Digital Contact Tracing Landscape During Covid-19 Pandemic: Role of Mobile Applications in Contact Tracing

By

Deeksha Parashar

Dissertation submitted in partial fulfillment of the requirements of the degree

MBA Hospital and Health Management

Academic year, 2018-2020

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TO WHOMSOEVER MAY CONCERN

This is to certify that Deeksha Parashar, student of MBA Hospital and Health Management from The IIHMR University, Jaipur has undergone internship training at ZS Associates, New Delhi from 3rd February, 2020 to 29th May, 2020.

The Candidate has successfully carried out the study designated to her during internship training and her approach to the study has been sincere, scientific and analytical.
The Internship is in fulfillment of the course requirements.

I wish her all success in all her future endeavors.

Dean, Academics and Student Affairs
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June 17, 2020

EXPERIENCE CERTIFICATE

This is to certify that Deeksha Parashar (Employee ID – 23491) was interning in our organization from February 3, 2020 to May 29, 2020. At the time of leaving she was working in the capacity of Knowledge Management Associate – Intern based at the New Delhi office.

We wish you all the success in future endeavors.

For ZS Associates India Pvt Ltd

Mohit Sood
Office Managing Principal

THE IIHMR UNIVERSITY, JAIPUR

CERTIFICATE BY SCHOLAR

This is to certify that the dissertation titled *'Digital contact tracing landscape during Covid-19 pandemic: Role of mobile applications in contact tracing'* and submitted by **Deeksha Parashar**; Enrollment No. 0739 under the supervision of Dr. PR Sodani for award of MBA in Hospital and Health/ Pharmaceutical / Rural Management in Health and Hospitals of the University carried out during the period from February 3, 2020 to May 29, 2020 embodies my original work and has not formed the basis for the award of any degree, diploma associate ship, fellowship, titles in this or any other institute or other similar institution of higher learning.

Deeksha Parashar
0739
MBA HM- 23

Abstract

Contact Tracing is considered as the first and the most effective step towards containing an outbreak, as resources for mass testing and large quantity of vaccines are highly unlikely available for immediate utilization. Effective contact tracing can allow societies to reopen from lock-down even before availability of vaccines. The objective of mobile contact tracing is to speed up the manual interview based contact tracing process for containing an outbreak efficiently and quickly. This paper aims to throw light on the digital contact tracing landscape of the world and understand the issues and challenges pertaining to the adoption of contact tracing mobile apps. This paper also aims to compare the existing prominent contact tracing mobile applications developed by certain countries on the basis of transparency, penetration and data safety, which in turn, determine the scalability of each app.

Methods: An exploratory research was conducted by analyzing 21 existing publications present on Google Scholar, PubMed and MedrXiv, along with an internet search using relevant keywords. Further, eight apps were evaluated on the basis of transparency, data safety and penetration to determine their acceptability

Results: Contact tracing mobile applications are rapidly emerging as a durable supplement to the laborious manual contact tracing methods. Early adoption of these apps was seen in Asian countries, particularly Singapore, Taiwan and China. However, the European Union faces barriers to adoption owing to the region's strict privacy laws like General Data Protection Regulation (GDPR).
Two technologies, Bluetooth and Location services, inherent to smartphones are being used as basis of development of these contact tracing mobile applications.
Further, Australia's CovidSafe mobile app is the most user acceptable option amongst 8 other apps evaluated in this study

Conclusion: In the current crisis, we will have to endure more and deeper encroachments on fundamental rights than we are used to. Still, there is no reason to tolerate such encroachments to a greater extent than strictly necessary. Even under the current time pressure, it is important to find solutions that minimize data processing as far as possible. We have shown above that this is possible for the case of contact tracing. As the pandemic progresses, many other challenges will emerge. For each of them, one will have to check which data processing is necessary to address them and which ones can be avoided.

Keywords: COVID-19, Contact Tracing, Security, Privacy, Acceptability

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Finally, I must express my very profound gratitude to my parents for providing me with unfailing support and continuous encouragement throughout my years of study and through the process of researching and writing this thesis. This accomplishment would not have been possible without them.

Thank you.

Table of Contents

List of Tables and Figures

List of Abbreviations

S.No.	Abbreviation	Full Form
1	WHO	World Health Organization
2	CTA	Contact Tracing Applications
3	BTE	Bluetooth Technology
4	GPS	Global Positioning System
5	UNICEF	United Nations Children's Fund
6	SARS	Secure Acute Respiratory Syndrome
7	SARSCov2	Secure Acute Respiratory Syndrome Corona Virus 2
8	Gov.	Government
9	AI	Artificial Intelligence
10	OS	Operating System
11	PEPP-PT	Privacy-Preserving Proximity Following project
12	DP 3T	Decentralized Proximity Tracking
13	U. S. A	United States of America
14	U. K	United Kingdom
15	EU	European Union
16	SEAR	South East Asian Region
17	MIT	Massachusetts Institute of Technology
18	JHU	Johns Hopkins University
19	Tech.	Technology
20	Apps	Applications
21	BT	Bluetooth

Chapter 1: Introduction

Secure Acute Respiratory Syndrome (SARS) is a primary atypical pneumonia that's characterized by a high rate of transmission. It began in Guangdong, China, in November 2002. One among the most significant SARS outbreaks so far began in Singapore in mid-March 2003 and was traced to a traveler coming back from Hong Kong . Recently in China, several local health facilities in Wuhan, Hubei Province, reported clusters of patients with pneumonia of unknown cause that they supposedly and epidemiologically linked to a seafood and wet animal wholesale market within the province. However the due spread through untraced contacts eventually cause its spread on a worldwide scale which is what we see today as the Covid-19 pandemic[1]

Contact tracing is a key public health response to slowing the spread and containing infectious diseases. By mitigating the flaws of detection based solely on symptoms , contact-tracing increases the sensitivity and the readiness of the community for an emerging epidemic . Further, contact-tracing allows citizens to relieve burden from a community's containment measures, as it pushes perspective infected members to isolate themselves voluntarily

As part of a comprehensive strategy proposed by the World Health Organization, case identification, isolation, testing and care, and contact tracing and quarantine, emerged to be critical activities to reduce transmission and control the pandemic[2]

World Health Organization has broken it into 3 basic steps:

- **Contact identification:** Once someone is confirmed as infected with a virus, contacts are identified by asking about the person's activities and the activities and roles of the people around them since onset of illness
- **Contact listing:** Efforts are made to identify every listed contact and inform them of their contact status, the actions that will follow, and the importance of receiving early care if they develop symptoms .
- **Contact follow-up:** Regular follow-up is conducted with all contacts to monitor for symptoms and test for signs of infection[4]

Containment, the key strategy in quickly halting the pandemic, requires rapid identification and quarantine of the infected individuals, determination of whom they have had close contact with in the previous days and weeks, and decontamination of locations the infected individual has visited. Achieving containment demands accurate and timely collection of the infected individual's location and contact history. Traditionally, this process is labor intensive, susceptible to memory errors, and fraught with privacy concerns. With the recent almost ubiquitous availability of smart-phones, many people carry a tool which can be utilized to quickly identify an infected individual's contacts.

Governments and organizations around the world are broadly employing these methods to trace cases and their contacts:

- **Traditional case and contact identification methods:** WHO contact-tracing steps are broadly adopted to monitor cases and contacts. Following steps elucidate the highlights of traditional contact tracing efforts[5]:
    - **Preparation:** setting up co-ordination teams, mobilizing resources to identify cases and contacts
    - **Contact identification:** Cases interviewed, and contacts listed and classified as high-risk (close contact) or low-risk exposure contacts
    - **Isolation and monitoring of contacts with either high-risk or low-risk exposure to the index case**
    - **Testing of symptomatic contacts**
    - **Overall coordination of the response at local, national and international levels**

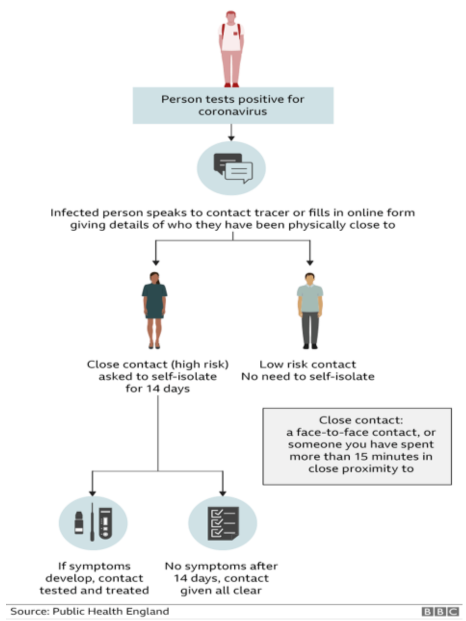

Figure 1: Process of contact tracing

- **Digitally driven contact tracing methods:** Digital tools are leveraged through mobile applications, websites, Bluetooth wristbands, etc. to identify the 'cases' and 'contacts', as a supplement to the traditional methods of manual case and contact identification Technological tools were leveraged in smartphones to monitor the spread of SARS-CoV-2 to relax the confinement measures by keeping them local. These tools often require an authority to track people and see when, how long, and at what distance they encounter .

Primarily, the following technological tools/ combinations are most prevalent

- Location: Some apps identify a person’s contacts by tracking the phone’s movements (for instance, using GPS or triangulation from nearby cell towers) and looking for other phones that have spent time in the same location .
- Bluetooth: Some systems use “proximity tracking,” in which phones swap encrypted tokens with any other nearby phones over Bluetooth. It is easier to anonymize and generally considered better for privacy than location tracking .

Chapter 2: Review of literature

Table 1: Review of literature

Author (Date)	Location	Study design	Sampling	Salient features
Davide Golinelli, Erik Boetto, Gherardo Carullo, Maria Paola Landini, Maria Pia Fantini (May 1, 2020)	Italy	Literature review	38 full text publications	Digital solutions and innovative technologies have mainly been proposed for the diagnosis of COVID-19, especially the use of AI. Digital technologies are useful also for surveillance measures like contact-tracing
Luca Ferrett, Chris Wymant, Michelle Kendall, Lele Zhao, Anel Nurtay, David Bonsall, Christophe Fraser (March 12, 2020)	Oxford, UK	Mathematical modeling	NA	Mathematical model to gauge combined impact of isolation and contact tracing on transmission. Suggest that an algorithm for first degree instantaneous contact tracing in the form of a mobile phone app could dramatically reduce transmission from contacts, to a level that is sufficient to reach herd protection for Covid

Ramesh Raskar, Isabel Schunemann, Rachel Barbar, Kristen Vilcans (March 19, 2020)	U.S.A	Literature review	NA	Compares various technological interventions in the U.S. on the basis on privacy, consent and systemic challenges
Yves-Alexandre de Montjoye, Florimond Houssiau, Andrea Gadotti, Florent Guepin (March 21, 2020)	Itlay	Literature review	NA	Evaluates 3 model COVID-19 contact tracing apps on 8 privacy centric parameters
Tyler M Yasaka, Brandon M Lehrich, Ronald Sahyoun (April 2020)	U.S.A	Literature review	NA	Highlights the need of privacy centric technology and proposes a contact tracing mobile app that creates “checkpoints”, reducing hacking risk and thereby preserving privacy of users
Rafael A Calvo,Sebastian Deterding, Richard M Ryan (April 6, 2020)	U.S.A	Literature review	NA	Outlines the use of invasive digital technologies for contact tracing and emphasizes on privacy centricity
Klaudia Klonowska (April 2020)	Netherland	Literature review	NA	Compares two distinct waves of technological contact tracing: location tracking and contact tracing apps on the basis of privacy,

				transparency and effectiveness"
Samuel Altman, Luke Milsom, Hannah Zillessen, Raffaele Blasone (April 2020)	U.K	Cross sectional study	5995 individuals in France, U.K, Germany and Italy	Investigate user acceptability of contact-tracing apps. Although willingness is high, concerns about privacy and app security underlie some of the key variation in support for the app
Kelsie Nabben (April 21, 2020)	Australia	Exploratory review	NA	Outlines major digital contact tracing efforts being undertaken in Australia, and identifies gaps in policies for privacy protection
Iniobong Ekong, Emeka Chukwu, Martha Chukwu (April 27, 2020)	Nigeria	Exploratory review		Compares and contrasts the digital contact tracing efforts of various nations with that of Nigeria, and concludes that mobile position data contact tracing is superior, though privacy centricity should be at the centre for building apps
Wasilij Beskorovajnov, Felix Dorre, Gunnar Hartung,	France	Exploratory review	-	Propose a new model "ConTra Corona", using Bluetooth technology, which

Alexander Koch, Jorn Muller-Quade, Thorsten Strufe (April 2020)				guarantees user data protection and reduced false negatives
Johannes Abeler (April 2020)	U.S.A	Exploratory review		In the case of contact tracing, the approach that requires the least amount of data also seems to be the most effective epidemiologically. This is because an app like the one described above would be better suited to determine who actually was in close proximity than any of the other proposed solutions. Moreover, even digital contact-tracing systems need users to cooperate (by installing the app and carrying their phones with them) for any chance of success. Consequently, the effectiveness of any contact-tracing system depends on public support. There is reason to believe that the level of support

				can be increased by opting for a data-minimizing solution
Scott McLachlan, Peter Lucas, Kudakwashe Dube, Graham A Hitman	U.S.A	Exploratory review		Highlights various contact digital contact tracing efforts being adopted by South East Asian nations like Alipay Wellbeing Code app in China and TraceTogeter in Sinapore. Outlines various differences in technologies behind the mobile apps
Steven Shoptaw (May 2020)	U.K	Exploratory review		Provides an overview of the ways in which technology can support non-pharmaceutical interventions during the COVID-19 epidemic and outlines the ethical challenges associated with these approaches. need for an ethical framework for digital epidemiology and technological interventions to support contact tracing in public health

				emergencies. The successful use of these interventions can only be achieved if they can secure public trust. This paper aimed to outline several requirements for these interventions to be ethical and to be able to ensure public confidence during the COVID-19 pandemic such as privacy-preserving design; voluntariness in uptake; avoidance of discrimination and punishment resulting from the use of the app; open-source approach; maintenance by a governing body
Mohammad Javed Alam and Marine Al Dahdah (May 2020)	Qatar	Cross-sectional study	5677 individuals	86% of COVID-19 cases are undocumented (pre-symptomatic), and these cases are responsible for 55% of all documented cases. Given the high rates of infection and the significant contribution to transmission from

				asymptomatic individuals, the traditional efforts to halt the epidemic by contact tracing and isolation become largely ineffective

According to findings, about 70% of contacts need to be traced to control the majority of outbreaks . Additionally, a study suggests that 86% of COVID-19 cases are undocumented (pre-symptomatic), and these cases are responsible for 55% of all documented cases[1] Given the high rates of infection and the significant contribution to transmission from asymptomatic individuals, the traditional efforts to halt the epidemic by contact tracing and isolation become largely ineffective[2] .

Recent studies suggest that as traditional methods of case and contact identification become increasingly outdated, technological tools are being evaluated for the purpose of contact tracing[3,4,6]

Javed et al highlight the usage of mobile applications for the mitigation of the pandemic. These mobile applications rely on pre-existing smartphone technologies like location and Bluetooth [4]

Further, many countries are relying increasingly on such technologies, rather than their manual methods[5]

China is unwinding the lockdown measures by inquiring citizens to utilize the Alipay Wellbeing Code app [6]. After announcing their travel history and current side effects, Wellbeing Code clients get a color-based QR-code demonstrating their wellbeing status. Clients with a ruddy code are teaching to be isolated for 14 days; clients with a yellow code are told to remain interior for 7 days, whereas clients with a green code may travel unreservedly [7]. The app is utilized to track development at travel checkpoints (prepare stations or thruways) as well as at the neighbourhood level . All administrations require individuals to appear their QR-codes some time recently entering . Over 180 million individuals are utilizing Health Code .[8] Israel will be following individuals' phones to discover out where a suspected carrier has been and with whom they have come into contact. Potential contacts will be informed through content messages with orders to self-quarantine . These orders can be assist upheld through the location-tracking capabilities of cellphones [9].

In Taiwan, individuals who are requested to self-quarantine are checked employing a mobile-phone based location-tracking 'electronic fence.' The framework screens phone signals to caution authorities in the event that isolated patients move absent from their address or turn off their phones . Authorities too call twice a day to guarantee individuals don't dodge following by clearing out their phones at domestic . On March 20, Singapore discharged the TraceTogether app that employments Bluetooth to track when two app clients have been in near vicinity . The app trades time-limited tokens between adjacent phones . These tokens are moreover sent to a central server[10]. When a individual reports they have been analyzed with COVID-19, the app permits the Service of Wellbeing to decide anybody who logged to be close them . A human contact tracer will caution these contacts and decide fitting take after up activities [11].

Comparative approaches are as of now considered by other governments, counting the UK and the US . A group of therapeutic analysts at Oxford College empower the UK government to investigate the utilization of smartphone apps for instant contact following . In the event that the signal is quickly and broadly sent, they accept such an app might offer assistance to contain the spread of COVID-19 . MIT analysts unveiled a model of an app (Private Kit: Secure Paths) that employments geolocation to caution individuals approximately their presentation dangers . The MIT approach will be adapted by eight European nations partaking in Pan-European Privacy-Preserving Proximity Following project (PEPP-PT Official Site) [12]. The venture proposes to form an open-source app that analyzes Bluetooth signals between phones to identify users who are near sufficient to contaminate each other . The WHO is considering a comparable app for advanced contact-tracing to be advanced around the world [13]

A global contact-tracing tool can be a product of the recent collaboration between Google and Apple [14]. The two tech giants have joined forces to develop an opt-in contact-tracing tool, similar to the Singaporean TraceTogether app . Both companies will make changes to their operating systems to let devices exchange a private key with nearby phones via Bluetooth, logging any time users come in close proximity . If someone tests positive for COVID-19 and enters that information into an app, 14 days' worth of their contacts with other users are sent to a server . These contacts will be advised to take precautionary measures. This tool will not collect location or personally identifiable data and will not identify people who test positive to other users [14].

In addition to computerized contact-tracing, information mining on social media can give bits of knowledge into the timing and topography of the coronavirus spread within the US, because it has been already utilized for following regular flu on Twitter [14,12]

At-home gadgets such as wearables or mass-distributed thermometers that store data on the cloud, can be utilized for early case distinguishing proof . For occasion, Kinsa Wellbeing, the company that has already utilized internet-connected thermometers to anticipate the spread of flu, presently tracks the coronavirus in real-time . Hong Kong and Bahrain are utilizing electronic tracker wristbands to geofence individuals beneath isolation [15].

However, the advent of these contact tracing applications comes with an array of issues on privacy. Many studies conducted on varied population suggest that most people would not download a contact tracing application, owing to the privacy concerns they harbour[16]

Rationale:

It has been three months since Covid-19 was declared as a pandemic by WHO, and in this short span of time, it has shown a drastic increase in transmission, infecting about 1 in 4 people upon exposure, according to latest research. A cure or vaccine still seems a long time away, and hence, governments have adopted various non-pharmacological like mass testing, contact tracing and quarantine. Contact tracing has since proven to be an effective way in controlling the transmission of infectious diseases, such as Ebola and HIV, with certain countries using contact tracing effectively during the MERS and SARS outbreak.

Digital contact tracing is rapidly emerging as a durable supplement to the traditional contact tracing methods, and since March, numerous contact tracing mobile applications have either launched or are set to launch.

Since the topic of contact tracing mobile applications is new and dynamic, not enough literature exists that compares and contrasts the various contact tracing mobile applications and studies their usefulness, an exploratory research has been done to map the usefulness of such applications, the challenges to their uptake and where they lie in terms of transparency, data safety and penetration

This study, hence, aims to understand the digital contact tracing landscape and assess the role of contact tracing mobile applications in controlling the transmission of Covid-19.

Objectives:

This study aims to:

- Study the digital contact tracing landscape and understand the role of contact tracing mobile applications in controlling the spread of Covid-19
- Understand the major technologies behind contact tracing mobile applications and outline prominent examples of apps leveraging the same
- Study, in detail, the challenges to adoption of contact tracing mobile applications
- Qualitatively analyse and compare the contact tracing mobile applications of Iceland, Bulgaria, India, Australia, China, Singapore and Israel on the basis of data safety, transparency and penetration

Chapter 3: Methodology

An examination of literature of quantitative and qualitative studies using diverse designs, and major mainstream media publications was done to critically analyze the current digital solutions for contact tracing as a response to contain the Covid-19 pandemic.
The initial search was implemented on March 15th 2020. The search ended on May 15th 2020. The search query consisted of terms considered by the author to review the literature on the use of digital technologies for tracing cases and contacts (process known as contact tracing) in response to COVID-19.

Google Scholar, PubMed/MEDLINE, were searched using the following search terms and database-appropriate syntax :
("COVID-19"[All Fields] OR "COVID-2019"[All Fields] OR "severe acute respiratory syndrome coronavirus 2"[Supplementary Concept] OR "severe acute respiratory syndrome coronavirus 2"[All Fields] OR "2019-nCoV"[All Fields] OR "SARS-CoV-2"[All Fields] OR "2019nCoV"[All Fields] AND ("Contact Tracing" [Title/Abstract]) AND (digital [Title/Abstract] OR technology [Title/Abstract]) OR ("Mobile Applications" [Supplementary Concept])

Additionally, since the COVID-19 pandemic is emerging and only three months old, the author conducted an exploratory (non-systematic) internet search for technology approaches and mobile applications being developed in response to COVID-19

Chapter 4: Results

From the review of existing literature and internet research, few results stand out:

4.1 Contact tracing is a paramount non-pharmacological measure to reduce Coronavirus transmission:

Mathematical modelling suggests that transmission can be reduced by tracing and isolating symptomatic carriers without significant delay, in a process potentially enabled by technology[17] In the meantime, many countries are concluding that the disproportionate weight of symptomatic cases in driving transmission makes the aggressive pursuit of contact tracing well worth the effort. Contact tracing of COVID-19 patients early in the outbreak reduced the time secondary cases were in the community by nearly 2 days [18].

Many studies have argued that contact tracing is effective in controlling the spread of infectious diseases . It has also been considered a cost effective method .

Contact tracing is the process of identification of a case (infected individual), follow up of their contacts (manually through health workforce or through leveraging digital means) and follow up of those contacts .

This process concludes at testing the contacts for Covid-19, and if a contact is found positive, the process of contact tracing is repeated by treating this ‘contact’ as a new ‘case’

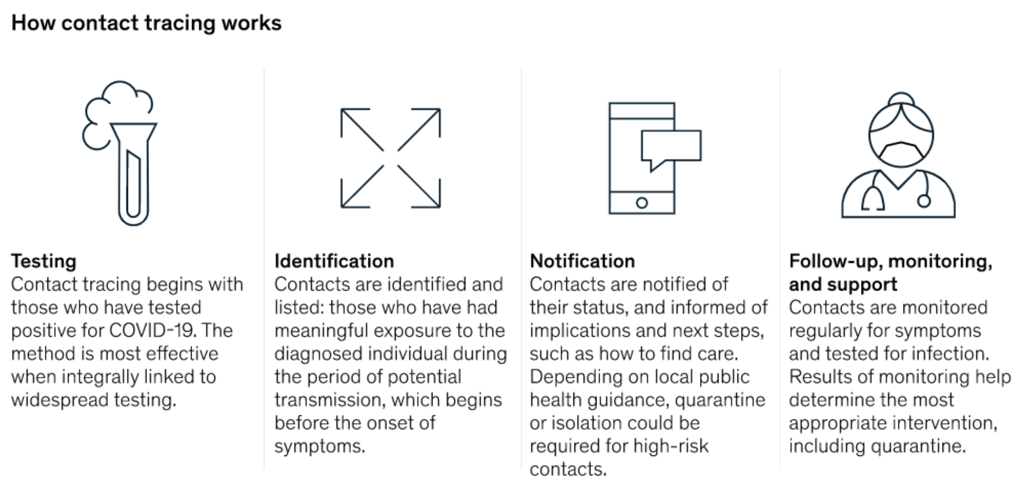

Figure 2: Manual contact tracing process

4.1.1 Digital contact tracing through mobile applications is quickly emerging as a durable supplement to laborious manual contact tracing

Contact tracing is possible to do manually, but is a time-consuming and imperfect process. Digital tracing provides a more scalable approach to traditional contact tracing, which relies on patients' memories of recent exposure to others. As the coronavirus spreads rapidly, traditional contact tracing efforts are unlikely to keep up and would require an "army" of public health workers [19].

Following are the benefits of leveraging mobile applications for contact tracing:

i. <u>Automated and effortless:</u> Mobile applications occupy very less space on an average smartphone with Android OS or Apple's iOS. Since smartphones have become an indispensable part of our daily lives, we tend to carry them everywhere . The apps downloaded onto these smartphones could then be leveraged to record whether a user comes in contact with an infected individual . This thus would become a less labor intensive option vis-à-vis manual contact tracing [19]

ii. <u>Cost efficient:</u> Mobile apps do not require any additional resources for download, apart from a smartphone . They are free to download and hence are a more cost efficient alternative to manual contact tracing [19]

iii. <u>Low dependence on patient recall</u>: Manual contact tracing relies heavily on the infected individual's memory . The use of a mobile application eliminates the dependence on recall of patient[17]

iv. <u>Faster Reporting</u>: The contact tracing apps generate instant data points onto a server (centralized or decentralized) and hence are rapid in contact list generation[17]

v. <u>Bigger, Better Data:</u> Moving away from manually recorded data (location, temperature, humidity, etc.) to automated RTLS allows for more accurate and complete information . Hospitals that tag their staff, patients, & assets can have accurate records of location data sets for each individual group but also information regarding the interactions among them (staff-patient-equipment) [19]

vi. <u>Historical Reporting:</u> Automation not only allows for ease of recording, but also quicker more accurate reporting on this data. Information can be gathered immediately or retrieved later . Most customer-facing applications store data for up to 30 days[19]

4.2 Contact tracing mobile apps were first deployed in South East Asian nations; limited deployment in the west due to privacy concerns and policies

China is effectively flattening the curve, but so is South Korea, a vibrant democracy. Other democracies — the U.S., Spain, Italy, and France, are faring less well. China, South Korea, Taiwan, Singapore and to a lesser extent Japan — where a collectivist spirit may encourage civic-minded embrace of and a more willing compliance with governments' infection control . In addition, these countries tend to be actively deploying technology to collect data on the virus's progress and efforts to contain it, including tracking those who are infected and their contacts[21] . These two aspects of East Asian societies do not work independently; they reinforce each other .

Drawing on the experience of countries that are effectively using technology for contact tracing, the first step — and a requirement — is to encourage, or, better yet, mandate, the installation of tracking apps on phones . In East Asian countries, this has been more mandatory than voluntary . In Singapore, a country known for its efficiency and no-nonsense government, citizens are encouraged by the government to install TraceTogether, which exchanges Bluetooth signals between mobile phones in close proximity [22]. This is a modern counterpart to the traditional and time-consuming contact-tracing method, which relies on fallible human memory .

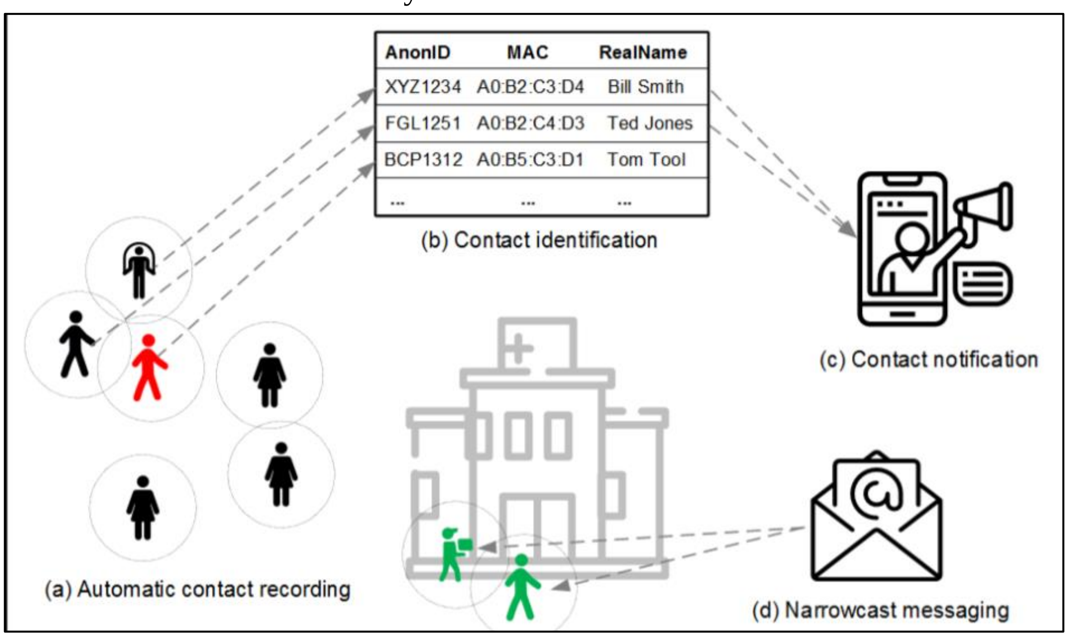

Figure 3: Smartphone based contact tracing

A government poll reported in Nikkei Asian Review found that more than 70% of respondents supported this move . Hong Kong[22], which has also seen effective containment, recently implemented a mandatory 14-day quarantine upon entry for all overseas arrivals . To enforce this, the Hong Kong government required each new arrival to download the StayHomeSafe app and gave them a paired wristband that uses geofencing technology to help catch violators, and, as reported in Quartz, warned anyone violating the quarantine that they could face up to six months in prison and a $3,200 fine[22]

The more striking case of curve-flattening is South Korea, where The Washington Post reports that private developers took it upon themselves to develop apps that supplement official government contact tracing efforts, which many find insufficient . Corona 100m, which, according to MarketWatch, South Koreans downloaded over one million times in just a few weeks with "overwhelmingly positive reviews,"[22] collects data from public government sources that alert users of any diagnosed Covid-19 patient within a 100-meter radius along with the patient's diagnosis date, nationality, age, gender, and prior locations. Corona Map similarly plots locations of diagnosed patients to help those who want to avoid these areas and, as Business Insider reports, was the second-most-downloaded app in Korea.[23] A vibrant democracy that has also won praise for its Covid-19 containment, Taiwan is believed to be the first to have used mobile phone tracking to enforce quarantines, which the government reportedly reinforces by calling those in quarantine twice a day to ensure they do not evade tracking by leaving their phones at home[24]

While mobile tracking of infectious disease has been available for at least a decade — Cambridge University's voluntary FluPhone app developed in 2011 is an early example — the adoption rate varies dramatically across regions. Wired reports that fewer than 1% of the people in Cambridge signed up for FluPhone, for example, compared to the widespread adoption of mobile contact tracing we're now seeing in East Asian countries[24] Concerns in Western democracies about privacy and civil liberty could create substantial impediments to rolling out such technologies in these countries and may have contributed to FluPhone's low penetration . Even within democracies, there are clear cross-national differences in the degree of voluntary adoption of contact-tracing technologies . But without widespread adoption, such contact tracing efforts will fail[24].

4.3 Location services and Bluetooth emerged the top techs for the basis of development of apps

Countries are using Bluetooth or mobility data (eg, Global Positioning System [GPS], cell tower) collected by the phone for contact tracing . One method of contact tracing involves scanning and recording Bluetooth signals from other nearby phones, usually within a 30 feet diameter[24] The real time data offer a novel means to track proximity and potential interaction with others[23]. Another method for contact tracing involves use of mobility data (often GPS) collected by the phone that allows a digital trail of timestamped locations visited to be easily recreated

Public health officials can leverage either approach, Bluetooth or mobility, to determine who an infected person may have been in close contact with—and then notify those exposed of possible risk[25] Countries have taken different approaches in what information they share with individuals identified as being at risk .

4.3.1 Location services

The apps based on location services/navigation technology ideally use internet data and GPS satellite locations, like other navigation apps like Google Maps. The Global Positioning System (GPS)is a satellite-based radio-navigation system owned by the United States government[26] The GPS satellite framework and cellphone towers make it feasible for governments and system administrators to track locations on cell phones[26] Utilizing a database, health authorities are able to see when and where an individual who tested positive encountered others .

How GPS is leveraged in location tracking contact tracing mobile applications[27]:

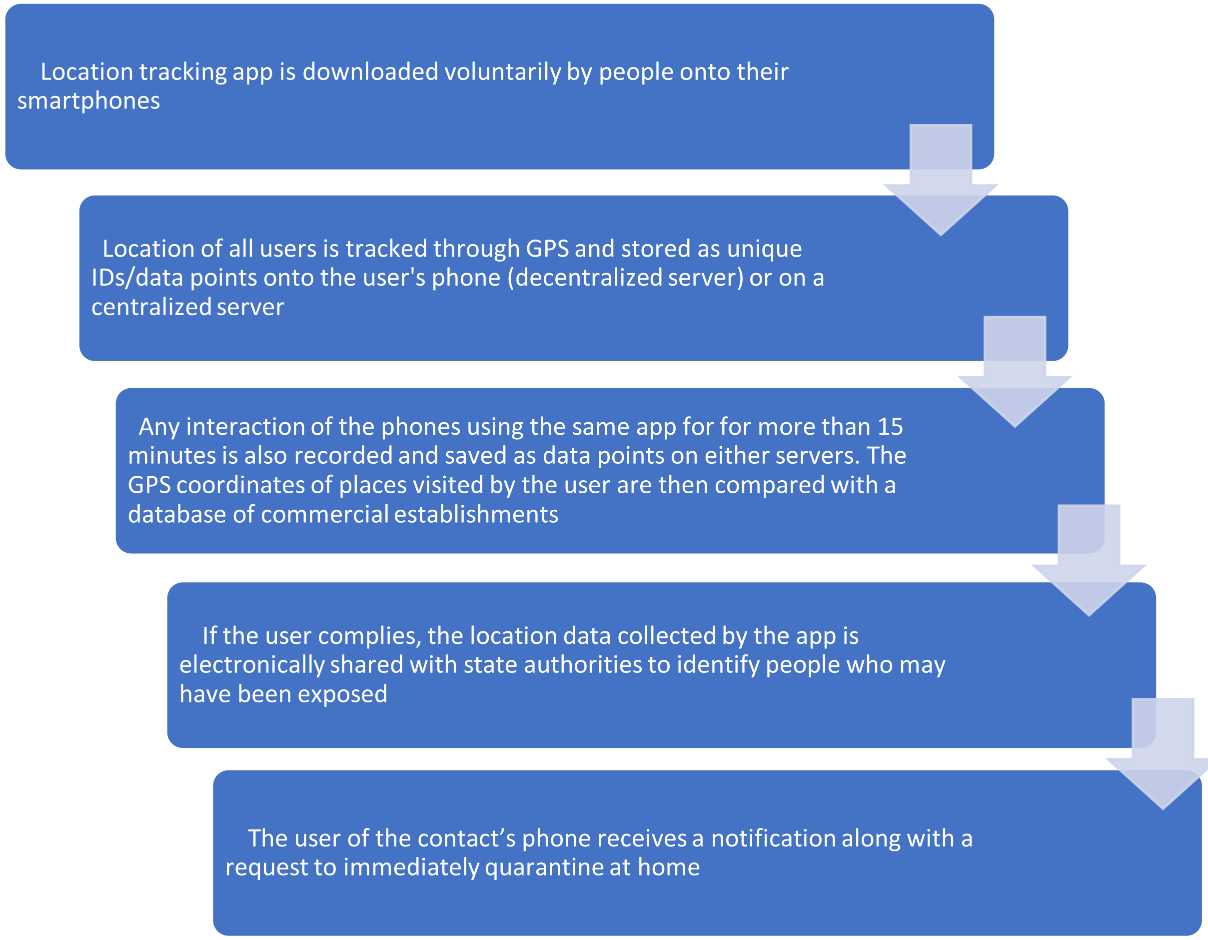

Figure 4: Flow diagram of GPS based contact tracing

The location based apps track users' location via the inherent GPS on their phones. The GPS operates independently of any telephonic or internet reception, though these technologies can enhance the usefulness of the GPS positioning information[27]

- Location tracking app is downloaded voluntarily by people onto their smartphones
- Location of all users is tracked through GPS and stored as unique IDs/data points onto the user's phone (decentralized server) or on a centralized server
- Any interaction of the phones using the same app for for more than 15 minutes is also recorded and saved as data points on either servers. The GPS coordinates of places visited by the user are then compared with a database of commercial establishments
- If the user complies, the location data collected by the app is electronically shared with state authorities to identify people who may have been exposed

- The user of the contact's phone receives a notification along with a request to immediately quarantine at home

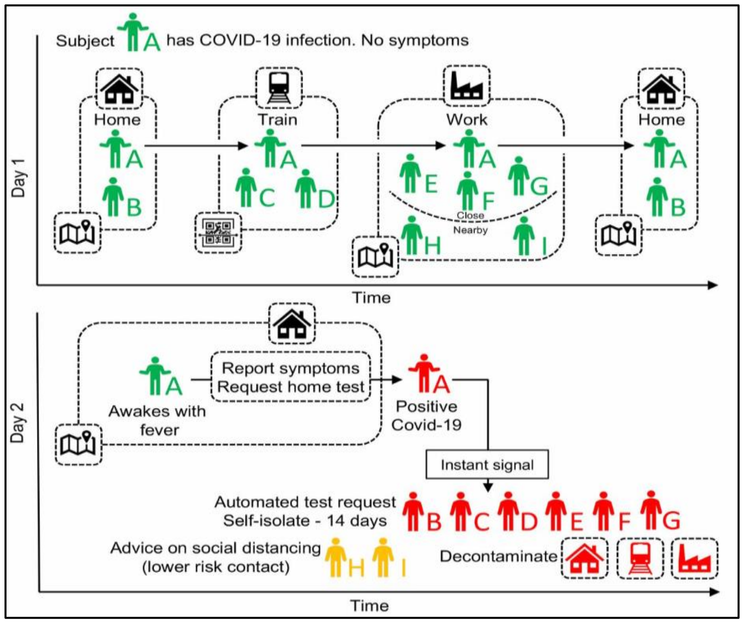

Figure 5: Process of GPS based contact tracing

Prominent examples of countries adopting location tracking contact tracing apps

A) Bulgaria's ViruSafe:

VirusSafe is a mobile application, created to assist society and governmental institutions in the fight against COVID-19. The app was approved by the Bulgarian Ministry on April 4th and launched for mass use on the Google Play and Apple Store on April 7th .

The application has features, specifically built to support in the fight against COVID-19 . The current version of ViruSafe has the following:

- Daily symptoms and health status tracker
- Location tracker, enabled voluntarily by the user, to create a heatmap with potentially infected people
- Notifications, which inform users on hot news, related to COVID-19
- Information and best practices, connected to the pandemic[29]

In order to enable the full range of features of the application, users need to enter personal data, such as personal ID, age, any chronical diseases they may have and allow the app to use their location . This in turn will give Ministry of Health and local authorities all necessary information, in case further actions are needed .

Uptake by population[30]:
Downloads as of 13 May, 2020 = 55,000
Population of Israel as per last national census = 7,364,570
Penetration [(downloads/population)*100] = 0.74%

B) Iceland's Rakning C-19

When Iceland got its first case of covid-19 on February 28, an entire apparatus sprang into action . The country had already been testing some people at high risk of catching the virus, thanks to DeCode genetics, a local biotech company . Once the arrival of the disease was confirmed, it began rapidly rolling out public testing on a much wider scale . The government, meanwhile, quickly built a team of contact tracers to interview those with a positive diagnosis and track down people they'd been in contact with[31] Within a few weeks, Icelanders had another high-tech tool at their disposal, too: a government-backed automated tracing app . Rakning C-19, which launched in early April, was hailed as a way to "make the tracing of transmissions easier" at the time[31]

How it works:
It tracks users' GPS data to compile a record of where they have been, allowing investigators—with permission—to look at whether those with a positive diagnosis are potentially spreading the disease[31]

Uptake by population[30]:
Downloads= 140,000
Population of Israel as per last national census = 341,243
Penetration [(downloads/population)*100] = 41%

Salient features:

- <u>Decentralized data storage model:</u>
  Iceland's app is an outlier when it comes to data storage. Out of all countries using location tracking contact tracing apps for controlling Covid's spread, this is the only one using a decentralized model of data storage, which means the data gathered by the application, is stored onto the user's phone, which acts as a decentralized server .
  No data is communicated with the central or cloud server of the main

database. The data is stored onto the “decentralized phone server” for 14 days, post which it is deleted permanently[32]
This ensures privacy preservation of the users’ personal data

- Voluntary:
  This app is purely voluntary and relies on permission to release data, analyzes users’ GPS data to map where they’ve been in order to assist Iceland’s Contact Tracing Team. Location data is saved locally on users’ phones, and if the Contact Tracing Team needs the user’s assistance, it has to send a request for the information. If users agree, their data is stored for 14 days in the Tracing Team’s database [32]

C) Israel’s HaMagen

Israel’s contact tracing app came after infections had crossed 1000 in late March . To control Covid spread before this effort, the ministry had published the epidemiological history of COVID-19 patients on a central website, listing all the places they have been and advising those who were at any of the locations at the same time to self-quarantine for 14 days .

However, as the number of cases diagnosed each day leaped into dozens and then hundreds it rapidly became impractical for the public to review all the listings .[34]

The app came alongside a controversial measure approved last week by the government to use emergency powers which allows the Shin Bet security agency to track the movements of all smartphones users via their devices and automatically send alert messages to those who may have been exposed to the virus by coming close to a COVID-19 patient .

The Shin Bet surveillance program, approved for 30 days, has been attacked as an infringement on civil rights .[35]

Uptake by population[30]:
Downloads as of 13 May, 2020 = 1,500,000
Population of Israel as per last national census = 9,152,100
Penetration [(downloads/population)*100] = 16.88%

How it works:
After a user installs the app, it keeps track of their movements and compares the information with Health Ministry data on where those who

are positively diagnosed have been . If the app finds a match (user in the same area at the same time as that of case), it links the smartphone's owner to the Health Ministry website for information on what to do next, and how to register while going into self-quarantine .

Salient features:

Decentralized data storage model:

Not unlike Iceland's app, the cross-referencing of a user's GPS history with the locations of COVID-19 patients happens on the user's phone and is not sent to any third party . The data from the Ministry of Health is sent to the user's mobile phone for cross-referencing, and no data is sent back to the Ministry of Health[36]

Voluntary:

The information on the app is secure and that the movements of users won't be otherwise mined by the government to trace the movements of citizens who aren't known to be infected with the virus .

If the app does not detect the user having been exposed, it informs them that "according to data collected thus far, no points of intersection have been found with coronavirus patients."[36]

Transparent:

Israel uploaded its app onto GitHub, an online repository of free to use and share bits of code and any security expert and programmer can now examine the code, find and even fix any problematic features that the developers may have missed – and even close any security breaches that exist .

D) **China's Health Code System**

Chinese officials, along with mobile payment service Alipay and messaging service WeChat launched a virtual passport, which enables these apps to evaluate the public health risk posed by a user based on their state-issued ID number, address, travel history, and self-reported health status, post which they are given a 'health code' or 'colour code' (QR code) - from green for good-to-go, to red for quarantine, which grants them access to public places[17,36,12]

Uptake by population[30]:
Downloads (according to Shanghai Post News post, dated 8 May,2020) = 180,000,000 million people had signed up for health codes
Population of China as per last national census = 1,430,000,000
Penetration [(downloads/population)*100] = 12.5%

How it works:

People in China sign up through Ant's popular wallet app, Alipay, and are assigned a color code — green, yellow or red — that indicates their health status . After users fill in a form on Alipay with personal details, the software generates a QR code in one of three colors . A green code enables its holder to move about unrestricted . Someone with a yellow code may be asked to stay home for seven days. Red means a two-week quarantine .

Neither the company nor Chinese officials have explained in detail how the system classifies people [36].

Salient features:

- Mandatory: Chinese government has made the downloading of the app mandatory to the entire population. People are not allowed to access public places if they don't have the app downloaded[17,36,12]
- Centralized data storage: As soon as a user grants the software access to personal data, a piece of the program labelled "reportInfoAndLocationToPolice" [17,36,12] sends the person's location, city name and an identifying code number to a server . The software does not make clear to users its connection to the police

Note: Iran's Mask.ir and Cyprus' CovTracer are other apps using location services, but have not been described in detail due to lack of availability of relevant literature

4.3.2 Bluetooth technology

Bluetooth is a short-range radio technology used commonly for connecting wireless headphones to a smartphone . It detects when another Bluetooth signal is near and can estimate the distance between devices — making it a good tool for contact-tracing [37,12]

How Bluetooth technology is leveraged[37]*:*

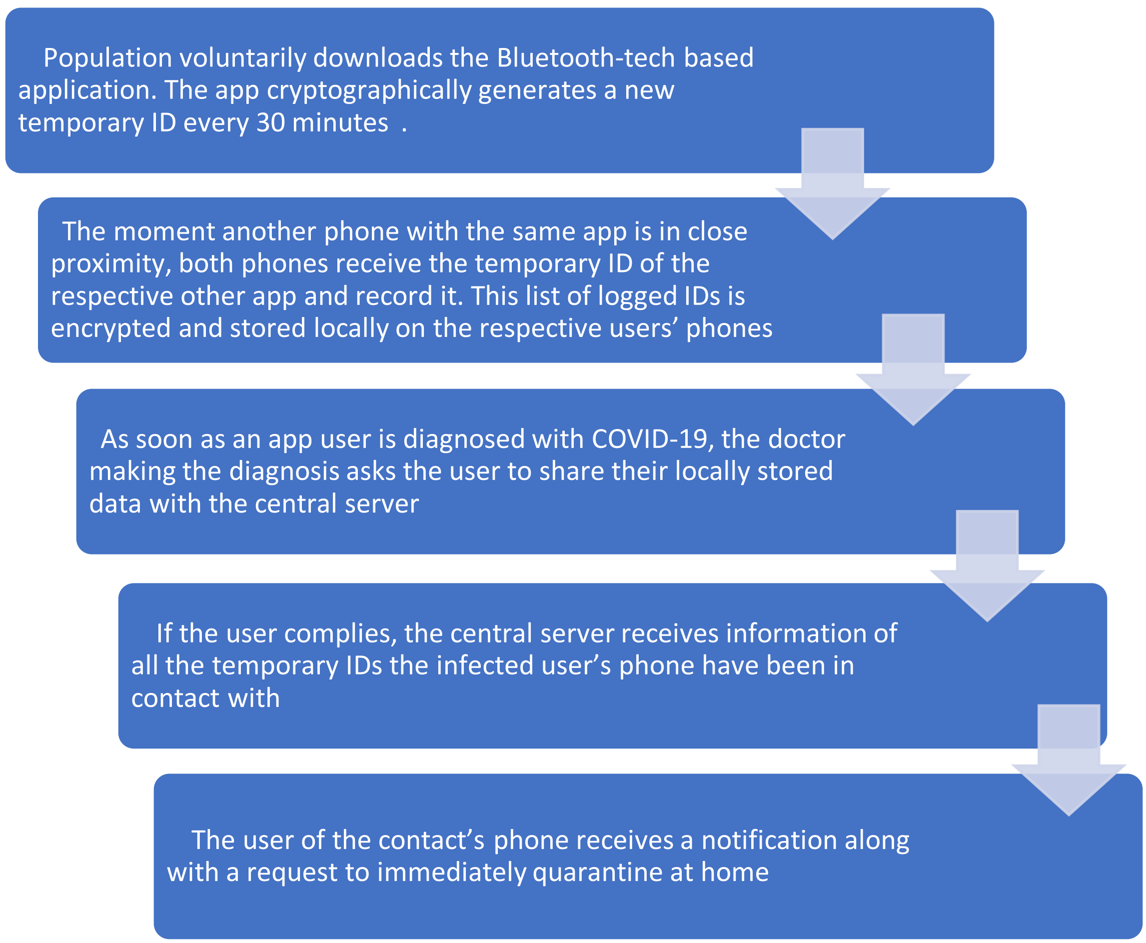

Figure 6: Flow diagram for Bluetooth based contact tracing

An illustration of the funtioning of a typical contact tracing application based on Bluetooth services is given below

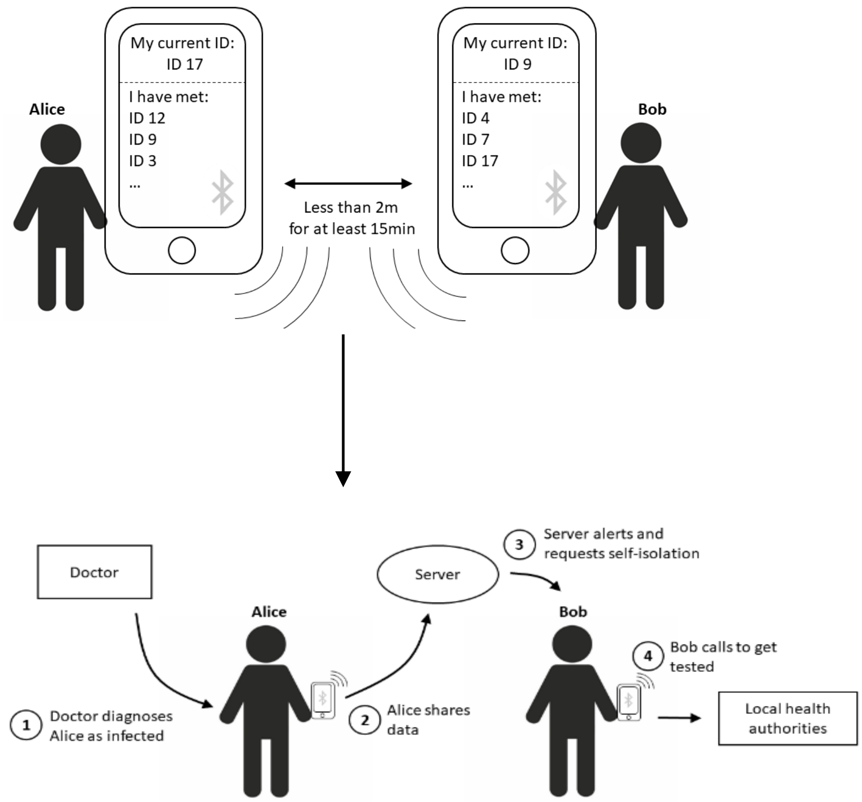

Figure 7: Process of Bluetooth based contact tracing

Prominent examples of countries adopting Bluetooth based contact tracing apps

E) Singapore's TraceTogether:

Launched on 20 March 2020, TraceTogether was the first Bluetooth-based contact-tracing app. TraceTogether supports Singapore's efforts to fight the spread of COVID-19 through community-driven contact tracing . TraceTogether does not collect data about GPS location, it instead uses Bluetooth to approximate the distance to other phones running the same app . It creates temporary IDs that change regularly. The lack of a persistent identifier means it is impossible for third parties to identify or track users [32]

Uptake by population[30]:
Downloads as of 13 May,2020= 1,400,000
Population of Singapore as per last national census = 5.64 million
Penetration [(downloads/population)*100] = 25%

How it works:

- Person voluntarily downloads app and grants permissions
- Bluetooth feature is used by app to exchange information between phones over short distances (2m) for 30 minutes
- If a user of the app gets infected, they can allow health authorities to access record of encounters, which is stored in the phone for 21 days, in order to alert contacts [37,39]

When two users of the app pass by, it uses the Bluetooth Relative Signal Strength Indicator (RSSI) readings between devices across time to approximate the proximity and duration of an encounter between two users. This proximity and duration information is stored on one's phone for 21 days on a rolling basis . Once a user tests positive for infection, the MOH works with them to map out their activity for past 14 days and requests the contact log. The user cannot legally refuse to share it [37,39]

Salient features:

- Non-anonymized: TraceTogether is explicitly designed to preserve the privacy of users from each other, but in contrast to alternative approaches favoured in other countries, is not anonymous as participants have to register the app using their phone number and national registration number . In order to safeguard participant's mutual privacy and ensuring their control over the data
- Centralized data storage: When signing up, a random User ID is generated and associated with the mobile number . Both the mobile number and User ID are stored in a secure server, and never shown to the public . The data will never be accessed[37,39], unless the user has

been in close contact with a COVID-19 case and is contacted by the contact tracing team

- Mandatory: Downloading, installing and activating (registering) the app has been made mandatory[37,39] for a significant part of the population by the government, and government employees have been pressed into installing the app, with some agencies claiming that it was mandatory . Users are only able to request opt-out via an email to the government agency

F) Australia's COVIDSafe

Released on 26 April 2020, the COVIDSafe app is the only contact trace app approved by the Australian Government. It helps find close contacts of COVID-19 cases. The app helps state and territory health officials to quickly contact people who may have been exposed to COVID-19 [38]

Uptake by population[30]:

Downloads as of 13 May, 2020= 5,300,000
Population of Australia as per last national census = 25.98 million
Penetration [(downloads/population)*100] = 20.4%

How it works:

- User is asked to register name, age range, postcode and phone number
- This information is stored encrypted on a government server, and then passed on to state and territory health authorities in the event that someone you've been in contact with has tested positive.
- Using Bluetooth, the app records anyone you get close to who also has the app. The two apps exchange anonymised IDs, which cycle every two hours and are stored encrypted on phones and deleted after 21 days.
- If someone is infected with coronavirus, they then get a unique code from a health official via SMS to use in the app to consent to upload the list of anonymized IDs onto the government's central server for the past 21 days of contact[38]

Salient features:

- Voluntary: State and territory health officials can only access app information if someone tests positive and agrees to the information in their phone being uploaded. The health officials can only use the app information to help alert those who may need to quarantine or get tested[38,17]
- Data destruction in 21 days: Data is stored and encrypted on phones and deleted permanently after 21 days.
- Limited: At the end of the Australian COVID-19 pandemic, users will be prompted to delete the COVIDSafe app from their phone. This will delete all app information on a person’s phone. The information contained in the information storage system will also be destroyed at the end of the pandemic
- Anonymized: Although personal information like phone numbers and names are collected, the information is stored onto the phone’s server and is anonymized by generating into a unique ID[38,17]

G) India’s Aarogya Setu

Released on 2 April 2020, Aarogya Setu is a “mobile application developed by the Government of India to connect essential health services with the people of India”. The App is aimed at “augmenting the initiatives of the Government of India, particularly the Department of Health, in proactively reaching out to and informing the users of the app regarding risks, best practices and relevant advisories pertaining to the containment of COVID-19”[40]

Uptake by population[30]:
Downloads as of 13[May,] 2020 = 100,000,000
Population of India as per last national census = 1.33 bil.
Penetration [(downloads/population)*100] = 7.39%

Aarogya Setu crossed five million downloads within three days of its launch, making it one of the most popular government apps in India. It became the world's fastest-growing mobile app. It reached 100 million installs by 13 May 2020, in 40 days since its launch [41]

How it works:
Aarogya Setu leverages both Bluetooth and GPS technologies

- After installing the app, user is prompted to switch on Bluetooth and set 'location sharing' to 'Always'

- It has a tool for self-testing. The user is asked to answer a number of questions. In case some of the answers suggest Covid symptoms, the information will be sent to a government central server. The data will then help the government take timely steps and initiate the isolation procedure, if necessary
- When two smartphones with Aarogya Setu installed come in each other's Bluetooth range the app will collect information. If one of the two people have already tested positive, the app will alert the other person and in the process allow the government to trace potential cases[41,37]

Salient features:

- Centralized data storage: The data on personal information, diagnosis status, symptoms, etc. collected by the app is stored onto a central government server, and can always be accessed by public health authorities[41,37]
- Non-anonymized: The data collected is non-anonymized and appears as raw data points on the central server
- Mandatory: The MoHFW has made the app mandatory for government employees, travelers and residents of certain high risk zones like Noida

4.4 Data safety, transparency and penetration

4.4.1 Anonymization, decentralized data storage and eventual data destruction from server determines data safety of an app

i. A*nonymization of data* - Data anonymization is a type of information sanitization whose intent is privacy protection. It is the process of either encrypting or removing personally identifiable information from data sets, so that the people whom the data describe remain anonymous. This is an inherent property of an app which is in the hands of the developer. Countries like Bulgaria, Iceland and Australia have developed apps that ensure data anonymization, thereby increasing data safety

ii. *Decentralized data storage* – In a centralized system, a singular authority or administrator retains total control over all aspects of the network. This authority is typically exerted through a central server that manages all data and permissions. Decentralized networks are organized in a much more distributed fashion. Each node within the network functions as a separate authority with independent decision-making power regarding how it interacts with other systems. These networks also distribute processing power and workload functions among connected servers

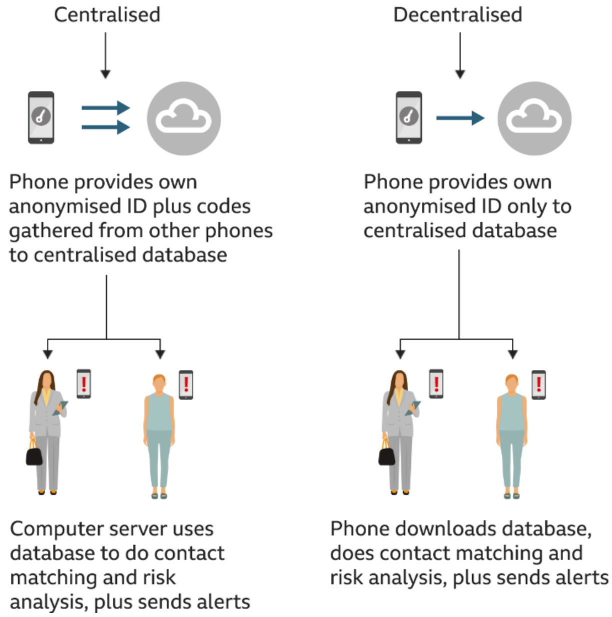

Figure 8: Centralized vs. Decentralized data storage

iii. *Data destruction*: The apps store data onto the phone or onto a central server, depending on which storage model they use (decentralized or centralized). Most apps guarantee that data is destroyed after a stipulated time frame from the servers, varying from anywhere between 14 days, as in the case of Singapore, to 30 days, in the case of Iceland[17,12,30]. The eventual data destruction is what makes the app safe to use, ensuring maximum privacy protection. Contact tracing apps of China and India, however do not delete the data they collect on an everyday basis, and hence are poor in terms of data safety[21,19,40]

Table 2: Data safety assessment

App name	Country	Anonymized	Decentralized data storage	Data destruction
Health codes	China	✗	✗	✗
HaMagen	Israel	✗	✓	✓
ViruSafe	Bulgaria	✓	✗	✓
Rakning-19	Iceland	✓	✓	✓
TraceTogether	Singapore	✗	✗	✓
CovidSafe	Australia	✓	✓	✓
Aarogya Setu	India	✗	✗	✗

4.4.2 **Transparency** of an app is determined by whether the government authorities or developers of app upload the code behind the applications, onto a public developer portal, like GitHub, wherein the citizens can assess and even detect bugs through ethical hacking.[42] If a country puts up the entire code, the transparency is high; if only bits of the code are uploaded, it is moderate and if no information is provided around the developer code, transparency is low, like in the case of India, wherein the government authorities have refused to upload the code of the app onto any developer portal

4.4.3 Penetration

Penetration of an app is determined by the proportion of downloads from the total population as per last census conducted in each country

The penetration is bucketed into High, Medium and Low based on the sample's distribution

Low penetration < 10%

Medium penetration = 10% to 20%

High penetration > 20%

Hence, Iceland Australia and Singapore's apps have greatest penetration, whereas Bulgaria, India and China's have least penetration

4.5 Australia's CovidSafe mobile application leveraging Bluetooth technology is the safest, most transparent app in the cohort, with highest penetration rate; India's Aarogya Setu fairs poorly in all three parameters

Table 3: Assessment of Data safety, Transparency, Penetration

App name	Country	Data safety	Transparency	Penetration
Health Code	China	Low	Low	Moderate
HaMagen	Israel	Moderate	High	Moderate
ViruSafe	Bulgaria	Moderate	Moderate	Low
Rakning-19	Iceland	High	Moderate	High
TraceTogether	Singapore	Moderate	High	High
CovidSafe	Australia	High	High	High
Aarogya Setu	India	Low	Low	Low

4.5 Challenges in uptake of contact tracing mobile applications

Despite their perceived benefits over traditional contact tracing methods, contact tracing mobile applications face the problem of limited uptake. One recent study of 2,612 Americans reports "widespread reluctance" to embrace smartphone-based contact tracing. Only about one in four respondents (27%) "expressed willingness to download a hypothetical app with GPS location tracking, while 32% were willing when the app was described as using non-location-tracking

Bluetooth technology"[11,27], the team reported. According to a report in The New York Times, only about 3% of the population of North Dakota had downloaded that state's Care19 app as of late April.

i. Accuracy issues: One key practical challenge to phone-based contact tracing is making accurate measurements of how close two devices are. For location based contact tracing, cell phones work by continuously connecting to a set of radio antennas called "cell sites" . The records generated by cell sites is often only able to place a phone within a zone of 800 meters to three kilometers. GPS sensors built directly into phones can do much better. GPS enabled smartphones are typically accurate within a 4.9 m (16 ft.) radius under open sky. However, GPS radio signals are relatively weak; the technology does not work indoors and works poorly nearlarge buildings, in large cities, and during bad weather. In Bluetooth based contact tracing apps, signal strength can vary on the basis of the orientation of the phone and whether it is in your hand or in your pocket. Information besides just the Bluetooth signal strength is needed to make measurements work right

ii. Issues on privacy protection: According to two studies on different populations, respondents from varied countries including, but not limited to U.S, U.K, France, Italy and India, expressed that they were unwilling to download the respective contact tracing apps owing to "privacy concerns". A study found that over 56% of people in the state of Minnesota were convinced that the mobile contact tracing app introduced by their state "launders their private data to aggregators" and hence were unwilling to download the app. Data breaches and hacks, that release personal data into the public sphere, are not uncommon in the telecom industry. So is the case of data associated with social media and other apps. In the hands of stalkers, extortionists, blackmailers, contract killers and lynch mobs, location data can be used for "going after people. A lot of this data finds its way into the data market. Location data can be bought from data brokers i.e. companies that collect and collate data and then sell it to local (smaller) data traders, advertisers, and even state agencies. Trading in location data is big business. Location data in the market is usually available tagged with an anonymous id. The largest amount of location data comes from apps. App makers sell location data to various data aggregators who trade in this commodity. It could be a weather app. It can be any type of device. Some of the more well-known location data aggregators have thousands of partners. A significant amount of data also makes it to the secondary market for location data. Mobile carriers are not allowed to sell subscribers' personal data to anyone. Now, when an app requests for location data (and the app cannot take it directly from the mobile itself), the mobile carriers do not provide location data directly; they pass on this data to location data aggregators who in turn give it to the app. This arrangement is considered a kind of subcontracting, and not the sale of data.

The aggregators are middlemen, and are not properly regulated. So they monetize this data by selling it to whoever wants it. Neither the carriers nor the aggregators care about how this data is used or have any effective way to monitor it. The US Federal Communication Commission (FCC) recently imposed hefty fines on four major US mobile carriers for selling users' location data. This market is not restricted to the US alone and location data sales for regions like Canada, India and the Philippines have also been advertised. India too seems to have a fast-growing general data brokerage sector, with significant presence of international players, fed significantly by data from mobile carriers

iii. Requires mass downloading: Enough people need to download the app to make it effective. The TraceTogether team said that 1.1 million people had downloaded its (non-Gapple protocol) app as of 20 April — roughly one-fifth of Singapore's population. But that means there's just a 4% chance that any two given people will have the app, limiting its efficacy. Apps also obviously exclude anyone who doesn't own a smartphone — who are often among those most vulnerable to COVID-19, such as older people and migrant workers. In Singapore, for instance, foreign workers have borne the brunt of the country's roughly 24,000 cases. Many of those 1.4 million individuals cannot afford smartphones and live in crowded dormitories, with up to 20 people in a room. In such a scenario, contact tracing is less important, because almost everyone is exposed to the virus

iv. Issues around interoperability: Since most of the apps introduced by the government authorities across the globe are based on different technologies, server interactions, privacy policies, etc. they are not interoperable, meaning, if an Indian national using Aarogya Setu mobile application were to travel to the U.K, they would have to download the indigenous U.K. app and re-enter all their details into U.K's contact tracing app, since Aarogya Setu would not function in U.K. This deficiency in interoperability is harmful for correct contact tracing. If apps were interoperable, one user travelling to another state or country, would not have to go through the added effort of downloading another application, only to switch back to the prior one on return to their country of permanent residence

v. Issues on battery drainage: For some of the apps to be useful, iPhones must remain unlocked all the time with the app open, a major inconvenience and a drain on the battery. On Apple’s iPhone, the app has to be open at all times for it to work, which is a drain on the battery. Singapores’s TraceTogether app does not work reliably on iOS devices and can pose a significant drain on battery life, which will deter those who are using Apple devices such as the iPhone from downloading the app

Chapter 5: Discussion

Covid-19 is changing the landscape across all industries. Having given a boost to the tech industry, with options like telemedicine, contact tracing, etc. rapidly emerging, we see ourselves amid a paradigm shift in how data is used by private tech firms like Google and Apple, or the governments across the globe.

In such a change, privacy remains at the center. Hence, while resorting to or downloading mobile applications, the users consider the privacy regulations the apps have.

As highlighted in this paper, privacy concerns are high in the west vis-à-vis the Asian countries. However, privacy protection laws are most stringent in the EU. The U.S is still lagging when it comes to policies around privacy preservation.

On the other hand, in countries like China and South Korea, neither ar the policies robust, nor are the citizens as concerned about their privacy, given a multitude of reasons like top-down policy approach in China and South Korea.

lso, according to the WHO, although several countries and areas have deployed digital tools for their COVID-19 response, there is currently limited evidence to evaluate the effectiveness and impact of these tools. As such, digital tools should not be considered as ‘single solutions’ for contact tracing, but rather as complementary tools.

Additionally, the implementation of digital technologies in contact tracing carries the potential to do harm through privacy breaches, provision of incorrect medical advice based on self-reported symptoms, and the systematic exclusion of some members of society who cannot access such technologies. It is therefore important to have sufficient regulatory oversight of digital tools for contact tracing.

Ethical issues surrounding privacy, security, transparency and accountability also need to be considered throughout the design and implementation of digital tools for contact tracing.

Marginalised and disadvantaged groups will be more likely to be excluded, particularly in low-and middle-income settings. In humanitarian and conflict settings, mobile phones can present opportunities for theft and violence.

The timing of the introduction of digital tools for contact tracing also needs careful consideration; ideally, the tool should be introduced during the preparedness phase in training. During the response, refresher training can facilitate the timely launch of digital contact tracing.

Public-health institutions have led contact-tracing efforts in most past disease outbreaks. The global scale of the COVID-19 pandemic makes it a unique crisis with many parts. It has, for example, expanded into domains where the private sector plays a more prominent role in healthcare. To address the sheer number of cases in particular areas, authorities are assembling many partners, including from the private sector, in contact-tracing efforts. The use of technological enhancements is also drawing in companies with an array of specialized capabilities. Private healthcare organizations and employers are playing an important role in both testing and tracing. The complexity of those invested in

controlling this pandemic creates both challenges and opportunities for contact tracing

Chapter 6: Conclusion

In the current crisis, we will have to endure more and deeper encroachments on fundamental rights than we are used to . Still, there is no reason to tolerate such encroachments to a greater extent than strictly necessary . Even under the current time pressure, it is important to find solutions that minimize data processing as far as possible . We have shown above that this is possible for the case of contact tracing As the pandemic progresses, many other challenges will emerge. For each of them, one will have to check which data processing is necessary to address them and which ones can be avoided.

Trying to find a data-minimizing solution does not just protect fundamental rights Such solutions will often increase the effectiveness and efficiency of the respective data-processing system . Only if people trust a system—because it does not spy on them—will the system find broad support in the population"

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