lower costs of the contact tracing process. On the other hand, the use of digital data of users for 'intelligent physical distancing' raises several important ethical issues such as data privacy and security.

In this paper, we introduce the basic concepts related to this monitoring process. Then, we give an overview of various contact tracing models by summarizing different approaches and applications used in many countries to control the spread of COVID-19. Afterwards, we describe some ethical challenges encountered while designing and implementing these applications. Finally, we discuss some proposals that could help to deploy such digital contact tracing solutions in a safe way.

As prospects, an ethical framework is needed to support health authorities to deploy contact tracing solutions with respect to ethical considerations that protect the users' rights. Moreover, further efforts should be done in the future to enhance the performance of contact tracing process.

REFERENCES

[1] C. S. M. Currie et al., "How simulation modelling can help reduce the impact of COVID-19," J. Simul., vol. 00, no. 00, pp. 1–15, 2020.

[2] G. Giordano et al., Modelling the COVID-19 epidemic and implementation of population-wide interventions in Italy. 2020.

[3] ECDC, "Contact tracing for COVID-19 : current evidence options for scale-up and an assessment of resources needed.," ECDC, Tech. Rep., no. April, pp. 1–9, 2020.

[4] S. KC, A. C, and W. CS, "Contact tracing performance during the Ebola epidemic in Liberia," PLoS Negl Trop Dis, 2018.

[5] T. Scantamburlo et al., "Covid-19 and contact tracing apps: A review under the European legal framework," 2020.

[6] L. Ferretti et al., "Quantifying SARS-CoV-2 transmission suggests epidemic control with digital contact tracing," Science (80-.)., 2020.

[7] P. R et al., "Investigation of three clusters of COVID-19 in Singapore: implications for surveillance and response measures," Lancet, pp. 1039–1046, 2020.

[8] W. H. O. (WHO), "Report of the WHO-China Joint Mission on Coronavirus Disease 2019 (COVID-19) 2020," 2020.

[9] W. H. O. (WHO)., "Pandemic Influenza Severity Assessment (PISA): A WHO guide to assess the severity of influenza epidemics and pandemics. Geneva 2017."

[10] B. Q, W. Y, M. S, Y. C, Z. X, and Z. Z, "Epidemiology and Transmission of COVID-19 in Shenzhen China: Analysis of 391 cases and 1,286 of their close contacts," medRxiv, 2020.

[11] C. W, W. Q, L. Y, Y. H, X. Y, and Z. M, "Early containment strategies and core measures for prevention and control of novel coronavirus pneumonia in China," Zhonghua Yu Fang Yi Xue Za Zhi, 2020.

[12] M. H and V. A, "Lessons Learned From Korea: Covid-19 Pandemic. Infection Control & Hospital Epidemiology," 2020.

[13] C. YJ, "Coronavirus disease-19: Summary of 2,370 Contact Investigations of the First 30 Cases in the Republic of Korea," medRxiv, 2020.

[14] World Health Organization, "Contact tracing in the context of COVID-19," vol. 2019, no. May, pp. 1–7, 2020.

[15] Africa Centres for Disease Control and Prevention, "Guidance on Contact Tracing for COVID-19 Pandemic," p. 16, 2020.

[16] B. J. Stanley and J. S. Granick, "The Limits of Location Tracking in an Epidemic," Aclu, pp. 1–9, 2020.

[17] M. Mahjoubi, "Traçage des données mobiles dans la lutte contre le Covid-19," pp. 1–43, 2020.

[18] P. Sutheebanjard and W. Premchaiswadi, "QR-code generator," Proc. - 2010 8th Int. Conf. ICT Knowl. Eng. ICT KE 2010, no. February, pp. 89–92, 2010.

[19] J. Li and X. Guo, "COVID-19 Contact-tracing Apps: A Survey on the Global Deployment and Challenges," pp. 1–7, 2020.

[20] Apple Inc. and Google LLC., "Exposure Notification," no. May, pp. 1–7, 2020.

[21] K. Bock, R. Mühlhoff, C. R. Kühne, and R. Rehak, "Data Protection Impact Assessment for the Corona App," 2020.