Digital contact tracing landscape during Covid-19 pandemic:

Role of mobile applications in contact tracing

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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.

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

Introduction

Context

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]

`"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"

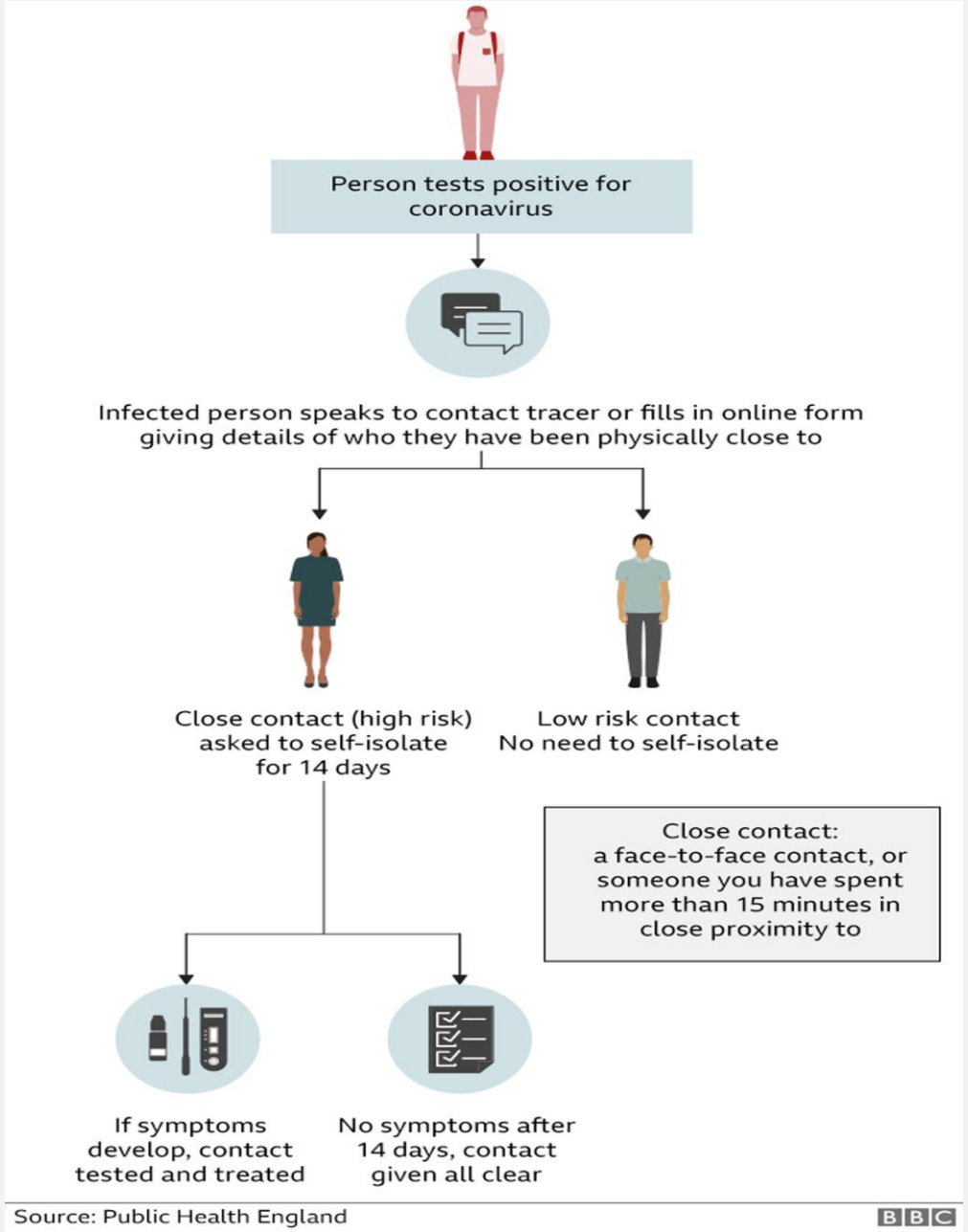
"**Contact listing:** Efforts are made to identify every listed contact and inform them of their contact status, the actions that will follow, and the importance of receiving early care if they develop symptoms".

"**Contact follow-up:** Regular follow-up is conducted with all contacts to monitor for symptoms and test for signs of infection[4]"

Contact Tracing : Methods (1/2)

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"**



Contact Tracing : Methods (2/2)

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

Singapore's contact tracing landscape

Singapore limits case count through inter-sectoral collaboration, robust contact tracing methods and stringent quarantine measures

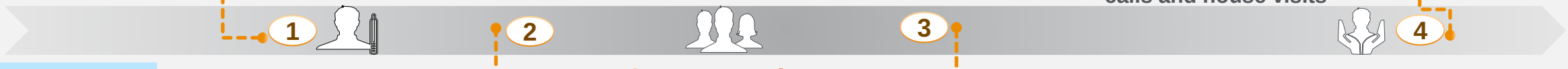
Activity mapping of patient

Case is interviewed by hospital staff and an **activity map,** covering **places visited; recent activities and close contacts** is created, for the last 14 days

Ministry of Health creates a single database of the activity maps of all cases

Subsequent testing, ensuring quarantine

Suspect cases (close contacts with symptoms) isolated and tested at government facilities; other contacts to self-quarantine for 14 days, monitored closely by a health security officer via **calls and house visits**



Contact Tracing

Collaboration of Health Ministry and police has uncovered numerous clusters

Epidemiological and police investigations

Teams of epidemiologists and volunteers from govt. departments chart detailed activity maps **within 24 hours** of diagnosis.

Singapore Police Force is contacted incase of missing links, which then deploys:
- **Analysis team:** identifies possible links by analyzing activity logs
- **Interview team:** performs in depth interviews of third parties
- **Field team:** combs streets to identify contacts

Digital platforms aiding contact tracing

TraceTogether mobile application

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

Literature review

Literature Review

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.

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"

Author (Date)	Location	Study design	Sampling	Salient features
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, Alexander Koch, Jorn Muller-Quade, Thorsten Strufe (April 2020)	France	Exploratory review	-	"Propose a new model "ConTra Corona", using Bluetooth technology, which guarantees user data protection and reduced false negatives"

Author (Date)	Location	Study design	Sampling	Salient features
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"

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

Methodology

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

Results

Results

- Contact tracing is a paramount non-pharmacological measure to reduce Coronavirus transmission
- Digital contact tracing through mobile applications is quickly emerging as a durable supplement to laborious manual contact tracing
- Contact tracing mobile apps were first deployed in South East Asian nations; limited deployment in the west due to privacy concerns and policies
- Location services and Bluetooth emerged the top techs for the basis of development of apps

Results

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

Contact tracing is effective in controlling the spread of infectious diseases. It has also been considered a cost effective method

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

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

- Automated and effortless
- Cost efficient
- Low dependence on patient recall
- Faster Reporting
- Bigger, Better Data
- Historical Reporting

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

Process of location tracking contact tracing apps:

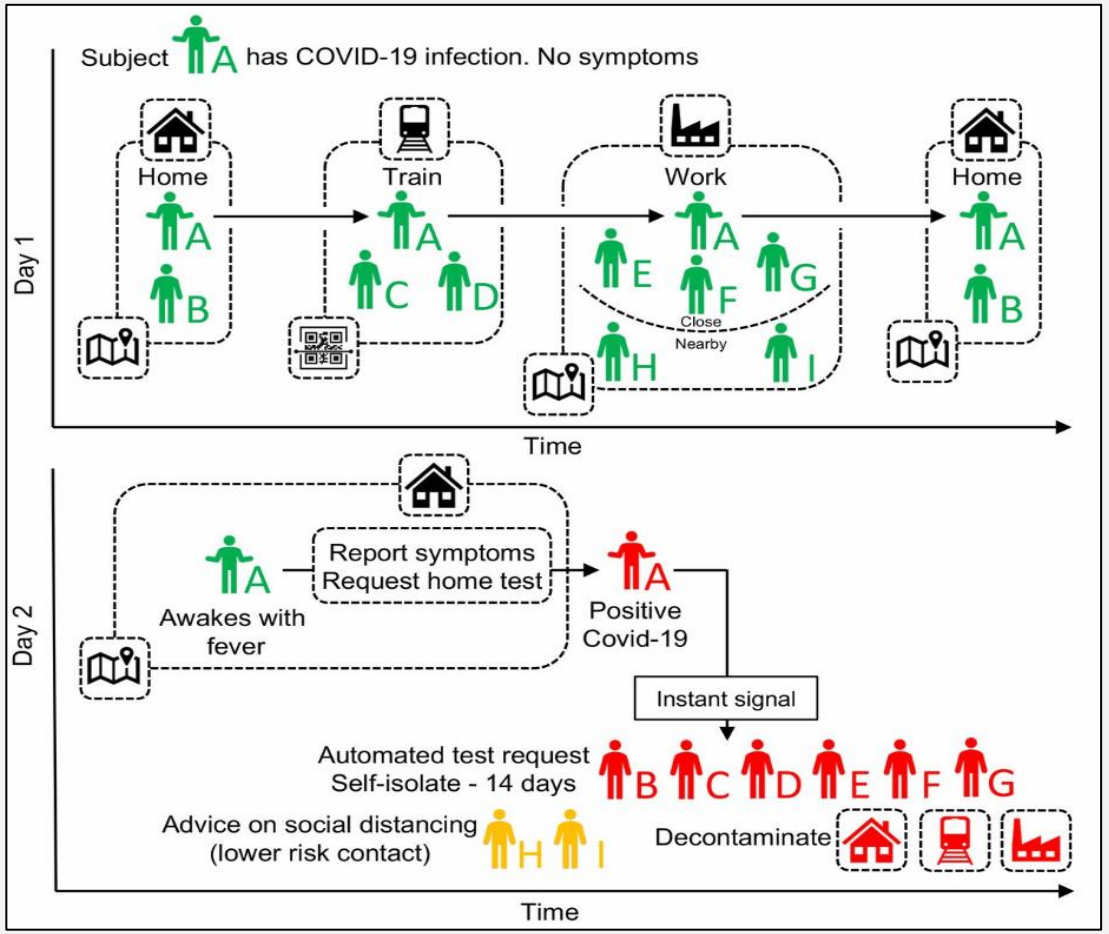
Location tracking app is downloaded voluntarily by people onto their smartphones

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



Prominent examples of countries adopting location tracking contact tracing apps

- Bulgaria's ViruSafe
- Iceland's Rakning C-19
- Israel's HaMagen
- China's Health Code System

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

Process of Bluetooth based contact tracing apps

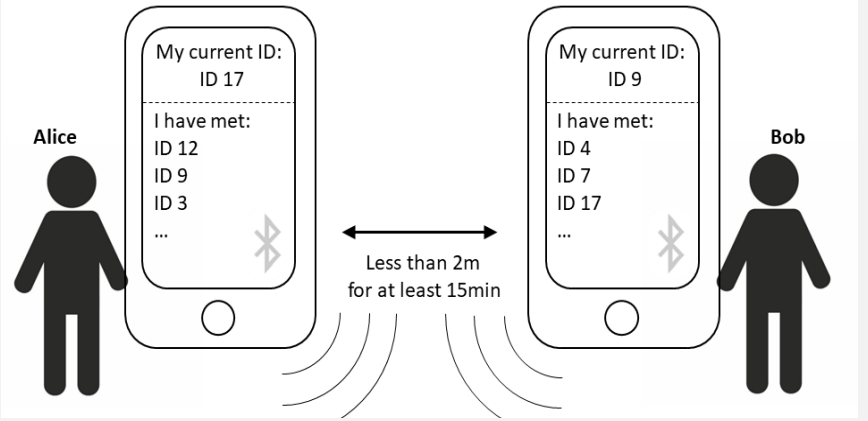
Population voluntarily downloads the Bluetooth-tech based application. The app cryptographically generates a new temporary ID every 30 minutes

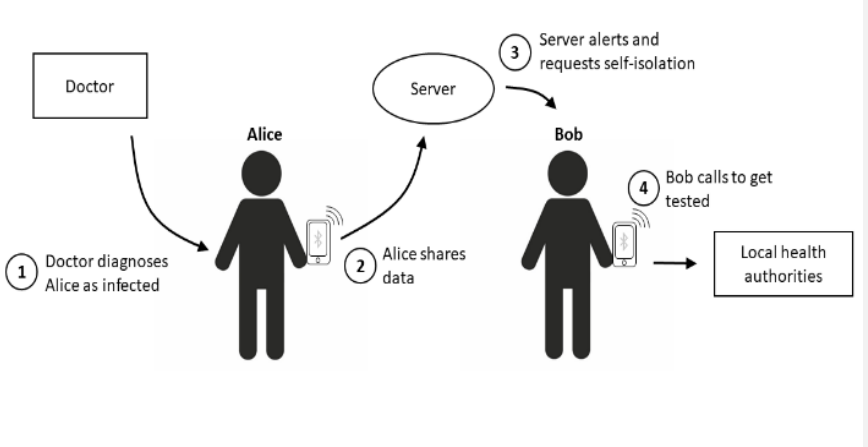
The moment another phone with the same app is in close proximity, both phones receive the temporary ID of the respective other app and record it. This list of logged IDs is encrypted and stored locally on the respective users' phones

As soon as an app user is diagnosed with COVID-19, the doctor making the diagnosis asks the user to share their locally stored data with the central server

If the user complies, the central server receives information of all the temporary IDs the infected user's phone have been in contact with

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



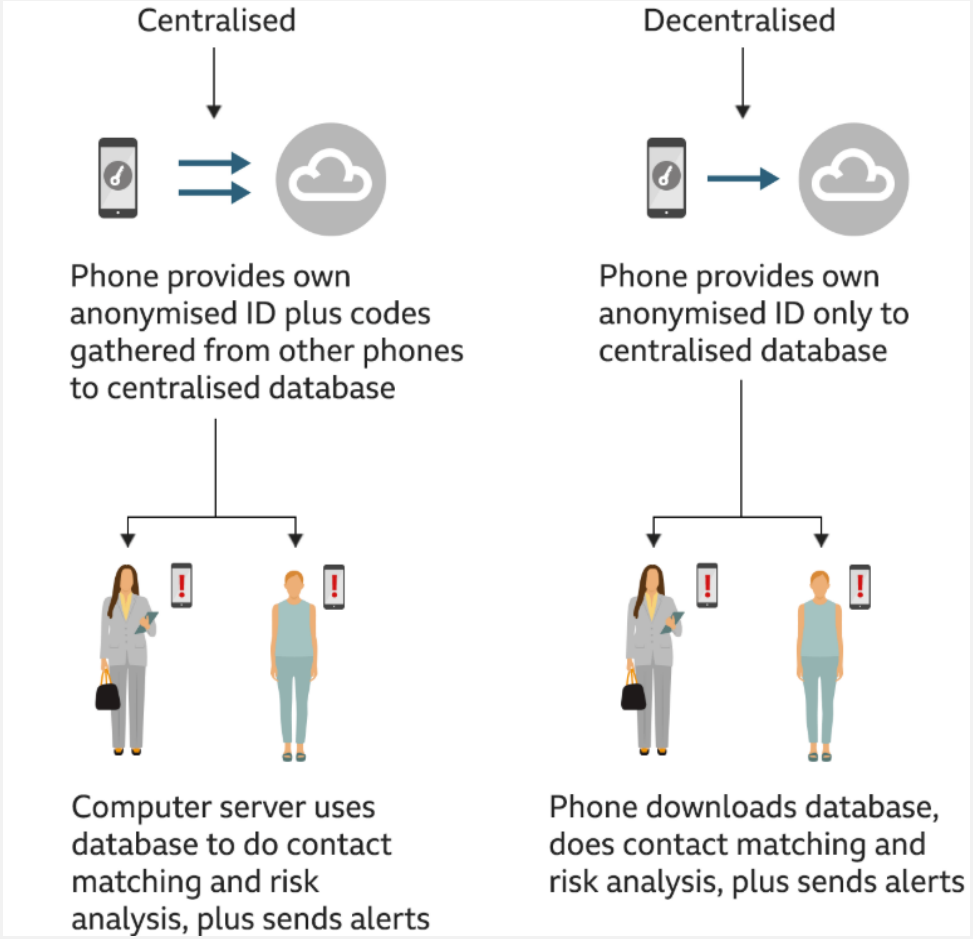


Data safety, transparency and penetration (1/4)

Data safety: Anonymization, decentralized data storage and eventual data destruction from server determine data safety of an app

- *Anonymization 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

- *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



Data safety, transparency and penetration (2/4)

- *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]

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	✗	✗	✗

Data safety, transparency and penetration (3/4)

Penetration

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

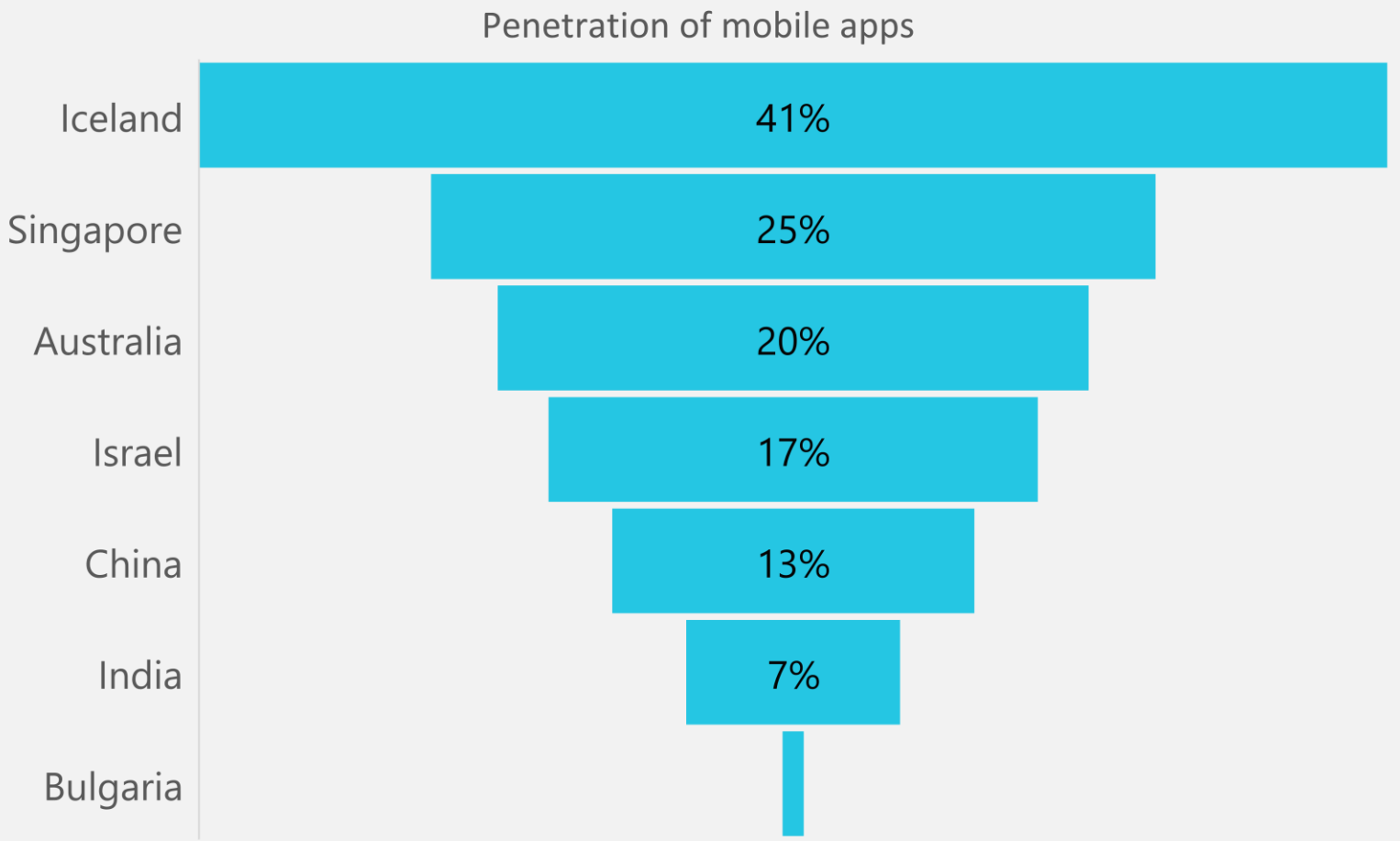
The penetration is bucketed into High, Medium and Low based on the sample's distribution

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



Data safety, transparency and penetration (4/4)

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

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

Discussion & Conclusion

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.

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.

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Thank you