The probability of transmitting the virus, but this has not been properly measured.

Q: What would it take for contact tracers to consider bluetooth contact tracing more than a speculative technology? What should an app developer be able to show?

> See questions from contact tracers in the section below

Q: How accurate would the distance and duration of contact measures need to be? Can you put a number on this, a guess or a max?

> Some jurisdictions are using “15 minutes face to face” as a heuristic, less than that would be a casual contact

Q: If an app user is alerted that they’ve had significant contact with someone who tested positive for COVID-19 during their infectious incubation period, *what anonymous automated messages should we send them*?

> From Covid Watch: Our privacy-preserving system is designed to alert people early who could *choose* to call their public health agencies, not for contact tracers to track them down directly. We’d like to know what automated messages are best to send in this case. What do we instruct people to do? Currently: Call this # to inquire about testing, start wearing a mask outside, and self-isolate.

Questions that Contact Tracers have for App Developers

Q: from one jurisdiction’s public health officials: can you reliably identify *close* contacts for us? Not just the same cafe or restaurant, but who was actually close to the patient for some time?

> Covid Watch Response: Yes, using bluetooth, we have a notion of both duration of contact and proximity, accurate possibly to 1-2 meters.
>
> GPS: see the section on types and sources of data below.

Q: What percentage of the population have to be using this for us to have a high expectation of finding close contacts?

> The answer depends on many variables, such as how accurate each phone's sensors are, how good the user interface on the app is, on adoption among laboratories and health authorities that are doing testing. In one simulation that varies across these variables: if an app needs to be installed on both user's phones at the time of exposure, at least 50-70% of users should have it to make a significant difference. For apps that can use retrospective data for diagnosed patients, impact might be seen from 30-40% penetration.

Q: What percentage of the population have to be using a Contact Tracing App in order to effectively contain the outbreak ?

> According to Monte Carlo simulations for a Bluetooth contact tracing approach effective damping of the epidemics outbreak occurs with an overall efficiency of 60-70% (see Fig.6). This overall efficiency parameter considers users adhesions and other technical aspects (e.g. smartphones or bluetooth shutdown).

Questions that App Developers have for other App Developers

- [iOS] How are app developers going to continuously background scan and record specific BLE advertisements while a potential tracer app runs in background mode on Apple iOS? To my knowledge, iOS effectively prevents exactly this scenario for **battery** reasons. (I am aware of implementations from around 2013, however, things have massively changed since then.) I have heard suggestions that Apple can grant special Entitlements to allow third-party apps using APIs which are also used by "Find my", so that effectively BLE Proximity Tracing can be implemented without the need for an iOS update – but none has been confirmed, yet.

Notes on types & sources of data

Around the world, various initiatives are exploring or using the following types of data:

- Cell tower triangulation (not particularly accurate, but may be sufficient for correlational uses such as recognizing users who are in the same vehicle)
- Assisted GPS (accurate enough to put people in specific buildings, but with a fairly high error rate unless there's lots of time average)
- IP addresses -- complicated, but correspond to street addresses for devices that are using residential WiFi networks
- WiFi triangulation (improves on assisted GPS -- accurate enough to often, but not always, place people in specific businesses)
- Wifi proximity estimation (accurate on its own to within 2.5 - 3m 90% of the time, perhaps 1.5m on average)

- Bluetooth proximity (seems to be accurate to within 1-2m?)
    - Apple and Google will be shipping an API to use this method in mid-May 2020
        - A September 2020 evaluation of this API's ability to sense proximity.
    - Previous notes:
        - Both Covid Watch and TraceTogether have encountered difficulties in interworking between Android and iOS. Covid Watch resolved this issue and partially resolved the iOS-iOS issues. More Info
        - Audio proximity (cf google nearby but tbd whether there's a way to do this in the background)
- Hybrids of the above
    - Eg: IOS and Android default location system [which is a hybrid of cell tower, assisted GPS and WiFi triangulation?]
        - The fact that various troves of mobile location data are already sitting around in various places (eg Google Maps Timeline, or where it's been gathered by apps with varying levels of user awareness) makes it enticing, because it allows apps to do some amount of *retrospective* tracing at the time they are installed or activated and thereby considerably reduces the number of users the app needs to be effective.
- Precise locational check-ins, e.g., via QR code
- Some human contact tracing efforts turn to previously installed surveillance equipment to identify unknown contacts, such as:
    - Video surveillance footage
    - Facial recognition systems
    - Potentially, previously installed IMSI catchers / cell site simulators could be used for this purpose too [though there are no reports of their use for public health purposes?]
    - Korea's tracing operation is a relatively extreme example of reliance on surveillance methods
    - In general most privacy groups discourage the deployment of the above systems under most circumstances

Notes on Privacy Preservation

"Anonymization" or "de-identification" of a mobile (eg GPS) location history is difficult to do correctly. Given the weak epidemiological case for this kind of data at present (at least until testing latency is down to hours, not days) we would presently advise apps for most purposes not to try to collect GPS location for automated contact matching.

> (**Note 2020-03-30**: one location expert at a tech company told us that they think that in some cases the combination of GPS+WiFi might be accurate enough to identify close contacts, because reflections that increase lat/long error don't necessarily impact proximity measurements to the same degree-- both devices may observe similar reflections. This may be especially true on higher end devices that shipped in the last 2-3 years)

For apps that are trying to do it anyway, we recommend reaching out to cryptographic privacy experts (openmined.org for instance has a team available to help other projects) to ensure that de-identification processes are secure.

Colm MacCárthaigh, who works on cryptography and privacy at Amazon, has written up a cryptographic sketch of how to do minimally disclosing contact identification using GPS/SSID location matching. The scheme avoids sharing any searchable location data and records only “pairings” of people being in the same place at the same time (to any degree of fidelity of place or time that is needed).

Bluetooth and similar proximity based tracing methods (as opposed to using cell phone tower locations to triangulate or otherwise locate a phone) have been identified as the most likely to produce effective warnings to exposed individuals without extremely high false positive rates (which are inherently harmful). However, because they cannot be correlated against any location data, they need to be enabled on a significant fraction of devices before this provides a high likelihood of tracing contacts.

- Apps that are being deployed for bluetooth contact tracing are using a range of cryptographic identity protections. Singapore’s TraceTogether app, for instance, has rotating encrypted IDs that are controlled server-side, so the government’s server can decrypt IDs for and notify exposed individuals. This is a reasonably good level of privacy protection, but stronger models are also available.

Decentralized Bluetooth protocols like those developed at Covid Watch and CoEpi in early March, now under the TCN coalition umbrella, are the standard for privacy-preservation. Similar protocols that preserve-privacy were also later developed by DP3T, PACT (Washington), and PACT (Ron Rivest). These are also likely functionally the same in terms of privacy protection as the APIs to be released by Google/Apple in May, given that Google/Apple open source their implementation and it is found to be in accordance with the specs.

In terms of privacy protection, the best case scenario is: decentralized Bluetooth-only like TCN, PACT, DP3T, and the upcoming Google/Apple APIs. Worse: decentralized Bluetooth plus GPS data handed to contact tracers (like the MIT SafePaths model). Even worse: centralized Bluetooth (like Singapore, and what Australia is considering).

Apple’s built-in Find My app is an example of a similar but stronger privacy model: it uses bluetooth to detect nearby devices, but does so without Apple ever knowing which devices were near each other.

Another approach based on asymmetric encryption was proposed by Proximity. Daily asymmetric encrypted strings (phone number, timestamp, contact duration) in a decentralized system.

The Covid Watch project is working on an open source library in addition to their own app. This library can be included in many apps and offers similar levels of anonymity to Find My.

Secure Authentication of Diagnoses

Different projects are taking different approaches for inputting diagnoses of COVID-19 cases. Some projects are allowing users to self-report a test based diagnosis or collecting self-assessed symptoms. Other projects are expecting to work with public health authorities or testing laboratories to securely authenticate diagnoses.

Self-reporting may be an appropriate approach for small pilot projects in specific communities or institutional settings, but we can expect that apps that are widely deployed would be subject to spurious or malicious claims to be COVID-19 positive, and need to be securely authenticated.

Relevant projects & Circulation list

Application Developers

	Project	**Technology**	**State**	**Links**
1	Accenture	Central GPS	?	?
2	AITIA	Self Reporting (Web)	rel	aitia.app
3	AliPay Health Code	GPS and QR Code	rel	NY Times
4	Aarogya Setu (India)	GPS and Bluetooth	160m users	**A great talk about this app!**
5	BanDemic (German)	Bluetooth	prop?	bandemic.app Contact repo
6	Bluetooth Contact Tracing (BCT)	Bluetooth	dev	Design doc

7	CAuDHT	Bluetooth	prop	Whitepaper
8	Coalition Network	Bluetooth	rel	Website App Research Github
9	Code Orange (Israel)	Local GPS	dev ?	Design doc
10	CoEpi	Bluetooth, using Covid Watch	dev	coepi.org
11	Corona Data Scraper	Map	?	coronadatascraper.com
12	Coronastatus	Self Reporting (Web)	rel	repo
13	Corotrack	Self Reporting (Web)	gone	corotrac.com
14	Coronamap (Korea)	? MAP	rel	coronamap.site
15	Corona Network	Self Reporting (app)	demo	repo thread
16	Corona Trace	GPS + Self Reporting (App)	beta	Coronatrace.org Google Doc repo
17	Covapp (Germany)	Self Reporting (Web)	rel	covapp.charite.de
18	Covid-App (Germany)	AI	prop	Covid-app.de
19	CoV-erage (Germany)	Self Reporting (Web, iOS, Android)	beta	github
20	Covid Community Alert (global)	Bluetooth (iOS, Android)	rel	Website Code
21	Covid Flutter (India)	(Central / Global?) GPS	dev	Blog post Repo Slack
22	Covid Near You	Self Reporting (Web)	demo	covidnearyou.org

	CovidSafe(University of Washington)	Memory Aid, “Narrowcast”, GAEN (iOS, Android)	demo	Website code
23	CovidSafe (Australia)	Bluetooth, App (iOs, Android)	rel	Australian Government Department of Health
24	CovidSafePaths (MIT)	Tracing (App)	relCOVIDSafe app	CovidSafePaths.org
	CovidShield	Tracing app (uses GAEN)		Github
25	Covid Symptom Tracker	Self Reporting (App)	rel	Covid Symptom Tracker
26	Covid-19-Track	Self Reporting (Web)	rel	Covid-19-track.com
27	COVID19Radar (Japan)	Bluetooth (Android/iOS)	beta	Website; GitHub; Tester registration
28	Covid Watch	Bluetooth	dev	Covid-watch.org repo @
29	Covid World (Sygic)	(Central / Local ?) GPS + Bluetooth	rel	Sygic post: repo;
30	Covi-ID (South Africa)	Self-sovereign status verification	dev	https://coviid.me
31	CoWin-20 / Corona Kavach (India)	? GPS + Bluetooth	?	News
32	CrowdsourceRescue	?	?	crowdsourcerescue.com
33	Cubeiq	Map / Big Data	?	cuebiq.com/about/data-for-good
34	DP^3T	BLE	prop	DP^3T

35	EpiCollect	Self Reporting (Web) + KML	rel	epi-collect.org
36	Epidose	Bluetooth based on DP*3T	demo	Repo
37	Edward Burton Blockchain	?	demo	Medium article
38	FeverMap	Map	prop	Repo
39	GeoHealth (Germany)	?	?	?
40	Gesund Zusammen			https://gesund-zusammen.de/
41	Ghana Health Services App	Self Reporting (App)	rel	Android
42	Guardian (Private Pandemic Tracker)	Self Reporting (App), (GPS & Bluetooth)	dev	myguardian.life
43	Hamagen (Israel)	Local GPS	prop	Repo Privacy Review;
44	Healium (Alams) (Pakistan)	GPS + Bluetooth + Dashboards	Demo	App Mock, Dashboard Mocks
45	Hi5X	QR, Bluetooh	rel	iOS, Website
46	Infection Chain	QR	demo	Infection Chain, Prototype;
47	Ketju (Finland)	Bluetooth	dev	https://gdprhub.eu/index.php?title=Projects_using_personal_data_to_combat_SARS-CoV-2#Finland:_Ketju_project_.28Private_.26_Public.29
48	LivNao	Bluetooth	demo ?	https://livnao.com/covid19/

49	Mask.ir (Iran)	GPS	rel	https://mask.ir/faq.html
50	Memiah	Bluetooth	demo	Repo; Google Doc; Facebook
51	Mila (Canada)	Local GPS (Privatekit)	Prop	Google Doc;
52	MyLog14 (Taiwan)	Local GPS ?	dev	Devpost
53	MyTrace (Canada)	Local GPS (PrivateKit) + Bluetooth	test	Mytrace.ca info@mytrace.ca
54	NextTrace	Web-based survey	prop	Nextrace.org Contact;
55	NinjaPad	Separately Encrypted GPS (or other location)	demo/ rel	github
56	NOVID	Microphone (background sound), bluetooth	rel	https://www.novid.org/
57	OpenMined	Local GPS (library)	dev	OpenMined.org Repo
58	PACT (MIT)	BLE	prop	https://pact.mit.edu
59	Pandemic.Events	KML Upload	rel	pandemic.events Repohttps://docs.google.com/document/d/16Kh4_Q_tmyRh0-v452wiul9oQAiTRj8AdZ5vcOJum9Y/edit#

60	Pan-European Privacy-Preserving Proximity Tracing	BLE	prop	Pepp-pt.org @
61	Pandoa (German)	Local GPS +	dev	Pandoa; Devpost;
62	Pisarasi (“Droplets”, Finland)	KML Upload, web self report	demo	pisarasi.fi (demo: app.pisarasi.fi)
63	Privacy Preserving Proven Prior Proximity Protocol (P6)	BLE	prop	https://github.com/approov/bluetooth-p6 Blog article
64	PrivateKit: Safe Paths (MIT)	Local GPS	rel	safepaths.mit.edu; Article;
65	Proximity (Italy)	BLE Asymmetric encryption Certified case report	prop	https://arxiv.org/abs/2003.10222
66	Safe2	Test Results + Self-Assessment + Local GPS + Local Bluetooth	dev	https://safe2.org
67	Safegraph	Bluetooth + Mobile	rel	Website
68	Safetrace (Enigmampc)	KML Upload	dev	repo
69	SafeTraceAPI (Faction)	Cryptographically Private Trace Matching - Library	dev	repo website
70	Sharetrace (UK/USA)	Bluetooth	dev	Website, Whitepaper
71	Simmel	Open Hardware, Bluetooth and Near Ultrasound	dev	website
72	Sneeze Map	Self Reporting (Web)	rel	sneezemap.com

73	TCN Coalition	Bluetooth	protocol	TCN Coalition Protocol source
74	TraceTogether (Singapore)	Bluetooth, using bluetrace.io	rel	iOS Android faq news more news repo
75	Trustee Immunity Passport	UMA2, OAuth2, uPort (SSI)	dev	summary slides video
76	Unmaze (Bulgaria/UAE) Cyborg Sys	Bluetooth, GPS, Wifi, Dashboards	rel	News, website
77	Virus Trackers	All Technologies	public	VirusTrackers.org Slack
78	WHO Sponsored App	Local GPS /Self-Report ?	dev	News Repo design doc
79	XMode Social	Bluetooth + Mobile	rel	Website
80	Zerobase	QR, Dashboards	Beta	Website repo
81	PACT Digital Cairo Software	Local GPS/Self-Report	rel	Website

Major Tech Companies

Apple & Google	Framework and APIs for Contact Tracing	Announcement Contact Tracing - Bluetooth Specification Contact Tracing - Cryptography Specification Contact Tracing - Framework API Bloomberg 2020- 04-10, NYT 2020-04-10,
Google	Framework and APIs for Contact Tracing	Announcement Overview Powerpoint Contact Tracing Bluetooth Specification

		Contact Tracing Cryptography Specification Android Contact Tracing API
Facebook	Sharing Carnegie Mellon Survey	Announcement Disease Prevention Maps
Amazon	?	?

Projects and products based on existing location data records

(Including aggregated location data across widely installed apps, secondary mobile location data markets, and/or intelligence community capabilities and assets)

Company / project	**Source of data**	**Notes**
SafeGraph	Mobile phone data May include secondary mobile location data	Advocated by in-q-tel which is the US intelligence community's Venture Arm (wikipedia)
NSO group	According to news reports, telecommunication company assistance (which would not be accurate enough for contact tracing)	NSO group is a company linked to Israeli intelligence agencies that sells malware to national security markets and has a controversial human rights record Cory Doctorow overview

Key:

- Bluetooth - uses bluetooth connections between users
- Central GPS - sends GPS data to central point for analysis
- Local GPS - retains GPS data on user's device, only shared with permission
- Map - Displays a map with data sourced from some other location
- Web Self Report - maps generated by user's self reporting symptoms and location
- KML Upload - users upload Google location data, for comparison with data sets
- QR - scans QR codes to check in at locations

Status

- Gone: Website not responding, or otherwise project appears to have been abandoned

- Proposal: There's a white paper or design doc, maybe a call for volunteers but little else we've found.
- Dev: Some people are actively working on it, nothing to show yet
- Demo: Work has started, there's a demo, Proof of Concept, or something that can be looked at
- Beta: It is supposed to work, maybe bugs need fixing so not ready to ship
- Released: It's up and running - usable or downloadable by the general public

Notes & summaries of projects

- **Accenture Australia** has a preexisting app built for previous disaster response purposes
    - Based on GPS traces
    - Sends a full location trace to a (government?) worker who then produces anony mized maps of exposure risk
    - See Redcross/Accenture
- **AITIA** Self reported public database creation ?
- **BanDemic**
    - BLE Contact; Privacy aware, randomized keys, data on phone, protocol for integration into other apps
    - Moreover, a protocol that places additional burdens on health authorities (e.g., requiring them to deploy complex cryptography like MPC or carefully manage cryptographic key material) faces severe adoption barriers compared to one that does not, so reducing trust requirements may allow accelerated deployment.
    -
    - As part of the German government's #WirVsVirus hackathon, the team developed the open source STRICT (Simply TRack InfeCTions) protocol for privacy-preserving, Bluetooth-based contact tracing.
- Bluetooth Contact Tracer (BCT); Bluetooth using same mechanisms as CEN/TPN, but reports ids to the server. Goal is quick to build & deploy and scalable.
- **BlueTrace** Bluetooth (an App built on TraceTogether Singapore's Bluetrace protocol; press release only Github code release
- CAuDHT: Decentralized Contact Tracing Using a DHT and Blind Signatures
    - Whitepaper, demo code in development
    - Decentralized and privacy-preserving BT Contact Tracing
    - Notification of infections via a DHT-based message system
    - Blind Signatures for anonymous confirmation of test results to prevent trolling
    - Bluetooth IDs are public keys for message encryption in the messaging system
- **Coalition Network**
    - The Coalition App has been promoted by the City of Berkeley; working with the government of France, and the government of Senegal.

    - Uses existing secure Bluetooth technology and modern cryptography to anonymously and securely alert people who have crossed paths with those who have tested positive for the Coronavirus or are experiencing symptoms.
    - Launched on the Google Play Store; iOS app pending approval from Apple.
    - Privacy-first Whisper Protocol research paper: https://docsend.com/view/nis3dac
    - Launched an enterprise solution with Nodle.io and Avnet which includes the Coalition App and the Nodle M1 Smart Wearable, built to protect employees and help businesses reopen. The M1 records distances between employees with high accuracy and precision; buzzes them like a cellphone if they are within 1 meter and enables HR to notify employees if they have been in proximity of someone who has tested positive for COVID-19.
- **Code Orange**: Design doc; IOS and Android App (not yet launched as of l2020-03-22). Captures location locally. Pulls data on infected users hourly, and if flagged encourages appropriate behavior. If user subsequently is confirmed as tested positive then (voluntarily) they can add their location tracks.
    - Note Ran has said they are happy to see this forked for other countries, you'd need a local data set and a way to tie into local departments of health processes (e.g. telling people how to get a test). He is not aware of anyone forking it yet. (as of 2020-03-22)
- **CoEpi** - parallel partner project of Covid Watch focusing on a grass-roots app for symptom sharing, using the same BLE proximity and contact event matching protocol.
    - Collaborating with Covid Watch on backend + CEN generation, but with different approaches to symptom tracking for example.
- **Corotrac** - https://corotrac.com/ - Corotrac allows you to report your symptoms anonymously, sharing only necessary information such as age, sex, and location.
- **Coronamap** - Korean site - appears to be a map of an existing (dept of health?) data set. Mostly in Korean, and haven't responded to email.https://coronamap.site
- [**Corona Network** - A project by Péter Szilágyi which is designed to trace contacts within your friend circle and at specific, opt-in events. It doesn't do Bluetooth-based tracing, but does allow you to manually curate a list of contact events in a highly decentralized way.
- **CoronaStatus** - Web self reporting - repo, intended to be launched country by country. Github repo
- CoronaTrace - app, in development, beta testing. Onboarding doc has more info than website: Google Doc repo
- Corowarner: FromTurkey, under development.
- Corona Data Scraper https://coronadatascraper.com/#home
- **Covapp** - Questionnaire in EN /DE, can be combined with app/database for self-reporting
- CoV-ergage: anonymous self-reporting of symptoms by postal code, map shows hotspots and (daily) open dataset can be used for several calculations/statistics
- Covid-App - Privacy-preserving AI, Apheris AI collaborates w/ OpenMined
- Corona-datenspende: Smartwatch and fitness tracker data is collectted as well.
- **Covid-FLutter** Github repo Slack

- **Covid Near You** (https://covidnearyou.org/) - simple web-based self-reported symptom maps, backed by Boston Children's Hospital & Harvard Medical School. US-only. (Related to https://healthmap.org/ and https://flunearyou.org/.)
- **Covid Symptom Tracker**: Self reporting web page
- **Covid-19** - Track (https://covid-19-track.com). Simple web based private tracker for symptoms. Contact direct - https://twitter.com/jackwgh
- COVID360 : Contact trace is not the main focus for COVID360 yet as an important feature of solution.
- **COVID Alert**, a project from OpenMined.org on ingesting and anonymizing location histories
    - Patients can enter their last known locations with an estimated time stamp. Patients must be approved by appropriate government officials.
    - Comparison between mobile app user location and last known patient locations is compared anonymously by homomorphic encryption and computation.
    - Mobile app users are not shown a map, but rather will receive a push notification when they are in a 100m x 100m area that a patient has also recently been in.
    - Is open source and available for other projects' apps to use
- **Covid Watch**, an open source effort partnered with Stanford and assisted by international volunteers who care about privacy
    - Anonymous alert-only system similar to contact tracing using Bluetooth
    - Works for Android and iOS and cross-communication between devices. Covid Watch released the first known implementation of this communication protocol with functional cross-communication. [Open source code posted March 17th, 2020]
    - Alerts people of their risk with a protocol that uses Contact Event Numbers (CENs) that have no relationship with either user or device identifying information. CENs later renamed TCNs after joining the TCN coalition.
    - Alerted users cannot be identified by anyone including domestic or foreign govt, dataset cannot be interpreted, used for research, or sold, and CENs are cleared after 2 weeks
    - System is too private to be used directly in contact tracing effort because there is no access to identifying information for alerted people or devices, untraceable
    - Separate alert system requiring very little cooperation from existing contact tracing efforts,
    - Users can choose to follow advice and recommendations like calling health agencies, self-isolation, masks, etc. without being tracked
    - Project started out using GPS, wanted to build a heat map, but shifted approaches after determining GPS requires significant privacy tradeoffs not needed in a decentralized Bluetooth alert system
    - Low storage requirement approach found too
    - Makes location data collection unnecessary, contact event numbers are higher impact and more easily stored locally and privately
- **COVID World** by Sygic
    - GitHub repository
    - From the README:

        - In the basic scenario, the device is emitting an iBeacon signal (Bluetooth low energy) and at the same time listens to iBeacons around you. Thus creating an anonymous mesh of who met whom and when. This data is collected on server and when a person is positively diagnosed with SARS-CoV-2 (the infamous "corona" virus causing COVID-19 disease), the server will notify via push all the devices that were in a close and significant proximity with that person.
        - Alternatively, the user can flag herself or himself as quarantined in which case the app will regularly check his/her GPS location and warn him/her in case he/she leaves the quarantine.
- **Covi-ID** South African project which aims to provide self-sovereign proofs of COVID-19 status, with contact tracing as one of several applications.
- **CoWin-20** and **Corona Kavach**: from Government of India
    - uses your location data and Bluetooth to gauge if you've been near a person who was infected by COVID-19. It likely determines that by looking through a database of people who have been infected, as well as with one containing individuals' travel history. It's also said to be able to tell you if you're in an area with a high number of coronavirus cases.
    - The app asks for your permission to always access your location data, a step that might raise privacy concerns. However, it promises it to keep your data encrypted and limited to the device; it'll only share your data with the health ministry if you've tested positive for the disease. It isn't yet entirely clear how the government will track those people and match up their location data in the app.
    - Both apps use a person's location history and self-reported symptoms to give users a risk score, will send warning alerts if you are near a COVID-19 infected person, and allow health officials to monitor community spread.
    - Link to app: Google PlayStore
- ct-diag-server HTTP server written in Go for storing and retrieving Diagnosis Keys, as defined in Apple/Google's draft specification of its Exposure Notification framework. Open source, with community support from Code for NL.
- **crowdsourcerescue.com** - adapting app used for flood rescue, really unclear from the website how this works or what it does, it looks like it is just support for quarantined people?
- Cubeiq - Big Data analysis / mapping (Not seeing any Covid stuff here as of 2020-03-30)
- **DEGRAT** - Bluetooth
- DP^3T is a collaboration between a number of European Universities, with simple but well-specified protocol and security analysis. It is based on BLE and works similarly to CEN/TCN protocols like Covid Watch.
- diAry: Digital Arianna is its full name. By Italy. In beta test
    - Opensource: https://github.com/digit-srl/diAry-apps/
    - Backend: https://github.com/digit-srl/diAry-backend
    - Additional feature worth to mention is reward system
- EpiCollect - download anonymize, re-upload personal google traces.

- **Fever map:** Github Repo - also has list of other similar projects,**GeoHealth** Germany: Medical school in Hanover working with Ubilabs to build “GeoHealth” (no further details known at this time).
- **Hamagen**, from the Israeli Ministry of Health & National Cyber Directorate. Privacy review;
- **Infection Chain**: Scans QR codes: Prototype;
- Kwarantanna domona: Polish app that "facilitates and rationalizes" the mandatory 14-day home quarantine developed by Poland’s Ministry of Digital Affairs
  critics
- **Memiah**: Looks like have a prototype: Google Doc; repo -- building a contact tracer using Bluetooth. (Call for advice & volunteers on Facebook;)
- MILA COVID-19 Task Force (name temporary): Google Doc. Hoping to build a contact tracer app for Canada. Currently building off of PrivateKit, but planning to implement additional privacy guarantees using a Private Set Intersection and mix-nets protocol.
- MyLog14 : Hackathon project, Taiwan, app, looks like doing Local GPS
- NextTrace online survey to collect contact information | whitepaper
- PACT BLE Contact Tracing (MIT)
- Pan-European Privacy-Preserving Proximity Tracing (PEPP-PT) BLE info@pepp-pt.org
  - Includes Decentralized Privacy-Preserving Proximity Tracing (DP-3T), This is a cryptographic protocol from/for the EU PEPP-PT contact tracing consortium, from EPFL, ETHZ, KU Leuven, TU Delft, UCL, Oxford, CISPA and Fraunhofer Inst.
  - Uses BLE, no location data; servers, health authorities or other users learn nothing about infected/at risk individuals.
- **Pandemic.Events** (repo) - upload KML files and compare to known data sets (their data converters are generalized in c19.mitra.biz.
- **Pandoa** - (In German) looks like uses GPS and Self reporting of symptoms
- Pisarasi - (“droplets”) Finnish web platform based on users providing their data; MVP has KML or self-report to produce personal diary of movements, contacts etc.
- Privacy Preserving Proven Prior Proximity Protocol (P6): Proposal for a Bluetooth protocol using iBeacons and a privacy preserving approach to disclosure of proximity events. Blog article here.
- **Private Kit: SafePaths** is a project based at MIT that (appears to) collect its own full GPS traces and then rely on human public health officials to perform interactive anonymization before publishing an exposure risk map
  - Anonymization procedure unclear, seems to rely on health agencies to do it
  - See also https://www.popularmechanics.com/technology/apps/a31742763/covid-19-app-private-kit-safe-paths/
  - MIT Technology Review: A new app would say if you’ve crossed paths with someone who is infected
  - Android & iOS toolkits exist (beta versions being rapidly updated during Covid). Location data only leaves the user’s device with their consent -- e.g., to give to a doctor or public health authority; it’s not stored in the cloud. Future(?) iterations will make it possible to send alerts about exposures.

    - This app uses GPS+Bluetooth. For their Bluetooth technology, they use Covid Watch and CoEpi's open source decentralized protocols.

- **PrivateTracer**: Privacy upfronted contact trace software shortlisted by NL government.
    - Opensource: https://gitlab.com/PrivateTracer/
    - Bluetooth based, PeerDID per interaction to provide privacy
    - Prototype available, development on going

- **Proximity**: a recipe to break the outbreak.
  We described a smartphone application based on Bluetooth contact tracing to contain the epidemics outbreaks protecting people's anonymity, privacy and freedom. In particular we designed a new decentralized protocol with asymmetric encryption and we performed Monte Carlo simulations to evaluate the effectiveness of a large-scale contact tracing approach.
  (Submitted on 23 March 2020, https://arxiv.org/abs/2003.10222)

- ROBERT protocol INRIA (France)
- **Safe2** Self reporting, keeps BLE contacts & GPS local then uploads on infection.
- **Safetrace API** (Open Source / Faction Coop)
    - Library for using Multiparty Computation to allow Cryptographically Private Trace Matching (allowing databases to check for location matches without revealing their data to each other)
    - React App wrapping the library and allowing users to control who to share their data with
    - Co-founded by academics from the 2010 FluPhone Project at the University of Cambridge.
    - **Keen to collaborate with other efforts** *(eg providing library/API support to other apps)*
    - ***Status***: Whitepapers and GPLv3 open source code in active development
- **SafeTrace** by Enigma
    - Privacy preserving database and querying API for self-reporting Covid-19
    - Goal: Shared secure DB service for contact tracing applications
    - Using Trusted Execution Environment technology, user data (downloaded from Google Location data) is encrypted locally and is never accessible in plaintext form.
- **Sneeze Map**: Self reporting tool (https://sneezemap.com/)
- Smart quarantine: Czech government based on Telco data.**Strict**: Repo; Bluetooth, Hackathon proposal - no code in that repo as of 2020-03-30.
- **TraceTogether**: launched by the Singapore Ministry of Health (MOH) and Government Technology Agency (GovTech) [news] [iOS] [Android] [faq] [more news]:
    - Logs users phone numbers and pseudonymized proximal contacts via Bluetooth protocol called BlueTrace (not location beyond that)

    - Pseudonyms are rotated periodically, with the central service being able to map back to phone numbers in case of a diagnosis
    - Diagnoses are authenticated by a QR code?
    - Possibly susceptible to attack, but privacy-preserving decentralised approach requires way more bandwidth, also remains mostly centralised?
    - Not open source, but “We are working on reference protocol documents and a reference implementation [...] so that others may adapt BlueTrace to their own context.”
    - Protocol is called Bluetrace
- **Trustee Immunity Passport**
  Trustee is a consent, interoperability, and decentralized governance layer for symptom reporting, contact tracing, and other apps involving all kinds of personal health data. To do this, Trustee uses a novel combination of standards and self-sovereign (blockchain) identity principles that are demonstrated as a Trustee Immunity Passport.
- **Stopp Corona Red Cross/Accenture Austria** app
    - (German) news article
    - Android Play Store link
    - FAQ from the Austrian Red Cross
    - Fully self-sufficient: uses Google Nearby Messages API, stores contact data locally, sends notification to all contacts once, works for both Android and iOS with both manual and bluetooth automatic options.
    - Technical analysis
- **VirusTrackers.org**
    - Directory of projects working on on privacy-preserving contact tracing and exposure notification for COVID-19
    - Slack channel.
- **WeTrace**
    - A prototype built during the End Coronavirus Hackathon. Members of their team are now working on COVID Watch
    - https://devpost.com/software/wetrace-g9ocy
- **WHO**-sponsored app:
    - news article
    - Github repository
    - Intends to use a combination of self-reporting and device GPS history, per the design document COVID-19 - WHO App Syntheis (for Review).
    - Mentions PrivateKit (see above) to protect privacy
- **Zerobase** - Privacy-first QR code network that doesn’t require installing an app. See site
    - Businesses post QR signs on doors and cash registers, testing centers include QR codes in intake forms.
    - No-install means that most with a smartphone are instantly enrollable
    - Businesses/locations are first-class citizens and can have detailed insight delivered to business administrators

- Easy integration into testing centers and labs means that it avoids the disadvantages of self-reporting or waiting for a manual diagnosis confirmation

Teams at tech companies working on these questions

- **Apple**: Press ReleasePatients can enter their last known locations with an estimated time stamp. Patients must be approved by appropriate government officials.

Technical papers and materials

Arxiv Preprints

- Beyond R0: the important of contact tracing when predicting epidemics (10 Feb 2020)

- Quantifying dynamics of SARS-CoV-2 transmission suggests that epidemic control and avoidance is feasible through instantaneous digital contact tracing, a preprint published by University of Oxford researchers on March 16 (just under a month after we started work on the project).
    - Trevor Bedford cited this model as one of strategies that he believed could bring the pandemic under control. (16 Mar 2020)

- **Apps Gone Rogue: Maintaining Personal Privacy in an Epidemic** (19 Mar 2020)

- Proximity: a recipe to break the outbreak. https://arxiv.org/abs/2003.10222
  A preprint by a team of Italian physicists. (23 Mar 2020)

- Contact Tracing Mobile Apps for COVID-19: Privacy Considerations and Related Trade-offs (25 March 2020)
    - Discusses privacy tradeoffs in TraceTogether. Protocol proposals are somewhat out-of-date now.
    - More recent work by the authors has been done as part of the MILA Covid-19 Task Force, with an in-progress design doc.

- Decentralized Privacy-Preserving Proximity Tracing (DP-3T) (29 Mar 2020)
    - This is a cryptographic protocol from/for the EU PEPP-PT contact tracing consortium, from EPFLDP-3T/documents: Decentralized Privacy-Preserving Proximity Tracing -- Documents, ETHZ, KU Leuven, TU Delft, UCL, Oxford, CISPA and Fraunhofer Inst.
- Assessing Disease Exposure Risk With Location Histories And Protecting Privacy: A Cryptographic Approach In Response To A Global Pandemic (31 Mar 2020)

    - This is basically V3 of SafePaths.

- Privacy-Preserving Non-Wearable Occupancy Monitoring System Exploiting Wi-Fi Imaging for Next-Generation Body Centric Communication (3 Apr 2020)
- PACT: Privacy Sensitive Protocols And Mechanisms for Mobile Contact Tracing https://arxiv.org/pdf/2004.03544.pdf (7 April 2020)
    - Team from the University of Washington. Not to be confused with MIT PACT (see below)
- PACT: Private Automatic Contact Tracing (protocol specification, 8 Apr 2020)
    - 20 authors from MIT and elsewhere, including Rivest and Shamir
    - “Note the unfortunate collision of the use of the name PACT. One could disambiguate by calling [https://arxiv.org/pdf/2004.03544.pdf , above] the “West Coast PACT” and the current paper the “East Coast PACT”. The proposals are very similar.”
- CAuDHT: Decentralized Contact Tracing Using a DHT and Blind Signatures (8th April 2020)
    - Decentralized BT Contact Tracing
    - Notification of infections via a DHT-based message system
    - Blind Signatures for anonymous confirmation of test results to prevent trolling
    - Bluetooth IDs are public keys for message encryption in the messaging system
- Safe Blues: A Method for Estimation and Control in the Fight Against COVID-19 (April 21, 2020)
    - Not Contact Tracing - but may piggyback on contact tracing apps
    - A privacy preserving population wide diagnostics framework.
    - Projects the course of the epidemic based on the spread of a virtual safe “virus” (Safe Blue Strand).

Models

- Predicted effectiveness of privacy-friendly mobile location tracing, a preliminary simulation model for predicting the effectiveness of different types of contact tracing app designs
- Proximity: (section 4.) Monte Carlo simulations to estimate the effectiveness of a large-scale contact tracing approach. https://arxiv.org/abs/2003.10222

Reports and blog posts

- Expert advocacy for anonymized bluetooth contact finding & notification protocols:
    - A mobile app protocol for opt-in privacy-sensitive epidemic contact tracing
- Comparison of 4 mature German BLE-based tracking projects (in German)
- OpenMined has published this helpful analysis: Maximising Privacy and Effectiveness in COVID-19 Apps (2020-03-24)
- "Contact Transmission of COVID-19 in South Korea: Novel Investigation Techniques for Tracing Contacts"

- FPF Chart Comparing the Role of Mobile Apps in Pandemic Response (from a privacy and data protection perspective)
- Outpacing the Virus: Digital Response to Containing the Spread of COVID-19 while Mitigating Privacy Rihttps://ethics.harvard.edu/outpacing-virussks (review from Harvard and Vi Hart)
- Thoughts about the handling of PEPP-PT proximity history IDs (denken.io, 2020-04-05)
- DP3T: The technology behind "Corona Apps" and PEPP-PT?
- Netzpolitik.org (2020-04-06): "Covid-19. Why is contact tracing useful?"
    - "Covid-19 contact tracing and data protection can go together. [Three German legal scholars] lay out the details of how such a technology might work."
- CCC (2020-04-06): "10 requirements for the evaluation of "Contact Tracing" apps"
- A document on the data protection best practice.
- Contact tracing apps are not a solution to the Covid19 crisis (Brookings Institution TechStream blog)

Survey

- How does the public, across several countries, feel about an automatic contact tracing app to combat the spread of COVID-19? Survey result + data for: France- Germany- Italy- UK- US (on going) - University of Oxford. https://osf.io/7vgq9/
- COVID-19 Contact Tracing and Privacy: Studying Opinion and Preferences: https://arxiv.org/abs/2005.06056
- How Good is Good Enough for COVID19 apps: https://arxiv.org/abs/2005.04343
- User Concerns & Tradeoffs in Technology-Facilitated Contact Tracing: https://arxiv.org/abs/2004.13219

Visualization/ Infographic

- Contact tracing visualization under CC0/Public domain

https://blog.ncase.me/onestepahead/

- Exposure History of Covid-19 diagnosed cases of Sri Lanka
-

Media Coverage of Location Tracing and related privacy issues.

- Channel 4 re S.Korea's program
- A short documentary on Nanjing's COVID-19 containment measures, including several sections demonstrating apps in use, and civil liberties impacts.
- Wired "Phones Could Track the Spread of Covid-19. Is it a Good idea..
- NY Times re Israel using contact tracing.
- Coronavirus: Singapore develops smartphone app for efficient contact tracing

- UK: NY Times: "Translating a Surveillance Tool into a Virus Tracker for Democracies".
- US: Wash Post "US government discussing ways to use smartphone location data to combat coronavirus (paywalled)
- Bloomberg 2020-03-17 Surveillance Company NSO Supplying Data Analysis to Stop VIrus (paywalled)
- Experts urge development of COVID-19 app for instant contact tracing
    - Describes work by http://www.coronavirus-fraser-group.org (link resolves to https://045.medsci.ox.ac.uk/), which says:
    - "We ask whether, from a mathematical point of view, it is possible to stop the epidemic. We come to the conclusion that the epidemic can be stopped if contact tracing is sufficiently fast, sufficiently efficient and happens at scale. We suggest that the best way to achieve this is by using a mobile app. Read our paper which has just been accepted in Science or the accompanying policy piece or jump straight into exploring the results on our interactive dashboard below."
- Wall Street Journal: To Track Virus, Governments Weigh Surveillance Tools that push privacy limits.
- New York Times: European Mobile Operators Share Data for Coronavirus Fight (Italy, Austria, Germany)
- Associated Press: Europe eyes smartphone location data to stem virus spread (Czech Republic, Italy, Germany and Britain)
- ZDNet - Coronavirus: They want to use your location data to fight pandemic. That's a big privacy issue (lots of good links in here)
- EFF: article Protecting Civil Liberties During a Public Health Crisis.
- The Conversation: S.Korea's success in controlling disease is due to its acceptance of surveillance.
- Karnataka Government Publishes Addresses of People COVIID-19 Quarantine
- APC (2020-03-19): Ecuador Surveillance Measures to Confront Pandemic is a Threat to Human Rights
- APC (2020-03-23): Netanyahu Imposes Dangerous "Big Brother" Surveillance Under the Pretext of a Security Response to the Coronavirus
- Valencia Tracking People Via Mobile Phones
- ZDNet (2020-03-19): Deutsche Telekom providing anonymized data to govt via Robert Koch Institute
- NBC News (2020-04-07): Behind the global efforts to make a privacy-first coronavirus tracking app Coronavirus: They want to use your location data to fight pandemic. That's a big privacy issue
- The Atlantic (2020-04-07): "The Technology That Could Free America From Quarantine: Contact tracing is working in South Korea and Singapore. But it raises privacy issues."

Related Wikipedia article:

- https://en.wikipedia.org/wiki/COVID-19_apps

Other Links relating to privacy and Location tracking

- Statement of the EDPB Chair on the processing of personal data …
- Open letter - Coronavirus contact tracking and the NHS
- CIPESA: Covid-19 in Africa: When is Surveillance Necessary and Proportionate?
- New Zealand needs to talk about using private data to combat covid-19
- Austria: Telecom company providing data to the government - details in German.
- Some projects working on location data anonymization in the field (not necessarily contact tracing):
    - https://cpg.doc.ic.ac.uk/blog/fighting-covid-19/ used by:
        - https://web.flowminder.org/practice-areas/precision-epidemiology
        - https://www.opalproject.org/about-opal
- Other inventories of contact tracing app:
    - MyData
    - Le mouton nteumérique
    - European mHealth Hub project
    - A16z (2020-03-31): "Coronavirus Apps From Around the World, Translated" (screenshots)
    - https://coronavirustechhandbook.com/self-reporting