# COVID-19 Spatial Contact Tracing (SCT)

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**Abstract**

Extending the Google Apple Contact Tracing (GACT) system to infer additional variables related to COVID-19 transmission, we propose a system where static devices are tethered to indoor spaces as minimally functional mobile devices. Our Spatial Contact Tracing (SCT) system implements on these static devices ("SCT devices") a novel application, following the GACT application programming interface (API), capable of tracing COVID-19 transmission over a period of time within a given space and thereby supplementing the baseline GACT system, which only traces device-to-device proximity. Data collected through SCT could be used by epidemiologists for refining transmission models and hence the conditions triggering and severity of contact-tracing user alerts. SCT could also detect possible second-degree contact beyond the scope of GACT and environmental-level transmission by users who occupy the same space at different times. Finally, because SCT can correlate the presence of an infected GACT user with a given space, the data could be used by space managers to notify known users who either do not have the app installed or do not hold a mobile device. The SCT system can be deployed at scale by installing low-cost Android static devices equipped with Bluetooth (for GACT) and WiFi (for connectivity with the Diagnosis Server[1]). Because SCT devices run an app based on the GACT API, the SCT devices inherit the security and privacy features of the GACT system. Management and knowledge of the location of SCT devices is decentralized, and due to the cryptographic scheme, this infrastructure self-disassembles when COVID-19 infections cease being reported.

## Motivation and background

To reduce the impact of COVID-19, a number of strategies have recently been proposed for enhancing contact tracing using mobile devices, while notably maintaining the location- and identity-privacy of users. Likely the most scalable, the Google Apple Contact Tracing (GACT) system uses underlying mobile operating system capabilities to detect device-to-device proximity via Bluetooth radio signals and allows select software enhancements through an application programming interface (API). Due to the global reach of installations of Apple's iOS and Google's Android and the deliberate limitations already built into these operating systems (intersecting with both security and power concerns), most proposals for alternative mobile contact-tracing systems that operate outside of the GACT software ecosystem will prove difficult to implement effectively. Google and Apple are in a unique position because only they can modify the rules regulating how apps are

[1] In the Google Apple Contact Tracing (GACT) system, the Diagnosis Server "aggregates the Diagnosis Keys from all users who have tested positive, and distributes them to all the user clients that are participating in exposure notification." Google Apple "Exposure Notification Cryptography Specification" v1.1, April 2020, p. 8.

permitted to behave on their respective mobile operating systems, and only they can deploy these modifications comprehensively to their users' devices.

In the current GACT system, mobile devices act as proxies for people, and thus one may speak of devices that "test positive" for COVID-19. Once testing positive, the mobile device's Temporary Exposure Keys are added to a repository held by the Diagnosis Server, which distributes a set of Keys for user devices to search for in their individual contact histories. [2] GACT implements cryptographic safeguards that ensure these Keys are useless beyond a predetermined time period, such as the infectious period. Upon finding a positive match, in usual presentations of this idea, the device's user is suggested to self-quarantine for a specified time period. However, devices that overlap in space but not time, such as when a device occupied the same room moments after a positive-testing device left, cannot be traced with this technique and limit knowledge of environment-level exposure. Similarly, in addition to devices not running the tracing app, users may miss a GACT contact for reasons of distance, battery, or poor radio-communication.

**Spatial Contact Tracing (SCT) concept for tracking environment-level transmission**

We propose a Spatial Contact Tracing (SCT) system that addresses the spatiotemporal shortcomings of GACT outlined above with a simple idea that can be implemented at scale and with mechanisms for transmission-model feedback. We deploy static devices ("SCT devices") tethered to specific spaces and implementing a novel application that allows them to participate as "users" in the GACT system. The device application leverages the GACT API, allowing SCT to inherit GACT's Bluetooth specification, cryptographic specification, and framework API. By associating static devices with specific spaces, SCT adds two aspects to the GACT system:

1. A spatial context, the management of which can be decentralized through delegation to a space's operating institution or business. These stakeholders may choose to notify known users of their spaces who may not have installed a GACT app, which greatly increases alert effectiveness; and

2. An historical context, so that the transmission of COVID-19 via surface contact with objects and materials can be traced and the fomite risk assessed.

Unlike normal mobile devices tied to people, these static devices do not "test positive" through conventional means. Instead, upon receiving matching Diagnosis Keys through the GACT system notification, these static devices notify the Diagnosis Server using a separate data channel.

The primary initial contribution of the SCT system will be to aid the refinement of the transmission model for COVID-19. As observed in the frequent announcements made by the US Centers for Disease Control and Prevention (CDC) and other leading national public health institutions, our understanding of how COVID-19 is transmitted has been revised substantially over the last several months. A transmission modeling process that serves society's needs involves making assumptions about how the virus propagates that are then reviewed against evidence as policy evolves. While the GACT system may collect data concerning individual-to-individual contact, it does not collect data that allows for environmental-level tracing or model feedback. In transmission modeling, for instance, by understanding the population density of a room and the duration the population was

[2] For more information, see Google Apple "Exposure Notification Cryptography Specification" v1.1 April 2020, p. 8.

present within the room, the metrics we deem important to slow the spread of the disease can be refined and then incorporated into contact tracing alert systems. The SCT system allows for variations within environments to be better understood, providing insight about how the transmission of COVID-19 occurs in different physical environments. In effect, SCT provides a natural experiment in which individual and spatial data are used to refine the transmission model enabling more effective and efficient contact tracing.

**Second-degree contact tracing**

SCT devices permit the tracing mechanism to extend to second-degree users, such as: users who occupy spaces shortly after infected users; users present in the same space at the same time but not caught by the GACT system directly due to distance, battery, or poor radio-communication; or known users of an institution or business's space that do not have GACT or a mobile device. While SCT opens the Diagnosis Server up to an additional data channel communicating this second-degree contact, we note that the cryptographic structure used in GACT can readily secure the integrity of the data collected by the SCT devices.

Notifications of second-degree contact may be sent to recipients warning of a lesser exposure level than via normal GACT. A building with multiple static devices and a manager with a comprehensive view of the severity of contact between positive-testing traces in the building could send different levels of warning outside of the GACT system. For example: one notification for recipients within the same room as the positive-testing user; another notification for recipients occupying the same floor; and a third notification for recipients occupying the same building. Recipients could then decide on the relevant level of response to take, which is especially pertinent to those with preexisting health conditions or for recipients who live with or frequently visit individuals at higher risk. It is also possible, should the managers of SCT devices choose to include this information, that the time and space of potential contact be released, giving useful specifics to otherwise abstract GACT alerts. This notification also allows the managers of a space to take steps to notify users through other means outside of the GACT system, effectively extending the notification to all users of a space. For example, a university might notify all students who were in a lecture hall attending a regularly scheduled class; a hotel might notify its guests in rooms or those who had a meal in the hotel restaurant; and an airport might notify passengers who had been present at a departure gate.

**Decentralized and low-cost implementation of SCT**

By using the GACT system, we achieve parity with many of GACT's properties, in particular the absence of specific individually identifiable location information anywhere in the tracing system. No central database is maintained of the locations of SCT's "static devices," and no location information is needed for SCT to operate. Furthermore, no central database can be built; the GACT system effectively changes the identity SCT devices present to other users' devices every 10 minutes. SCT also requires the same demands on users' mobile devices as any other GACT implementation.

Further, SCT can be inexpensively implemented using an open-source Android distribution, with minimum storage and processing power for running the SCT app, a BLE radio for the GACT protocol, and a means for network connectivity (i.e., WiFi). A screen would not be necessary, and assuming wired power, neither would a battery. For immediate installation, older Apple and Android mobile devices can be repurposed.

Greatly increasing effectiveness globally, our SCT system could bridge GACT with existing tracing technologies at substantially lower cost than requiring users to own a mobile phone. For example, low-cost (USD $12 each) Bluetooth beacons using Eddystone Ephemeral Identifies (EIDs) can allow users who do not own a mobile phone to receive exposure notifications. Notifications for users holding these EID beacons could be sent via a physical address, an email address, landline telephone, or mobile phone.[3] Users could then choose when and where to carry the EID beacon, allowing users greater control over their participation within the SCT system. EIDs rotate every 17 minutes, and together with a resolving service, can preserve privacy levels roughly comparable to the GACT scheme.

At the time of writing (before the first public deployment of GACT), there are two implementation concerns: 1) Concern regarding the security of the interface between SCT and the Diagnosis Server via the additional SCT data channel; and 2) Concern regarding the local public health system's ability, inside the GACT protocol, to add nuance, duration and information to the warnings provoked by the data their systems broker.

Since GACT is engineered by the operating system manufacturers, we expect our SCT implementation to be straightforward and to not require explicit consent from Apple or Google. The SCT system works across any and all GACT implementation apps, with the sole assumption that the Diagnosis Server can vary its alerts on a per-Exposure Key basis. SCT adds incrementally to GACT's strength, as there is no minimum amount of infrastructure that needs to be deployed for SCT to begin functioning; each additional static device adds value to the system. Like GACT, this system effectively "self-disassembles" when COVID-19 infections stop being reported, and the system loses its ability to effectively correlate the Keys of any devices for more than 10 minutes.

[3] For a working example, see the Tile App: www.thetileapp.com