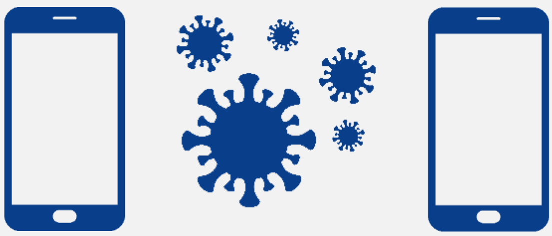
ASPHER Policy Report

Contact Tracing Apps for COVID-19

An Overview of the European Region



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The Association of Schools of Public Health in the European Region (ASPHER)

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ASPHER launched the 'This is Public Health-Europe' campaign challenge in 2019 to communicate the message of the importance of public health. The overall objective is to enhance the visibility of public health and opportunities for careers in public health careers for the benefit of our populations. This effort should also increase the level of interest among potential students to pursue public health education/training to reinforce the current public health workforce. For more information: https://www.aspher.org/this-is-public-health-tiph.html

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This first version may be updated based on feedback received by ASPHER over the coming months.

Introduction

The incidence of infections of COVID-19 is increasing again all over Europe as the colder season begins. As with the first wave, governments are struggling to contain the virus while avoiding severe social distancing measures.

Contact Tracing Apps (CTA) are a promising option that could help to break the chain of infections. For the purpose of this policy report, CTA are defined as a supplementary method of contact tracing that relies on the functions and features of mobile phones to electronically identify and notify individuals who may have been exposed to infected persons. Other COVID-19 apps, such as those which keep track people for quarantine enforcement, are not covered.

In traditional contact tracing, trained healthcare professionals or contact tracers spend hours investigating infected individuals to attempt to identify their close contacts. However, SARS-COV-2 represents new challenges with its high reproductive rate outpacing manual efforts (1). The virus continues to spread amid delays between confirming a case and manually finding a person's contacts.

In response, many European countries have deployed CTA – with often meagre results. The take-up has been low, rarely reaching more than ten percent of the population. Privacy protection issues, technical faults, false positives, and disinformation have diminished public trust and confidence in the effectiveness of CTA. Understandably, the initial excitement over CTA has subsided.

However, it may be too early to judge how effective CTA will be. Governments continue to invest in research and development aimed at improving their CTA, reducing the frequency of false positives and enhancing privacy protection. In addition, politicians and scientists alike are becoming more vocal about the potential benefits of CTA. They praise CTA as the 'silver bullet' for lowering infection rates and for preventing the reimposition of severe lockdown measures. Public health campaigns and CTA promotion have intensified in many countries, increasing the possibility that there will be significant CTA uptake across the European Region in the coming months.

Therefore, it is well-timed to have a closer look at the deployment of CTA in the European Region. The aim of this policy report is to give public health professionals and students a cross-country overview of CTA, looking at basic technical, political, and public health aspects.

The first part of this text serves as an introduction to fundamental technical concepts of CTA and their application in public health. App architecture, such as the difference between centralised and decentralised apps, will be described to acquaint the reader to the basic technical attributes of CTA. Based on this discussion, both strengths and limitations of CTA will be examined, focussing on the most common app type in Europe. To conclude this part, it will briefly be outlined how CTA can be integrated into existing public health systems.

The other part of this text is an attempt to map the European experience. It includes an overview of existing CTA in the European Region and a short analysis of patterns and differences. Furthermore, options for Pan-European cooperation will be discussed. Based on this information recommendations can be drawn for the application of CTA for COVID-19 in the coming months.

1. The Architecture of Contact Tracing Apps

First, the two most common methods utilized by CTA, location tracking and proximity tracing, will be distinguished. **Location tracking** is based on geolocation information, which allows for physical location and movement tracking of people. It is usually based on GPS tracking but also employs other means to increase the accuracy of the location, such as triangulation from nearby cell towers, Wi-Fi history or QR-Codes (2). This enables the matching of phone locations of infected persons to the phones of people in their vicinity.

In contrast, **proximity tracing** uses Bluetooth Low Energy (BLE) signals to determine whether two phones were close enough for their users to be exposed to each other. For this purpose, proximity tracing relies on the emission and reception of anonymous identifiers (a virtual handshake) if two phones are in close proximity. These anonymous identifiers are then saved on local databases on both phones, creating a so-called ‘proximity history’ (3).

Anonymous identifiers (also referred to as 'ephemeral identifiers') are randomly created and are used to distinguish individuals without revealing the personal identity of the user. These anonymous identifiers can only be 'read' with a series of cryptographic keys. These keys are held by the individual user or a competent authority (3).

Proximity is estimated on the basis of the strength of a received signal (RSSI) at each phone, which their BLE feature can measure. A strong signal indicates close proximity and potential for transmission of the virus; a weak signal indicates the phones were not close enough for transmission between their users (4). Proximity tracing is the most commonly used approach in the European Region (see "Cross-Country Overview"), due to the privacy implications of location tracking and data minimisation concerns.

Location tracking and proximity tracing both involve the reporting of either location data or contact encounters to a remote central backend server, usually controlled by a national authority, such as the public health service. When it comes to the collection and processing of the reported data, there is a split between two different types: **centralised and decentralised protocols**, whereby protocol refers to a standard set of rules that allow the phones to communicate with each other. CTA can be classified into centralised or decentralised according to (i) the function of the central backend server, (ii) the data storage location, and (iii) the matching of contacts (2). Both proximity tracing and location tracking can be either centralised or decentralised. As it is more common in the European Region, centralised and decentralised protocols will be explained in relation to proximity tracing.

CTA with a **centralised protocol** involve the sharing of the proximity history with a central server. It will be explained with the *Robert Protocol* used in the French CTA.

The anonymous identifier of each encounter is recorded in the proximity history. In most centralised apps in the European Region, the proximity history is stored on a local database on the phone. The infected user would have to inform the app of their positive testing and the app only then uploads the proximity history to a central backend server (3).

On the central backend server, meta data associated with the identifiers is retrieved. This meta data, consisting of proximity information and timestamps, is used to calculate the risk of exposure. The identifiers which meet the epidemiological threshold are flagged as 'at risk' (5).

The matching of contacts takes place on the central backend server. The CTA of other users periodically send exposure requests to the central backend server, providing their cryptographic key. The central backend server then searches the list of anonymous identifiers in the proximity history of the infected user, decrypting them using this cryptographic key. This associates the data of infected users with the data of exposed users. If the central backend server finds the anonymous identifiers in question as 'at risk', the exposed user receives an exposure notification (5). Some centralised protocols, such as *BlueTrace*, include a personal or direct alert and thus require their users to register after downloading the app and share details such as name, age bracket and /or phone number (2).

Thus, in centralised protocols, the central backend server performs many core functionalities, such as storing data, decrypting data, and matching contacts.

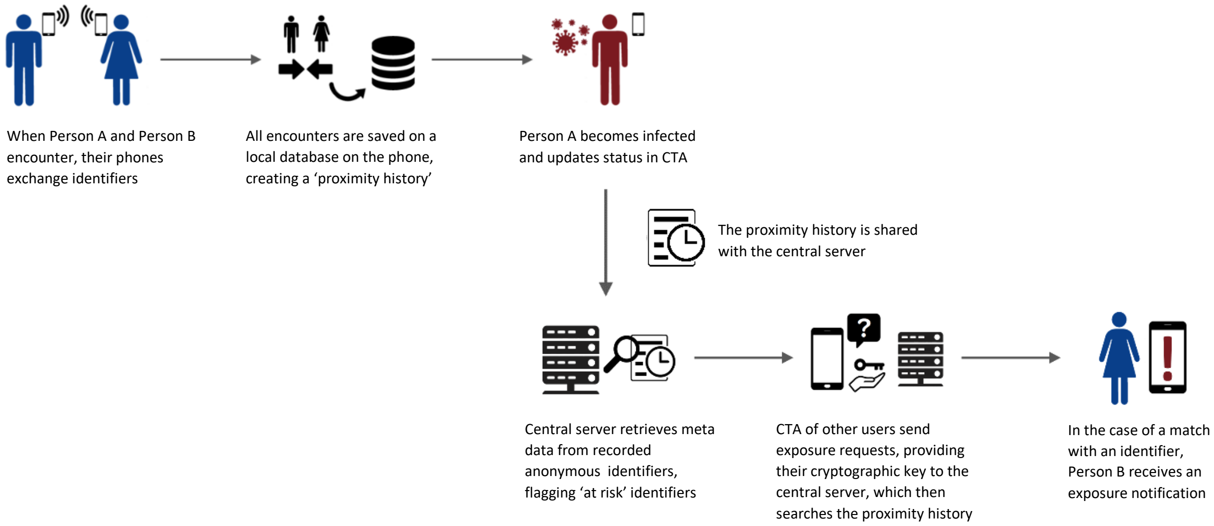

Figure 1. Centralised Protocol (simplified example)

CTA with a decentralised protocol will be explained with the DP-3T Protocol, which is used in various CTA across Europe. First, the exposure risk calculation happens directly on both phones during their encounter., The anonymous identifier will be recorded in the proximity history only if the measured exposure is epidemiologically relevant, according to the epidemiological thresholds set (6). Second, the proximity history is not shared with the central backend server and remains on the phone. Instead, an infected user voluntarily informs the app of their positive testing and the app uploads only a cryptographic key to the server (3).

This cryptographic key is generated on the phone and changes every 24 hours, making it unlikely that it can be traced back to the user. Multiple keys will be uploaded to the central backend server, depending on the number of days an individual was infectious (3).

The CTA of other users periodically examine the database on the central backend server. This way, cryptographic keys that have been obtained from infected users are downloaded and then matched with the anonymous identifiers in the local database. This determines whether an exposure event has taken place. Based on these matching processes, users will receive an exposure notification after they have been exposed to an infected user (3). Due to this automated and anonymised process, decentralised protocols do not require users to register before use and accordingly no personal data is shared with the central backend server. Thus, core functionalities happen on the user devices, meaning the central backend server acts as intermediary with minimal access to data.

Decentralised protocols are promoted by Google and Apple. They have jointly created the interface **'Exposure Notification'** to enhance BLE features and functions for official CTA. The aim of their collaboration is easing the implementation of the respective CTA and their interoperability across their smartphone operating systems iOS and Android (7).

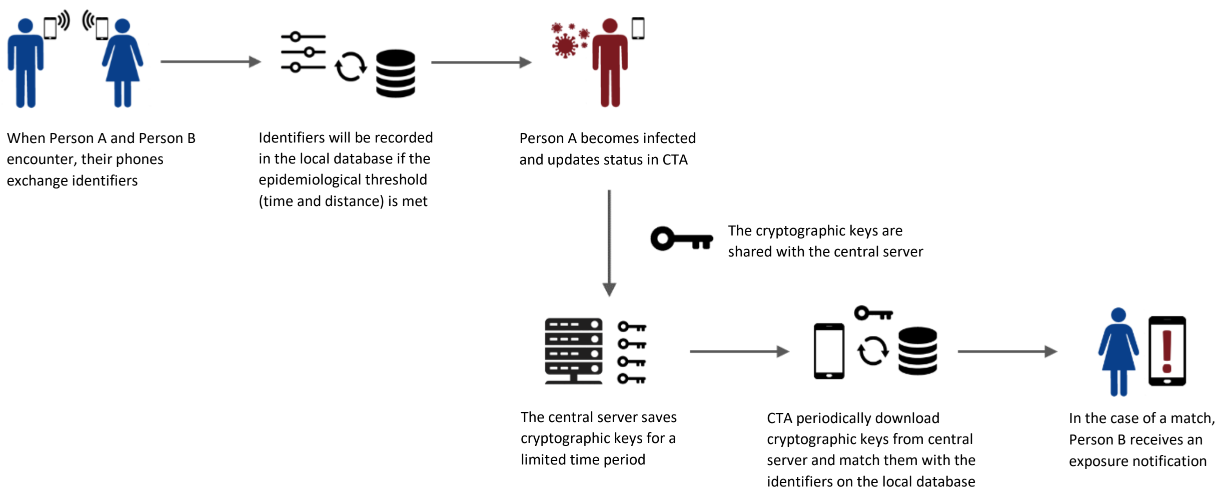

Figure 2. Decentralised Protocol (simplified example)

The distinction between these two protocols is getting more and more unclear – especially as hybrid protocols emerge (2). Each CTA may slightly deviate from the described protocols. Consequently, this section provides examples which do not exactly represent all protocols.

2. The Big Trade-Off: Strengths and Limitations

CTA are associated with strengths and limitations that can enhance or reduce their effectiveness in a European context. Governments and public health agencies must carefully evaluate these and the associated trade-offs before and after rolling out a CTA.

Strengths of Contact Tracing Apps

Reduction of Transmission. A systematic review by Braithwaite et al. found that the reduction of transmission through CTA has a positive correlation with population uptake (8). The higher the download rate, the better the chance that any two users who encounter each other both have a CTA. For effective reduction of transmission, CTA may require an uptake ranging from 56% to 95% (8). In an 'ideal' high-uptake situation, CTA could contribute to a significant lowering of the reproductive rate if they are coupled with fast and uncomplicated testing (9). CTA could trace the majority of downstream contracts of an infected user quickly, who would then isolate and get tested. This could remove many secondary cases before they infect others, breaking the chain of transmission. However, according to seminal epidemiological modelling by Hinch et al. (10), even at low levels of uptake, complementary CTA are more effective than manual contact tracing alone.

Speed and Scalability. Data from COVID-19 cases must be timely so that contacts can be informed, and the chain of viral transmission interrupted. Contact tracing must outrun the viral spread to prevent spiralling outbreaks. Yet, when the reproductive rate of COVID-19 increases, it may outpace manual contact tracing, overwhelming already-strained public health agencies (1). Due to the labour-intensity of manual contact tracing, it may not be possible to increase the public health workforce fast enough to cope with a rising reproductive rate (11). In addition, the serial interval – the time from symptom onset in the primary case to symptom onset in the secondary case – of the virus is shorter or close to its incubation period. Thus, secondary transmission may happen prior to the onset of symptoms (12) – which complicates manual contact tracing further. These viral factors result in notification delays, which in turn delay quarantine and testing, greatly reducing the ability of public health agencies to control the virus (1).

CTA are not affected by these constraints. They are not labour-intensive and can instantly be scaled up as they employ widely used mobile technologies, such as Bluetooth and GPS (11). CTA can support manual contact tracing through immediate and automatised contact tracing and notification of exposed individuals. Ideally, this involves comparatively low investment. However, there is a paucity of evidence on the cost-effectiveness on CTA (8).

Community Transmission Tracing. CTA are particularly advantageous for contact tracing when community transmission is common. In case of a respiratory disease, such as COVID-19, anyone who has been in physical proximity of an infected person for some time could have been infected. With manual contact tracing, it is unlikely that all these contacts are identified, in particular if they took place in public spaces and public transport (13). To capture the most significant encounters in public, CTA enable public health authorities to specify epidemiological thresholds, such as proximity and duration parameters (14).

Avoidance of Recall Bias. Conventional contact tracing is afflicted by recall bias, i.e. people are unlikely to recall all their encounters and visited locations over the course of their infectious period (15). CTA provide solutions for these issues, as they do not rely on the memory of infected users.

Mitigation of the 'Manifestation Problem'. Another challenge for manual contact tracing is the substantial proportion of asymptomatic transmission of COVID-19, which may account for up to 69% of transmission (16). This leads to a 'manifestation problem', meaning that infectious individuals who do not show any symptoms do not seek medical care (15). Since CTA record all significant encounters, asymptomatic secondary cases could be notified before they unknowingly infect other people.

To summarise, CTA could be crucial for avoiding severe social distancing measures and supporting a return to a somewhat normal life. They could contribute to breaking the chain of transmission despite people moving in public spaces, going to work, and having a social life. This could create business confidence and allow people to go to work, mitigating negative effects on the economy. Additionally, the negative psychological effects of long-lasting or repeated lockdowns could be avoided.

Limitations of Contact Tracing Apps

Utility depends on Network Effects. The overall utility of CTA depend on the strength of the network, meaning that they need a critical mass of users with the app installed and a good coverage across different population groups in order to be effective (17,18). First experiences with CTA have shown that population uptake is generally quite low, rarely reaching over 20% (19). With that being the case, the previously mentioned required uptake from 56% to 95% of the population marks very high thresholds (8). A significant percentage of the population may be hesitant to participate, often due to government mistrust and privacy concerns (20). Governments could make the use of CTA mandatory, but such draconian measures are unlikely in the European Region – for now. In addition to unwillingness, uptake may also be lower in population groups that have been disproportionately impacted by the virus, such as socio-economically disadvantaged, elderly, neurodiverse, and/or disabled people. These groups are often digitally excluded due to lower levels of device ownership and digital literacy (21). If CTA are not implemented with contextualized solutions for these vulnerable groups, they will not only further exacerbate the digital divide but also be less effective.

Imprecision in Contact and Distance Detection. CTA can be inaccurate as they may experiences measurement errors and have limitations in detecting distance. For example, Bluetooth Low Energy signals can be affected by physical obstacles and surfaces around the phone, such as walls, human bodies, pockets, and purses (4). Thus, it is likely that CTA will not reach 100% specificity or sensitivity for identifying exposed contacts. As for low specificity, they may produce too many false negatives, failing to capture all significant encounters and defying the screening purpose. As for low sensitivity, they may capture all significant encounters of infected users but could then have multiple false positives (22). Many users could falsely be notified of exposure and asked to quarantine needlessly, particularly those who frequent crowded places, such as offices or public transport. Frequent notifications could have severe ramifications, such as psychological distress, loss of income and overall loss of confidence in CTA (22). Moreover, inaccurate CTA can lead to an inefficient allocation of scarce resources in the wider public health system, as large numbers of false positive users would require testing, advice, and support from public health workers (11).

Blind to Circumstances. CTA lack a range of human capabilities that prevent them from controlling for transmission variables. Public health workers who manually trace contacts and conduct research on encounter circumstances can ascertain vital information on transmission variables such as ventilation, direction of wind, and the general environment (21). This is particularly important due to the airborne transmission of COVID-19 through aerosols, as viral clouds can linger in the air in enclosed spaces for hours – even after infected users have already left (23). CTA could only incorporate airborne transmission in their design if geolocation would be used – which is associated with significant privacy concerns (24).

Privacy Concerns. If personal data collected by CTA is not sufficiently protected by privacy-preserving technologies, mistrust can arise and people would feel discouraged to participate (14). This applies to privacy of the data from contacts, authorities, private sector actors, and hackers (17). To begin with, CTA should not reveal personal information of infected users to their contacts. Contacts should receive minimal personal information, such as a simple exposure notification, to prevent the ability to infer the identity of the infected user. However, in the absence of a completely decentralized peer-to-peer system, privacy from contacts can only be achieved by trusting government authorities or involved private sector actors to act as intermediaries (17). This may turn to mission creep, gradually increasing surveillance and diverting from the initial objective of contact tracing (25). In addition, insufficient cybersecurity provisions can make CTA vulnerable for hacker attacks, enabling them to obtain sensitive personal data (21). Thus, CTA without legal and technical protections create a window of opportunity for abuse (11).

With the General Data Protection Regulation (GDPR), the majority of the countries in Europe is already covered by a regime of high privacy protection. However, strict privacy-preservation has an epidemiological cost. It impedes the collection of data that could be used to understand the viral dynamics and leaves public health agencies with limited insight into population aspects, such as hot-spots or rate of spread (14).

Discriminatory Potential. The health status data collected by CTA could be (ab)used in a discriminatory way by, for example, determining who can and cannot get back to work, or by determining who can access public spaces (25).

CTA themselves could be used as requirement to participate in certain activities or be connected with benefits. For example, businesses could mandate that their customers use CTA as a condition for entering their building or people with CTA could be given accelerated access to testing. This could make the app quasi-mandatory and amplify existing disadvantages of vulnerable groups with limited access to digital technologies (26). Thus, anti-discrimination protections for people who choose not to or cannot use CTA are needed.

Harmful Behavioural Impact. Users may need a certain level of health literacy to properly use CTA. However, many people, in particular vulnerable groups, often do not have the ability to process health information – which is needed for informed health decisions. As a result, information received through the CTA may be misinterpreted (21). Additionally, CTA could change the risk perception of the population, as it may give them a false sense of security (21). The resulting divergence between risk perception and objective risk can lead to either insufficient health-protective behaviour, such as social distancing and hand washing.

To sum it up, CTA cannot be promoted as a 'silver bullet' solution for the control of COVID-19. A narrow focus on the perceived benefits conceals their limitations – both technological and social. As a consequence, they could divert attention and resources from other interventions and crucial epidemic control elements, such as manual contact tracing. Therefore, their weaknesses and potential negative effects on other public health activities must be considered at all times.

Table 1. Strengths and Limitations of CTA.

Strengths	**Limitations**
Reduction of Transmission	Utility depends on Network Effect
Speed and Scalability	Imprecision in Contact Detection
Community Transmission Tracing	Blind to Circumstances
Avoidance of Recall Bias	Privacy Concerns
Mitigation of the 'Manifestation Problem'	Harmful Behavioural Impact
---	Potential for Discrimination

3. Integration of Contact Tracing Apps into Public Health Systems

The comparison above shows that CTA should be a complement to, rather than a replacement for, existing contact tracing and COVID-19 prevention measures They could risk overwhelming public health systems due to inefficiencies and duplication of work. Consequently, CTA must be integrated with health services personnel, testing services, and manual contact tracing infrastructure. While public health systems vary greatly across the European Region, a few general considerations for this integration are given below.

As mentioned in the previous section, manual contact tracing has weaknesses, such as reliance on memory and difficulty in identifying community transmission contacts, which can be offset by CTA. Manual and app-based contact tracing should be closely integrated to enable task sharing and more efficient data collection (27). Manual contact tracing should continue to focus on the identification of all contacts with high-risk exposure, such as family members and friends. Due to their high risk of having been infected, it is important that these contacts are personally instructed about reporting symptoms early and how to reduce their risk of passing on the virus. It is not feasible that these instructions are solely delivered via CTA notification because this will not have the same effectiveness and social impact as messages delivered by public health workers (21).

CTA will likely address community transmission contacts, such as other passengers on public transport. They would be rapidly notified, advised to quarantine, and provided with a phone number for advice and support. For this purpose, specific phone helplines staffed with contact tracers are needed to provide information to CTA-notified individuals. This call could also be used to clarify if quarantining is necessary in the individual case. Such an approach could mitigate the negative effects of CTA inaccuracy (22). These individuals could also be asked if they would voluntarily share further details that may be relevant for contact tracing (27). To avoid confusion, contact tracers must be trained in the usage and functionalities of the CTA.

To support the follow-up process, CTA include additional functions besides contact tracing and exposure notification, such as an automated messaging-system which periodically follows up with users after the exposure notification.

Another consideration is symptom-checker features which enable exposed contacts to monitor themselves for COVID-19 symptoms (27). Both these features could motivate exposed users to seek medical care and reduce work for public health workers.

The tandem of manual and app-based contact tracing can only be effective if it is linked to laboratory testing for the virus. The time between receiving a notification and getting tested should be minimized in light of the short serial interval of COVID-19 (12). A necessary precondition is the widespread availability of high-sensitivity diagnostic tests. Tests in walk-in or drive-in testing facilities should be recommended to exposed individuals via the app. If they chose to take a test and are tested positive, they are connected to a contact tracer and their contacts are notified via the app, minimizing secondary cases. However, if the test is negative, their individual contact tracing process ends, freeing capacities for other contact tracing (9). The results of a COVID-19 lab test could be demanded via the app, connecting the user to the test result server, such as in the Belgian CTA 'CoronAlert'.

If the personal data collected by CTA is shared with public health agencies, such as in the centralized protocol, it must be ensured that it is relevant, accurate and detailed health status data that can be utilized for general contact tracing and digital epidemiology. Thus, interoperability across different public health jurisdictions and ideally different countries must be insured. This can be challenging depending on existing public health technology and the level of centralization and decentralization across the system (14). Robust technological governance is needed, which may require authorising legislation.

The integration of CTA should focus on inclusiveness and coverage. As outlined in the previous section, multiple population groups may be digitally excluded. Public health agencies must continuously identify these groups and work with their members to design support measures, such as subsidized internet access, substitute wearables or assistive functionalities. National helplines could be set up to offer guidance and support for using the app (28).

Lastly, evaluation and monitoring mechanisms for CTA must be in place, as there is no solid evidence-base for CTA effectiveness (21). It is not clear how they can best be used as part of existing public health systems, necessitating independent technical reviews and adoption of best-practices among countries.

4. Cross-Country Overview

Over the course of the past few months, a myriad of contact tracing apps have been developed and launched across the European Region. For the purpose of this paper, a cross-country overview of all CTA has been created to identify common patterns and differences. 53 countries of the WHO European Region were analysed. Data was collected from government statements, technical reports, and privacy policies. In addition, short summary tables by the European Union were used (6,29). The data was last updated in **October 2020**.

It should be noted that the cross-country overview only displays government sponsored national CTA. The United Kingdom has three separate CTA for its constituent countries Scotland, Northern Ireland, as well as England and Wales, which share an app.

App Status. 31 countries in the European Region are using or will use CTA, which is over 60% of all countries in the region. 21 countries, or around 40% of countries in the European Region, do not plan to launch an app.

33 CTA have been rolled out so far. The CTA of Norway and Slovakia have been suspended due to privacy and efficiency concerns. Norway* and Lithuania are currently developing CTA.

CTA Status	Absolute Number	Percentage
No CTA employed	21	39,6% (of countries)
CTA employed	32	60,4%
CTA in use	31	88,6% (of CTA)
CTA suspended	2	5,7%
CTA in development	2	5,7%

*Norway's CTA in development will not be included in the other parts of the analysis due to a lack of available information.

Participation. Using apps on a voluntary basis means that users can install and delete it at any time. In contrast, mandatory apps require by law that users install and use CTA. In line with ethical recommendations from the WHO, the EU, and other organisations, almost all CTA are entirely voluntary – with the exception of Turkey's CTA. 'Hayat Eve Sığar' is mandatory in practice since the app is needed to obtain codes for inter-city travels with mass-transportation and for entering some government buildings (30).

Participation	Absolute Number	Percentage
Voluntary	33	97,1%
Mandatory	1	2,9%

Technology. 30 CTA, or 91% of all CTA, utilize Bluetooth Low Energy (BLE), making it the most commonly used technology. Over 3/4 of all CTA (76%) use BLE as sole technology. Only three CTA (9%) are based on GPS-Location and another five (15%) use GPS with supplementary BLE and/or other means, such as QR codes or Wi-Fi Logs.

Technology employed	Absolute Number	Percentage
BLE	26	76,0%
GPS Location	3	9,0 %
GPS Location, BLE	3	9,0%
GPS Location, BLE and/or additional means	2	6,0%

App Protocol. CTA were divided into having centralised or decentralised protocols according to (i) the function of the central backend server, (ii) the data storage location, and (iii) the matching of contacts (2) (For more specific information, please go back to section 2 'Architecture of Contact Tracing Apps'). Based on these criteria, 11 CTA (32% of all CTA) were classified as centralised. Accordingly, 23 CTA (68% of all CTA) were classified as decentralised, making the decentralised protocol the most commonly used in the European Region. Most decentralised apps are based on the Exposure Notification System jointly provided by Apple and Google.

App Protocol	Absolute Number	Percentage
Centralised	11	32,0%
Decentralised	23	68,0%
GAEN	20	*Of all apps*: 59% *Of decentralised apps*: 87%

App Operator and Developer. The main actors when it comes to CTA are the national authorities that operate the app. These authorities are normally responsible for public health matters and , in many cases, are the 'data controller' (according to GDPR) that determines the how and why the collected data is processed. The most common operators are National Ministries of Health / Social Affairs, who operate 12 CTA (or 35% of all CTA) and National Public Health Agencies, which operate 9 CTA (or 26% of all CTA). Other operators include NGOs, research institutions, patient organisations, and other ministries. Regarding developers, the private sector has developed two thirds of all CTA (67%). Other important actors are government entities and research institutes. This highlights the increasing importance of private sector actors in public health.

App Operator	Absolute No.	App Developer	Absolute No.
Ministry of Health / Social Affairs	12	*Government Entity*	6
Public Health Agency	9	*Private Sector*	18
Other Ministry	4	*Research Institute*	4
National Health Service Organisation	4	*Private Sector & Government Entity*	*4*
Other	4	*Other collaborations*	*2*

Privacy. To ensure transparency and increase public trust, many CTA have been introduced alongside privacy measures to prevent mission creep.

Many CTA are open source, meaning that the source code and documentation is freely available online, usually on the platform https://github.com. The source code, which is a collection of human-readable codes created by a programmer, can be used to replicate or investigate the functioning of the CTA. To date, 23 CTA (68% of all CTA) are open source.

In addition, the regulations of CTA often include a sunset clause. Sunset clauses ensure that CTA cease to have effect or will be dismantled post-pandemic. This ensures that CTA do not outlive the effort against COVID-19. 21 CTA (62% of all CTA) have a sunset clause.

Privacy Measure employed	Absolute Number	Percentage
Open Source	23	68,0%
Sunset Clause	21*	62,0 %

*this information may be incomplete since these regulations are often only available in the official language.

5. A Pan-European Approach for Contact Tracing Apps

The freedom of movement for all nationals of Member States is a core pillar of the European Union. Thus, the Member States seek to keep Intereuropean borders open during this pandemic. However, the effectiveness of CTA across the continent could be compromised by the import of the virus by travellers and cross-border workers without the respective app. It cannot be expected that these people download multiple CTA if they live, work, or travel between multiple countries . Therefore, a Pan-European approach to contact tracing apps is needed to enable the tracing of cross-border infection chains (31). This poses multiple operational and technical challenges. Common solutions must be found for a multitude of apps with varying designs that are tailored for conditions unique to their health systems.

To streamline a European approach, the European Commission has issued various guidance documents in the past months. These documents were mostly developed by the e-Health network, a platform of Member state's authorities which are dealing with digital health. In mid-April, the commission published a *Common EU Toolbox for Member states* for mobile applications to support contact tracing (28). It lays down the central requirements and functionalities of apps in the EU: (i) voluntariness, (ii) authorization by national health authority, (iii) privacy preservation, and (iv) cessation once they are no longer needed. At the same time, the Commission adopted *Guidance on Apps supporting the fight against COVID 19 pandemic in relation to data protection* to address the need for full compliance with the GDPR and limitations for the risk of abuse (32). By mid-May, most EU members had started developing or rolled out CTA which were not interoperable. Interoperability refers to "being able to exchange the minimum information necessary so that individual app users, wherever they are located in the EU, are alerted if they have been in proximity, within a relevant period, with another user who has notified the app that he/she has tested positive for COVID-19 (31)".

Thus, the Commission published *Guidelines on Interoperability for approved contact tracing apps mobile applications in the EU* on 13 May. These guidelines were a baseline document for technical specifications of interoperability and intended as guidance for developers in designing and implementing the national CTA (31). On 12 June, the Member States agreed on a fixed set of technical specifications for interoperability of CTA (33). To cover the majority of CTA, the technical specifications are currently only for decentralised apps. The premise of this solution is that the mechanisms of decentralized apps are compatible because they are based on Exposure Notification by Google and Apple (GAEN) for proximity detection.

To allow communication between GAEN-enabled apps, the Commission has chosen to set up a single European Federation Gateway Service. This will enable the respective central backend servers of CTA to upload the cryptographic keys that they have received from infected users and download the cryptographic keys from all other participating countries every few hours. The respective national central backend servers will then share the keys with their users – depending on countries that they have been to recently. For this purpose, each user must specify their countries of interest, either via mobile provider metadata or manual user entries. The matching of cryptographic keys to the proximity history then happens on the mobile devices. This approach minimizes the amount of data exchanged and reduces users' data consumption to 10-20 MB per day (34). The gateway service temporarily stores keys and associated visited countries for 14 days for retrieval. These keys are confidential, meaning that only authorised national servers can access them. Just like decentralized CTAs, the gateway service does not know the identity of the people behind the keys (34).
As of September 14th, the Commission has started testing the gateway service for the national CTA. Currently, the CTA of Germany, Ireland, and Italy are compatible to pilot the gateway service (35).

Interoperability between these apps and between their central backend servers is essential for the tracing of cross-border infection chains. High-level pressure is being applied on all Member States of the EU to adopt common technical standards for interoperability (36). As of October, France is one of the few countries that remains determined to move on with its centralised CTA 'TousAntiCovid'.

Yet, interoperability between centralised and decentralised apps is difficult, being a major operational and technical challenge and involving additional privacy risks (37). Without France, a central puzzle piece of the Pan-European approach is missing, as the country is a major EU economy, represents 15,2% of the total EU-27 population, and is centrally located. If centralised CTA are able to connect with decentralised CTA, specific regulations for travellers from and to these countries must be found, such as targeted manual contact tracing – adding further complexity on a European approach.

6. Conclusion

The aim of this report was to give an overview of contact tracing apps and their role in the European Region.

The majority of countries employ decentralised BLE-based apps that aim to preserve privacy. Under the guidance of the European Commission, the previously heterogenous landscape of CTA is experiencing harmonisation, with CTA adopting similar features, such as the primacy of privacy protection and voluntariness. In addition, many countries are now working together to link up their CTA to form a European network.

However, the initial excitement about a quick, technical fix for the pandemic has been dampened by the difficulties in implementing CTA. Despite compelling strengths, such as the potential to reduce transmission or relieve public health authorities, their limitations can reduce their effectiveness significantly – in particular in a region like Europe. High standards for human rights and privacy mean that people have the autonomy to refuse using the app and are entitled to privacy protection. Consequently, many limitations reduce uptake, such as government mistrust, frustration over high numbers of false positives, or privacy concerns.

Thus, two final reflections can be derived from this report. First, CTA as a public health measure in the European Region is only justifiable if it strikes a balance between competing considerations, such as public health utility, technological feasibility, and privacy protection. Second, CTA must be a complement to, rather than a replacement for, existing manual contact tracing and other COVID-19 prevention measures.

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Country	Name	Participation Voluntary / Mandatory	Technology Bluetooth LE / GPS / Other	App Protocol Centralised / Decentralised	Apple / Google API Yes / No
Albania					
Andorra					
Armenia					
Austria	Stopp Corona	Voluntary	Bluetooth Low Energy	Decentralised	Yes
Azerbaijan					
Belarus					
Belgium	Coronalert	Voluntary	Bluetooth Low Energy	Decentralised	Yes
Bosnia and Herzegovina					
Bulgaria	ViruSafe	Voluntary	GPS Location	Centralised	No
Croatia	Stop COVID-19	Voluntary	Bluetooth Low Energy	Decentralised	Yes
Cyprus	CovTracer	Voluntary	GPS Location	Centralised	No
Czechia	eRouška	Voluntary	Bluetooth Low Energy	Decentralised	No
Denmark	Smittestopp	Voluntary	Bluetooth Low Energy	Decentralised	Yes
Estonia	HOIA	Voluntary	Bluetooth Low Energy	Decentralised	Yes
Finland	Koronavilkku	Voluntary	Bluetooth Low Energy	Decentralised	Yes
France	StopCovid	Voluntary	Bluetooth Low Energy	Centralised	No
Georgia	Stop Covid (iOS) / NOVID20 (Android)	Voluntary	Bluetooth Low Energy, GPS Location	Centralised	No
Germany	Corona-Warn-App	Voluntary	Bluetooth Low Energy	Decentralised	Yes
Greece					
Hungary	Vírus Radar	Voluntary	Bluetooth Low Energy	Centralised	No
Iceland	Rakning C-19	Voluntary	GPS Location	Centralised	No
Ireland	Covid Tracker	Voluntary	Bluetooth Low Energy	Decentralised	Yes
Israel	HaMagen	Voluntary	Bluetooth Low Energy, GPS Location, Wifi Log	Decentralised	No
Italy	Immuni	Voluntary	Bluetooth Low Energy	Decentralised	Yes
Kazakhstan					
Kyrgyzstan					
Latvia	Apturi COVID	Voluntary	Bluetooth Low Energy	Decentralised	Yes
Lithuania	N/A	Voluntary	Bluetooth Low Energy	Decentralised	N/A
Luxembourg					
Malta	COVIDAlert Malta	Voluntary	Bluetooth Low Energy	Decentralised	Yes
Monaco					
Montenegro					
Netherlands	CoronaMelder	Voluntary	Bluetooth Low Energy	Decentralised	Yes
Northern Ireland	StopCOVID NI	Voluntary	Bluetooth Low Energy	Decentralised	Yes
North Macedonia	StopKorona!	Voluntary	Bluetooth Low Energy	Centralised	No
Norway	Smittestopp	Voluntary	Bluetooth Low Energy, GPS Location	Centralised	No
Poland	ProteGO Safe	Voluntary	Bluetooth Low Energy	Decentralised	Yes
Portugal	STAYAWAY COVID	Voluntary	Bluetooth Low Energy	Decentralised	Yes
Republic of Moldova					
Romania					
Russian Federation					
San Marino					
Scotland	Protect-Scot	Voluntary	Bluetooth Low Energy	Decentralised	Yes
Serbia					
Slovak Republic	Covid 19 Zostaň Zdravý	Voluntary	Bluetooth Low Energy, GPS Location	Centralised	No
Slovenia	#OstaniZdrav	Voluntary	Bluetooth Low Energy	Decentralised	Yes
Spain	Radar Covid	Voluntary	Bluetooth Low Energy	Decentralised	Yes
Sweden					
Switzerland	SwissCovid	Voluntary	Bluetooth Low Energy	Decentralised	Yes
Tajikistan					
Turkey	Hayat Eve Sığar	Mandatory (in practice)	Bluetooth Low Energy, GPS Location, QR Code	Centralised	No
Turkmenistan					
Ukraine					
England and Wales	NHS COVID-19	Voluntary	Bluetooth Low Energy	Decentralised	Yes
Uzbekistan	Birga Yengamiz	Voluntary	Bluetooth Low Energy	Centralised	No

Country	Name	App Operator Broad Categories	App Developer Govt. entity / Research Institution / Private sector	Open Source Yes / No	Sunset Clause Yes / No
Albania					
Andorra					
Armenia					
Austria	Stopp Corona	Non-governmental Organisation	private sector	Yes	Yes
Azerbaijan					
Belarus					
Belgium	Coronalert	Research Institution	private sector	Yes	Yes
Bosnia and Herzegovina					
Bulgaria	ViruSafe	Ministry of Health / Social Affairs	private sector	Yes	N/A
Croatia	Stop COVID-19	Ministry of Health / Social Affairs	private sector	Yes	Yes
Cyprus	CovTracer	Research Institution	research institution	No	N/A
Czechia	eRouška	Ministry of Health / Social Affairs	private sector	Yes	Yes
Denmark	Smittestopp	Patient Organisation	private sector	No	Yes
Estonia	HOIA	Ministry of Health / Social Affairs	government entity, private sector	Yes	Yes
Finland	Koronavilkku	National Public Health Agency	government entity	Yes	Yes
France	StopCovid	Ministry of Health / Social Affairs	research institution	Yes	Yes
Georgia	Stop Covid (iOS) / NOVID20 (Android)	Ministry of Health / Social Affairs	private sector	Yes	No
Germany	Corona-Warn-App	National Public Health Agency	private sector	Yes	Yes
Greece					
Hungary	Vírus Radar	National Public Health Agency	private sector	No	Yes
Iceland	Rakning C-19	National Public Health Agency	private sector	Yes	N/A
Ireland	Covid Tracker	National Health Service Organisation	private sector	Yes	Yes
Israel	HaMagen	Ministry of Health / Social Affairs	government entity, private sector	Yes	N/A
Italy	Immuni	Ministry of Health / Social Affairs	government entity, private sector	Yes	Yes
Kazakhstan					
Kyrgyzstan					
Latvia	Apturi COVID	National Public Health Agency	private sector, research institution	Yes	No
Lithuania	N/A	N/A	private sector	N/A	Yes
Luxembourg					
Malta	COVIDAlert Malta	Ministry of Health / Social Affairs	government entity	Yes	Yes
Monaco					
Montenegro					
Netherlands	CoronaMelder	Ministry of Health / Social Affairs	government entity, private sector	Yes	N/A
Northern Ireland	StopCOVID NI	National Health Service Organisation	private sector	Yes	N/A
North Macedonia	StopKorona!	Ministry of Health / Social Affairs	private sector	No	N/A
Norway	Smittestopp	National Public Health Agency	government entity	No	Yes
Poland	ProteGO Safe	Ministry of Technology / Science	private sector	Yes	Yes
Portugal	STAYAWAY COVID	National Public Health Agency	research institution	Yes	Yes
Republic of Moldova					
Romania					
Russian Federation					
San Marino					
Scotland	Protect-Scot	National Health Service Organisation	private sector	Yes	N/A
Serbia					
Slovak Republic	Covid 19 Zostaň Zdravý	National Public Health Agency	private sector	N/A	Yes
Slovenia	#OstaniZdrav	Other Ministry	government entity	Yes	N/A
Spain	Radar Covid	Other Ministry	government entity	No	Yes
Sweden					
Switzerland	SwissCovid	National Public Health Agency	research institution	Partially	Yes
Tajikistan					
Turkey	Hayat Eve Sığar	Ministry of Health / Social Affairs	government entity	No	No
Turkmenistan					
Ukraine					
England and Wales	NHS COVID-19	National Health Service Organisation	government entity, research institution	Yes	N/A
Uzbekistan	Birga Yengamiz	Ministry of Technology / Science	private sector	No	Yes