Utilizing QR Codes for Public Health Contact Tracing in Low-Resource Communities

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Abstract

This paper discusses the development of a mobile contact tracing application (CTA), UPTrace, that uses Quick Response (QR) codes. A web version of UPTrace is also developed to address the issues on mobile compatibility, and to provide access to the authority in monitoring and contact tracing. By reviewing some existing CTAs globally and locally, together with their underlying technologies, the researchers decided to integrate QR codes in UPTrace. This is because QR codes, when used properly, offer a high level of accuracy, present acceptable level of privacy, security, confidentiality, and ease of use, address the issue on battery consumption of mobile phones, require less resources, contain relevant information that the authority can use, and fit in the context of a low-resource community.

To test the feasibility of UPTrace, University of the Philippines Diliman (UPD), a low-resource community, is used as a case study. In this context, the only authority is the UP Health Service (UPHS). And the underlying features of UPTrace were based from an interview with UPHS Contact Tracers and the existing protocols in UPD.

1 INTRODUCTION

An effective contact tracing methodology could help reduce the spread of viruses like COVID-19. Contact tracing was traditionally done manually by interviewing infected persons and identifying their close contacts. Such manual contact tracing (MCT) has been proven to be effective in controlling the spread of Ebola between 2014 and 2016 [28]. However, MCT largely depends on an individual's ability to recall who they were in contact with whom they might not even know personally. To overcome this limitation, the use of digital contact tracing (DCT) through contact tracing applications (CTAs) could be a better option given that DCT has a high adoption rate and will be followed up by testing and isolation. CTAs can provide more accurate data and can lessen virus transmission because there is no need to use pen and paper in filling out MCT forms anymore.

Given the various CTAs available, and given that each of them has its advantages and disadvantages, this research aims to compare and contrast different international and local CTAs, discuss the privacy issues that exist within them, and consider them in developing an exclusive CTA for a low-resource community, specifically the University of the Philippines Diliman (UPD). The goal is to make a CTA that is easy to use, effective, and offers a high level of accuracy, privacy, and accessibility. A review of existing technologies used in CTAs, as well as a review of existing CTAs in the Philippines and in other countries, is an important step in identifying the appropriate framework for proposing such an exclusive CTA for UPD.

2 REVIEW OF RELATED LITERATURE

2.1 Existing Technologies used in CTAs

Fortunately, with the use of technology, the struggle in manually identifying close contacts can be alleviated. Various CTAs for COVID-19 have emerged now across the globe, making use of web apps and mobile apps to perform DCT. Commonly used technologies used by CTAs are (1) Bluetooth, (2) Global Positioning System (GPS), and (3) Quick Response (QR) Codes which will each be briefly discussed in the succeeding paragraphs.

2.1.1 Bluetooth

CTAs that use Bluetooth technology often use Google/ Apple Exposure Notification (GAEN), a framework developed by Google and Apple for quickly notifying people who may have been exposed to a person with COVID-19. GAEN generates randomized keys for each device that change every 10-20 minutes to ensure that an individual or their location cannot be identified; thus, it offers a certain level of privacy because users remain anonymous and their locations are not collected. Generated random keys are then exchanged between users and are used in identifying and notifying those whose random keys were determined to have close contact with an infected user.

GAEN heavily relies on the strength of Bluetooth signals received from other phones. The downside of this can be its accuracy because Bluetooth signal strength, aside from proximity, can be affected by several factors like obstacles between phones [46]. Another downside is the absence of relevant information that health care units can use to identify the users that had close contact with an infected patient such as contact details and location. Added to this is the battery consumption of turning on Bluetooth for a long time on mobile phones, especially on iOS devices. On iOS devices, Bluetooth scanning on apps running in the background is disabled, so users are forced to maintain a CTA running in the foreground to scan nearby devices that use the same CTA [27]. Finally, Bluetooth signals may be intercepted by third parties and can be rebroadcasted and used for malicious purposes [24].

2.1.2 GPS

CTAs that use GPS identify close contact users through their geographic location and time information. A downside of this method is accuracy, especially in indoor locations. For example, if two users are in the same building, with the same x and y coordinates, but are in different levels (z coordinate), GPS technology will identify them to be in the same exact place. Not only that, the main downside of this is it basically tracks its users which raises a privacy concern. Also, just like with CTAs that use Bluetooth, CTAs that use GPS have an issue with battery consumption [46].

2.1.3 QR Codes

CTAs that use QR codes offer a level of accuracy because the information embedded on the QR Codes about an establishment or a user is accurate, assuming that both parties have provided factual information. Accuracy could also be guaranteed only if these CTAs are constantly used for logging visits. There are two types of how QR codes are used. It can either be the user scans the QR code of the establishment they are visiting, or it is the establishment that scans the QR codes of the users. Thus, it can accurately identify close contacts of infected individuals [30]. QR codes being accurate, however, raises privacy issues because the data stored in the database are raw and include relevant information about the users which may be used to identify them.

A summary of existing technologies used in CTAs is provided by **Table 1**.

2.1.4 Other Technologies

Other technologies that can be used for CTAs are not widely used because of any of the following reasons: (1) the technology is not widely available, (2) accuracy level is low, and (3) its use has privacy issues. For example, WiFi can be used to gather information about the location of users through different access points of WiFi in an establishment. However, it is inaccurate because users connected to a single access point may be in different rooms. Another type of technology is acoustic-ranging which utilizes the transmission of sound waves. The downside of this is that only few phones can perform simultaneous sound-based contact tracing. In addition, this requires phones' microphones to be turned on which can be a privacy concern [46]. RFID technology can be used too since it can provide accurate proximity calculation [29], but implementing such technology might be costly since it will require each establishment to purchase RFID readers for multiple entrances/exits and/or rooms.

2.2 Existing International CTAs

Different CTAs have been built and released by foreign countries since 2020 to augment their pandemic response. Some of these CTAs use a combination of technologies presented in the previous section, while others just use a single approach. Four international CTAs will be discussed in the succeeding sections.

2.2.1 Aarogya Setu

Aarogya Setu is the main CTA used in India, made by India's National Informatics Centre (NIC) under the country's Ministry of Electronics and Information Technology (MeitY) [1]. It has more than 114 million registered users as of May 2020, possibly making it the CTA with the most reach and impact globally based on a report released by MeitY [16], but this only covers around 10 to 11 percent of India's population of more than 1.2 billion [8]. The app reportedly helped trace around 33.25 percent of cases from October 25, 2020 to September 11, 2021 [49]. This may be attributed to the government's mandate to require the installation and use of the app for both public and private employees [6]. According to the same document, the source code of Aarogya Setu has been made open-source in line with India's policy on Open Source Software and its commitment to transparency and collaboration. The app uses a combination of Bluetooth and GPS to identify Bluetooth contacts of infected users for the past 14 days and potential hotspots of COVID-19. Location data are

	Bluetooth	GPS	QR Codes
Mode of Use	Requires app to run in the background (and in the foreground on iOS devices; requires Bluetooth to be on (which is battery-draining)	Requires app to run in the background; requires GPS tracker to be on (which is battery-draining)	Requires app to run every time a QR code is scanned
Accuracy	Low accuracy especially if there are obstacles between phones	Low accuracy if inside indoor locations	High accuracy if users provide factual information and constantly scan QR codes
Privacy	Privacy-preserving solution (provides anonymity)	Privacy concerns on location tracking	Privacy concerns on database security

Table 1. Summary of Existing Technologies Used in Contact Tracing Applications

collected at 15-minute intervals and are only uploaded to the server if a user tests positive for COVID-19 or if their self-assessment result which may be gotten from one of the app's features indicates that they may be infected. For infected users, collected data will remain in the server for 60 days, and for non-infected users, collected data will only be stored in their phones for 30 days. Close contacts of infected users also get a notification from the app. As of date, its required minimum Android version is 5.0 and its required minimum iOS version is 13.5 [10, 11].

As mentioned above, the app has a self-assessment feature that users can use to evaluate their risk of exposure and to get assistance if needed. When they register, they need to provide their name, phone number, age, gender, profession, and list of countries visited in the last 30 days. The app also shows COVID-19 updates, best practices, and relevant advisories concerning the pandemic. Aside from that, just in June 2021, an update was released to allow users to update their COVID-19 vaccination details and status in the app and to download their vaccination certificate which in turn, eases the process of vaccination status checking when traveling [40]. Changes in status made by users are verified in the Covid Vaccine Intelligence Network (Co-WIN) portal, a platform for matters related to vaccination in India [34], to ensure that the statuses are correct.

2.2.2 TraceTogether

TraceTogether is a CTA launched by the government of Singapore to complement the contact tracing efforts of their Ministry of Health (MOH) [45]. It uses Bluetooth signals to detect nearby devices that also have the app installed. Phones exchange anonymized IDs which get encrypted and stored only on users' phones, and would only be shared with contact tracers if a user tests positive for COVID-19 in order to identify close contacts and notify them through the app. Encrypted data in the device will only reside there for 25 days. As of date, its mobile app's required minimum Android version is 5.1 and its required minimum iOS version is 10.0 [3, 4]. Bluetooth scanning works offline and an internet connection is only needed once a week to retrieve new temporary IDs from the server [43].

For those without mobile phones or those who prefer not to use them, they may get and replace a physical TraceTogether Token via mail and vending machines in various collection venues [2]. These tokens are free and water-resistant, and work similarly to the app—it also uses Bluetooth to detect nearby TraceTogether devices and only retains data for 25 days. Both the app and the token require users to register using their National Registration Identity Card (NRIC) number, and the app also requires a user's phone number. In place of the NRIC number, foreigners may use their Foreign Identification Number (FIN) when signing up in the app.

2.2.3 Zwaai.app

Zwaai.app is a CTA developed by members of the Interdisciplinary Hub for Security, Privacy and Data Governance (iHub), a group of researchers focusing on the influence of digitization on society, in Radboud University in the Netherlands. The developers decided to use QR codes for this app to avoid privacy issues that come with using Bluetooth which is commonly used in other CTAs. iHub members mentioned several problems that may be encountered with using Bluetooth for a CTA including, but not limited to, the following: 1) it operates in the background so users don't know what happens to their data and where other data comes from, 2) there is a high risk for false positives and false negatives because Bluetooth provides inaccurate location

data (e.g. Bluetooth range will decrease when a mobile phone is placed inside a pocket), and 3) Bluetooth use has limitations on iOS devices [48].

As an alternative to Bluetooth-enabled CTAs, iHub created Zwaai.app. In this app, users can share and scan personal QR codes with other people that they meet. When a user scans a QR code from someone's phone, two completely random numbers are exchanged between the two phones which together, generate a new number [47]. This new number is stored locally on both phones for a limited period of time. Users may also scan QR codes in establishments and transportation means, and the scanning process works the same way as when scanning another individual's QR code. The random numbers stored on a user's phone can be voluntarily uploaded to a central server in case they have caught the virus and can be requested by health authorities. These numbers are then matched with other random numbers to identify and notify close contacts [23]. QR code scanning was the selected approach of iHub because they believe that scans logged in their app would only correspond to deliberate encounters, thus making identification of close contacts more accurate. They also put a great emphasis on making the app private and secure to allay privacy concerns of users. In addition, the annoyance of scanning QR codes for some users can be viewed as a way for users to actively engage in the contact tracing process, and is actually considered as an advantage by iHub. Once social distancing measures are relaxed, people would not want to keep on scanning at every establishment or appointment they go to. As a result, this basically self-destructs the app while eliminating the risk that the app will continue to collect data in the background which could occur in CTAs that use Bluetooth even after the pandemic is over.

The effectiveness of the approach used in creating Zwaai.app cannot be determined because it was not used by the Dutch government. Nonetheless, iHub is open for collaboration with other teams who might be interested in elaborating their approach and using it in their own communities.

2.2.4 NZ Covid Tracer

NZ Covid Tracer is a CTA launched by the Ministry of Health of New Zealand. Initially, it only used QR code scanning to create a digital diary of a user's visited places but it had a Bluetooth upgrade months after its release [35]. The upgrade was meant to give users two types of records: a) an anonymized record of close contacts using Bluetooth, and b) a location-specific record of visited places using QR code scanning. Data collected will only be stored on a user's phone and may be shared with contact tracers upon the user's consent. Those collected using Bluetooth will automatically be deleted after 14 days, and those collected using QR code scanning will be deleted after 60 days. As of date, the app's required minimum Android version is 6.0 and its required minimum iOS version is 10.0 [20, 21].

Businesses and public transport providers were mandated to post QR codes [44, 51]. For locations without QR codes, users can manually add entries to their digital diary to record their visits there [19]. In this manner, more accurate information on close contacts can be gathered from the app. Of note is the non-compulsory sharing of personal details such as email address, name, contact number and National Health Index number. A user may choose to share this information in case they test positive for COVID-19. In addition, COVID-19 guidelines can be accessed in the app's dashboard.

2.3 Existing Local CTAs

Several government agencies and local government units (LGUs) in the Philippines have developed their own CTAs. These CTAs mostly use Bluetooth or QR codes and require personal information such as contact details and addresses upon registration. Three local CTAs will be examined in this study and to do that, the researchers reviewed previous literature analyzing these apps, gathered information from each app's page in Google's Play Store and Apple's App Store, and determined whether requested data to be collected and app permissions are really necessary for the apps to function properly.

2.3.1 StaySafe PH

StaySafe PH is the official contact tracing system of the Philippine government launched by the Department of the Interior and Local Government (DILG) and Inter-Agency Task Force on Emerging Infectious Diseases (IATF-EID) in cooperation with MultiSys Technologies Corporation [42]. Previously, it used GPS and Bluetooth to collect device geolocation data and exchange data which raised data privacy concerns. As a response, its developers removed GPS and Bluetooth connection use in December 2020 [17]. However, the current version of the app still uses Bluetooth, now together with GAEN, and is the only app allowed to use GAEN in the country [38].

StaySafe PH uses separate platforms for digital logbook (web app), a replacement for manual logging of information using pen and paper which might possibly transmit the virus, and exposure notification (mobile app). As of date, its mobile app's required minimum Android version is 6.0 and its required minimum iOS version is 13.5 [13, 14]. The app can be used to see COVID-19 statistics in the country and to report positive cases. A positive report requires the user to provide their case

number to prevent false reports. For its digital logbook, a user has to provide private sensitive information such as their name, phone number, birth date, gender, and complete address, and has to enter an OTP sent to their mobile phone to login. The logbook offers two-way scanning. A user is given a QR code which may be scanned by establishments that they visit or individuals that they were in contact with, and vice-versa. For those without mobile phones, user registration on their website may be done to generate a QR code which can be printed and presented to establishments [31]. Scanning transactions data are only retained for 30 days.

Despite being the country's official CTA and the urge to patronize the app, it has not been adopted nationwide because not all LGUs have used StaySafe PH but have used their own CTAs instead. Health Secretary Francisco Duque III has even admitted that StaySafe PH has "almost no impact" and senator Pia Cayetano has criticized that the digital logbook web app only serves as a log and is not integrated with a system for contact tracing (i.e. no contract tracers are assigned to trace infected individuals based on the logs recorded in the app) [18].

2.3.2 Traze

Traze is a CTA launched by the Philippine Ports Authority in cooperation with Cosmotech Philippines and mainly used by Philippine port passengers and terminals [37]. It uses two-way QR code scanning, similar to StaySafe PH's digital logbook, to scan individuals, establishments or government agencies, transportation means, delivery crew, and vice-versa, and to trace places and people an individual has been in contact with. As of date, its required minimum Android version is 4.4 and its required minimum iOS version is 13.0 [15, 7], both of which are lower than the minimum OS requirements for StaySafe PH. Traze works with slow data and WiFi and also works offline, as confirmed by the researchers. It also stores each user's history of scanning transactions for 30 days like StaySafe PH. It has ads as well in order to provide its services for free.

To register in the app, a user has to provide their username, password, name, phone number, email address, profile picture, and town/city of residence. Their email address will only be used to retrieve their password if forgotten, and their profile picture will only be used for visual confirmation when scanning QR codes and is only stored locally, not in Traze's server. Users can register a maximum of 5 individuals who must either be their neighbors or must live in the same house as them who have no mobile phones. Barangays may also do this for their constituents without mobile phones.

2.3.3 eSalvar

eSalvar is a CTA used in Naga, Camarines Sur, and is an initiative of the City Government of Naga, Metro Naga Chamber of Commerce Industry (MNCCI) and Nueca Technologies Inc. [32]. Unlike StaySafe PH and Traze, it only uses one-way QR code scanning wherein only establishments have to scan QR codes of individuals which are generated through eSalvar's website. As of date, its required minimum Android version is 5.0 [25] which is between the minimum requirement for StaySafe PH and Traze, and its required minimum iOS version is 13.0 [26] which is lower than both StaySafe PH and Traze. To register and generate QR IDs, users must go to eSalvar's website and provide their name, phone number, birth date, gender, nationality, profile picture, and permanent address. Those who do not have the means to access the website may proceed to their barangay hall and be assisted by officials to generate a QR ID. This QR ID can then be scanned by establishments in the form of a printed image or an image in an individual's mobile phone both upon the entry and exit of individuals in their premises. QR scanning works offline but an internet connection is needed to sync the app with the server [29]. Like the two previous apps, eSalvar also retains data for only 30 days.

Table 2 shows a summary of the comparison of the mentioned international and local CTAs.

2.4 Privacy Issues on CTAs

Privacy and cybersecurity, together with the trust in the government, are major factors in user's willingness to adopt an application [5]. In the study of Cho et al. [2020], there are three desirable notions of privacy that are defined in the context of creating a CTA that utilizes Bluetooth technology and tokens—privacy from snoopers, privacy from contacts, and privacy from the authorities [12].

2.4.1 Privacy from Snoopers

Snoopers are users that capture data among users without authorization [9]. In the context of computer networks, snoopers are users that use sniffing programs to listen to a network. In other words, this is similar to eavesdropping. The CTA TraceTogether was able to address this privacy issue by letting users generate randomized time-varying tokens that are constantly refreshed [9]. With this, a snooper cannot track and link a token to a specific user.

2.4.2 Privacy from Contacts

The information of a user should be private and not accessible specifically to their close contacts. In Bluetooth-enabled CTAs, the data that are being passed on to the close contacts should not contain readable information about the users. Once confirmed to be a close contact

CTA	Aarogya Setu	TraceTogether	Zwaai.app	NZ Covid Tracer	StaySafe PH	Traze	eSalvar
Country that Developed the App	India	Singapore	Netherlands	New Zealand	Philippines	Philippines	Philippines
Technology Used	Bluetooth and GPS	Bluetooth	QR codes	Bluetooth and QR codes	Bluetooth and GAEN for mobile app, QR codes for web app	QR codes	QR codes
Minimum Required OS	Android: 5.0 iOS: 10.3	Android: 5.1 iOS: 10.0	Not applicable	Android: 6.0 iOS: 10.0	Android: 6.0 iOS: 13.5	Android: 4.4 iOS: 13.0	Android: 5.0 iOS: 12.0
Purpose	Notify exposed close contacts, identify potential hotspots, and display COVID-19 vaccination status	Notify exposed close contacts	Notify exposed close contacts	Notify exposed close contacts	Notify exposed close contacts and provide scanning history	Provide scanning history	Provide scanning history
Required Information	Name, phone number, age, gender, profession, and list of countries visited in the last 30 days	NRIC number for the app and token (or FIN for foreigners for the app) and phone number for the app only	None	None	Name, phone number, birth date, gender, region, province, municipality, barangay	username, password, name, phone number, email address, profile picture, town/city of residence	Name, phone number, birth date, gender, nationality, profile picture, permanent address
Required Users to Install the App	Individuals	Individuals	Individuals	Individuals	Both individuals and establishments	Both individuals and establishments	Only establishments
Data Retention Period	30 days for non-infected users in a mobile phone's local storage and 60 days for infected users in app's server	25 days	Not stated	14 days for data collected using Bluetooth and 60 days for data collected using QR code scanning	30 days	30 days	30 days
Works Offline	Yes, but only for scanning nearby devices	Yes, but only for scanning nearby devices	Unclear	No	No	Yes, but only for scanning QR codes	Yes, but only for scanning QR codes
Provides COVID-19 Statistics	Yes	No	No	No	Yes	No	No
Provides COVID-19 Information or Precautions	Yes	No	No	Yes	Yes	No	No

Table 2. Comparison of International and Local CTAs

of a positive case, the user should only be notified that he/she is a close contact and should not know which close contact was confirmed to be positive. In the context of TraceTogether, this privacy issue is addressed by putting the trust in the authority/government. Their ministry of health is the one responsible for this notification without exposing any other information [9].

2.4.3 Privacy from the Authorities

This notion signifies protection of privacy from whoever is administering the application. This issue is not addressed by TraceTogether simply because it requires government intervention in analyzing the data that were sent by the users through the application in order to implement an effective protocol. To be specific, TraceTogether gathers tokens from the diagnosed user and retrieves the mobile numbers of its close contacts through these tokens [9].

2.4.4 Privacy Issues on Bluetooth Technologies and GAEN

Bluetooth technology possesses privacy concerns because of its vulnerable wireless interface. This makes it susceptible to sniffing, bugging, and jamming [52]. To address these concerns, further innovations on this technology were made such as utilization of encryption methods and tokenization, and integration of decentralized systems. One of the popular Bluetooth technology frameworks is GAEN. While the aim of GAEN is to address the privacy issues of Bluetooth technology, there are new issues that arise within. The study of Hoepman and Jaap-Henk [2020] identifies the possible issues with GAEN [22]. To start with, GAEN uses local storage that is situated in the operating system. This can be a problem since this local storage is available outside the exposure notification feature of GAEN. Since it is lying in the operating system, it may be possible to uninstall GAEN. However, it is impossible to delete the code that enables it in the operating system. Another issue is that the generation of keys that is used in GAEN is under the control of Google and Apple. It may be possible for them to embed surveillance data on the keys generated. Lastly, GAEN claims that it uses a decentralized database by storing the data to the users locally. However, these data can still be centralized. It is possible for this data to be sent to Google and Apple's server without user intervention (without the user noticing it). Thus, GAEN heavily relies on the policies of Google and Apple.

2.4.5 Privacy Issues on Centralized Systems

The categorization of whether a CTA is centralized or decentralized does not rely on whether a central server exists. The distinction is dependent on whether the matching of contacts happens in a central or decentral manner. This is because all CTAs require at least a central server to perform other tasks [22]. In the central approach, a centralized database is used to store data of the users such as name and contact number wherein the health authorities have access to it. This raises a concern since centralized systems are a great tool for mass surveillance [41].

3 METHODOLOGY

This study emphasizes that the CTA that will be developed does not introduce new technologies. Instead, from existing technologies, this study aims to create a CTA that chooses the technologies that are most suitable in the context of contact tracing in UPD, a low-resource community, considering its existing protocols.

3.1 Requirements Gathering

To understand the existing protocols under the new normal, the documents released in the official website of UPD are cited [39, 50]. In addition to this, the researchers also conducted an interview with UPHS Contact Tracers.

Each office/unit has a Health Liaison Officer (HeLO) and/or Post ECQ Team (PET) assigned. A confirmed positive or suspected patient discloses that information to a HeLO or PET. HeLOs and PETs are expected to report daily to the UPHS Public Health Unit (UPHS-PHU) regarding the situation of their office/unit regardless if there is a patient that discloses to be positive or suspected. Once received by UPHS-PHU, UPHS Contact Tracers will contact them usually through text and/or call. They will investigate by asking a series of questions including their whereabouts, close contacts, and onset of their symptoms if applicable. They will also contact the identified close contacts of the patient for verification. From this, they will then evaluate and advise accordingly (i.e. to self-isolate or to test).

During the interview with UPHS Contact Tracers, they named a set of difficulties that they are experiencing with their current protocols. However, because of time constraints, this study will only address a subset from this set of difficulties. This subset is composed of:

1. The memory of the patients regarding their whereabouts and close contacts is unreliable.
2. Even though HeLOs and PETs are expected to submit their reports daily, what is happening in reality is that there are delays regarding this. Thus, it heavily affects the contact tracing.
3. The preference of patients regarding the time that the contact tracers contact them varies. Thus, the UPHS Contact Tracers suggested associating this information with the users.
4. The preference of patients regarding the type of interview that the contact tracers conduct their interview varies from having all questions asked

at one time to having to ask one question at a time.

4 RESULTS AND ANALYSIS

4.1 Proposed Design and Implementation

From the review of existing technologies and CTAs, and based on the interview with UPHS Contact Tracers, this study aims to create a CTA that is easy to use, accurate, accessible and available to the majority, effective, and addresses issues on security and privacy.

4.1.1 Easy to Use

Aside from having access to diagnostic testing and the ability of the technology to identify possible exposures, the success of a CTA also depends on widespread adoption [27]. And one of the factors that affect CTA adoption is ease of use [36]. The researchers decided to use QR code scanning as the primary tool of providing user input in the CTA. Given that the CTA would mainly be used inside different buildings in UPD, having a CTA that could identify specific rooms and buildings where infected patients have been to would be helpful in easily determining close contacts and location that should be immediately disinfected. Moreover, scanning QR codes is easier and more efficient than the traditional use of pen and paper in filling out contact tracing forms. This approach also fits well with the existing protocol for staff/faculty to fill out a health checklist when they report for work by scanning QR codes in the entrance of offices/units.

4.1.2 Accessible and Available to Majority

The researchers decided to develop a CTA in two forms: in a mobile application and a web application. The mobile application will solely be used for scanning QR codes while the web application will be used by contact tracers to view data about positive cases. The web application may also be used to scan QR codes by those whose phones do not meet the minimum operating system requirement of the mobile application. With this approach, any phone that has a camera that can scan QR codes, has a browser or an iOS or Android operating system, and can connect to the internet can use this application.

4.1.3 Accurate

In the said approach, QR codes contain relevant data in identifying the location of the QR code itself. To be more specific, it contains a unique ID of the room/entry point of a specific establishment and thus, is accurate. However, its vulnerability is when a user takes a photo of the QR code and scans this photo even if the user is not in the location specified by the QR code. Doing such will not benefit them, though, when they become classified as a close contact of an infected user. They might express annoyance when a contact tracer contacts them to verify whether they were actually in the location or not through text and/or call even though some or all of their logs are actually false.

4.1.4 Addresses Issues on Security and Privacy

Upon signing up and scanning, the only data that the application will require is their phone number verified using an SMS-enabled One Time Pin (OTP) and their chosen password. No names, addresses, email addresses, and educational information is required. Meanwhile, upon scanning the QR code, in the background, the user simply sends a POST request of its token to the server together with the unique ID of the scanned QR code and the timestamp of the scan. From this token, the user information can be derived in the server side wherein the contact number is stored in the logbook in the database. Since this application includes communication between client and server, the researchers want to ensure that the packets sent on the channel are not vulnerable to snoopers. Thus, the application will run on Hypertext Transfer Protocol Secure (HTTPS). This encrypts and decrypts the packets that are transmitted through the channel.

This application already exhibits privacy from snoopers and privacy from contacts since users have no information and interaction with other users. With regards to privacy from authority, the privacy concern of this notion is that people, specifically users, don't know how the data are handled, analyzed, and manipulated by the authority. But by letting the UPHS Contact Tracers be the only authority in this application, then this issue is already addressed. This means that only UPHS Contact Tracers can see and access the data in the application.

4.1.5 Effective

Having a centralized system is the only way of administering diagnoses properly [53]. The study of Nakamoto et al. [2020] mentions that a centralized database that accommodates infected patients is necessary on the reliability of the contact tracing system [33]. While there are privacy issues that come with having a centralized system and database, the researchers strongly believe that it is still suitable for UPD, especially that UPHS Contact Tracers still need to manually verify the patients who disclose their statuses. And in fact, this privacy issue is already addressed because only UPHS Contact Tracers are chosen to be authorities.

4.2 Implementation

The web application will be built using Angular and Bootstrap 5 for the frontend, while the mobile application will be built using React Native for the frontend.

With Bootstrap 5, the web application would be responsive and mobile-friendly. For the backend of both applications, NodeJS, Express, and MySQL will be used. Under the assumption that the Diliman Network (DilNet) can provide stable internet access across the university, both applications require an internet connection to function properly.

There are three types of users in the application. First is the HeLO who is in charge of adding the building of the office/unit they are assigned to if it is not yet in the database, and adding all rooms and entry points in that building. The next type of users corresponds to general users such as students, employees, and visitors who have to scan QR codes upon entry of buildings and rooms. Finally, the third type of users are UPHS contact tracers who access the list of the reported suspect or positive cases and the list of their possible close contacts and whereabouts. HeLOs and UPHS contact tracers may also use the application to scan QR codes just like the second type of users.

Both applications have the following main functions and features:

- **Signup/login using only phone number** - Logging in using phone numbers is available for all types of users. When users sign up, they have to provide the following information:
  - **Phone number** - This is required for all users to prevent the creation of fake accounts. A one-time password (OTP) is sent to the entered phone number and that OTP is required to be input in the application for verification.
  - **Password** - This is encrypted to offer protection against hackers.
  - **Preferred contact time** - This is asked so that UPHS contact tracers would know when patients want to be interviewed and contacted regarding their condition.
  - **Preferred way of interview** - This is asked so that UPHS contact tracers would know the method or approach preferred when interviewing the patients.
- **Scan QR code** - This allows all types of users to log their entry in each building and room in UPD at a specific time so that a list of close contacts and whereabouts can be generated in case they become (possibly) positive for COVID-19. This can be done by clicking the "Scan QR Code" button which redirects a user to the page for scanning. A user can only scan a specific QR Code once every 2 minutes.
- **Report suspect or positive case** - This allows all types of users to self-report their condition through the "I suspect to be positive" and "I tested positive" buttons.

The following features are exclusive to the web application:

- **Signup/login using phone number/Google account** - This is only available for HeLOs and UPHS contact tracers. Prior to their registration, they have to submit a list of their email addresses to the developers. They are then required to use Google sign-in when creating an account in the application in order to check whether their email address is included in the list of email addresses submitted or not, and if they are authorized to create an account either for a HeLO or for a contact tracer. Other information that they have to provide is the same as the ones listed in the bullets under "Signup/login using only phone number".
- **Add building and room** - This allows HeLOs to add buildings in UPD that are not yet in the list of pre-added buildings, and to add each room located in the building of the office/unit they are assigned to. They can also download a PDF file of all the QR codes generated for each room in a certain building which are meant to be printed and posted in rooms and entry points.
- **View and filter patients** - This allows UPHS contact tracers to see the list of the reported suspect and positive cases by clicking the "Patients" option in the navigation bar. They may filter patients by date and statuses (i.e. Suspected, Disclosed Positive, Confirmed Positive, Confirmed Negative). In the list of patients, they can view each patient's contact number, preferred contact time, preferred way of interview, status, and assigned contact tracer. Contact tracers can assign themselves to patients not yet contacted by other contact tracers, and they may filter out patients assigned to them. They can also click buttons on this page to see the patient's list of close contacts and list of whereabouts. They can change a patient's status here as well.
- **View possible close contacts** - This allows UPHS contact tracers to see the list of close contacts of each patient and export this as an Excel workbook. They can view each close contact's contact number, preferred contact time, preferred way of interview, type of exposure, and building, room and date of potential exposure here. A possible close contact is defined as someone who:
  - Was in at least one same building or room on the same day with a symptomatic patient two days prior to the onset of symptoms until the patient's disclosure date; and

  - Was in at least one same building or room on the same day with an asymptomatic patient two days prior to the patient's disclosure date until the disclosure date.
- **View whereabouts** - This allows UPHS contact tracers to see the list of whereabouts of each patient and export this as an Excel workbook. They can view each whereabout's building name, room name, and date and time of entry. The only whereabouts shown are rooms and entry points entered:
  - By a symptomatic patient two days prior to the onset of symptoms until the patient's disclosure date; or
  - By an asymptomatic patient two days prior to the patient's disclosure date until the disclosure date.
- **Search users by contact number and setting the users as positive** - This allows UPHS contact tracers to search for a specific user using their contact number and to easily find details about that user such as preferred contact time and preferred way of interview. This will also allow a contact tracer to set a user as positive in case the user was not able to self-disclose their condition.

With the use of the applications, there would be no delays in acquiring data about suspect and positive cases. This is highly important because delays can enable increased spread of the virus. Furthermore, the process of determining possible close contacts would be more accurate and would require less effort when the applications are used. Contact tracers would not need to manually determine or survey people who might have been in buildings and rooms where an infected patient went to on certain dates anymore.

Other approaches in creating CTAs only send notifications to close contacts of an infected person but that does not guarantee that close contacts would take these notifications seriously and take action. In the context of the UPD, it is still preferable that contact tracers would personally inform, assist, and monitor close contacts. In this way, close contacts can properly be guided on how to isolate and on what proper course of action is best to be done.

5 CONCLUSION

CTAs, when properly and constantly used, can help reduce the spread of COVID-19. Different countries including the Philippines use different technologies such as Bluetooth, GPS, and QR codes in their CTAs, with some being effective in reducing the spread of the virus, while others having little impact in their country's contact tracing efforts. By examining various CTAs and the privacy issues involved with them, the researchers were able to determine the appropriate approach and technology to be used in developing UPTrace, a CTA for UPD. UPTrace was fit into the context of the said community and was made while considering the needs of authorities, namely the UPHS Contact Tracers, who are directly involved in contact tracing.

UPTrace makes use of QR codes in order to provide accurate location information of visited places by infected users and to provide a list of possible close contacts without the need of personally identifiable information. In summary, UPTrace is intended to be easy to use, accessible and available to majority, accurate, addresses issues on security and privacy, and effective. However, user testing and improvement of user experience in using UPTrace are yet to be done. Once done, UPTrace may prove to be helpful in the efforts in mitigating the spread of the virus in the UPD community.

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