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# Development of a Microcontroller-Based Contact Tracing System

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***Abstract— Since the first case of Covid-19 detected in 2019, national governments pursued to implement lockdowns and contact tracing programs to minimize the spread of the disease. Most contact tracing procedures, no matter how varied from one country to another, commonly leaned towards digital methods that made use of modern technology. Such was not the case however in the Philippines as the masses are barely able to cope with the available contact tracing scheme that requires internet connectivity. Rated as one of the countries with the slowest and most expensive internet service, most of its citizens still resort to the traditional pen-and-paper approach when registering for contact tracing upon entry in establishments.***

***Guided by prototyping methodology, the research ventured in the development of a microcontroller-based contact tracing system that allows the participation of establishment visitors even without internet access. The system called ConTACTS, which is short for contact tracing using automated collection and tracking system, is made up of a deployable unit and a central database. The deployable unit was designed to be able to accept mobile number registrations of establishment visitors and transmit timestamped data to the central database. The design of the central database was aimed at its successful integration with a website to enable contact tracer access.***

***The developed deployable unit features the Arduino Nano as a central hub interfacing an LCD screen, a keypad, a buzzer, a USB adapter and a GSM module. WampServer was used to develop the central database. The system was tested in terms of the ability of the deployable unit to send a confirmation message to each establishment visitor and transmit timestamped data to the central database. The overall success rate of confirmation message sending was found to be 95.86%. The device is also immaculately able to send data to the central database in an average time of 3.15 seconds so long as the device has data access.***

***Keywords— ConTACTS, micro-controller-based, contact tracing system, Arduino Nano, deployable unit, central database***

## I. INTRODUCTION

The first case of Covid-19 was detected towards the end of 2019 in Wuhan, Hubei Province of China. Since then, the Severe Acute Respiratory Syndrome Corona Virus 2 (SARS-CoV-2) resulted in a pandemic that has infected and killed over hundreds of millions of people around the world. During the development of vaccines, the World Health Organization (WHO) urged the public to follow precautionary measures such as wearing face masks, maintaining social distancing, and applying sanitizers to contain the spread of the virus. Other steps taken by the national governments all over the world are implementation of lockdowns and contact tracing programs.

Contact tracing is the key process of slowing down the spread of SARS-CoV-2 by identifying, assessing, and managing the people who have been exposed to the disease [1]. It gives permission for authorized people to identify persons who possibly came in close contact with someone who is infected. These people are identified as “contacts” and are bound to be monitored by health authorities for fourteen (14) days. Contact tracing is a day-to-day activity whose effectiveness relies on the accuracy of data. Accurate data can drive a quicker response from authorities leading to a more efficient workflow.

 

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Although contact tracing methods vary from country to country, many have been leaning towards digital methods that take advantage of modern technology. China uses central mandatory surveillance with facial recognition and social scoring. Countries like Israel, Taiwan and South Korea make use of GPS-based systems to monitor their citizens. France, Australia, and New Zealand make use of Quick Response (QR)-based centralized applications while Italy, UK, Germany, Switzerland, and Austria utilize decentralized applications that are Bluetooth Low Energy (BLE)-based [2]. Tracking applications such as the Corona 100m in South Korea, and the StayHomeSafe in Hong Kong are being widely used to monitor locations and quarantine periods of contacts and diagnosed patients. Particularly, the StayHomeSafe app which makes use of geofencing technology is paired with a wristband to ensure seamless monitoring [3]. In Singapore, a website that displays up-to-date information of age, sex, occupation, travel history, and date of diagnosis and discharge of infected residents was developed [4]. Clearly, the initiatives and innovations from these countries were able to incorporate modern technology to help raise the effectiveness of their contact tracing.

In the Philippines, the earliest contact tracing model adopted by many of its provinces is a scheme initiated by Mayor Benjamin Magalong for Baguio City. The model embodies principles that call for the collaboration of law enforcers, investigators, and health authorities [5]. It relies on customers registering using pen and paper upon entry in establishments. Per Department of Health (DOH) Undersecretary Maria Rosario Vergeire, the registered information of customers that will be uploaded to repository systems should include customer name, address and phone number to ensure efficiency of contact tracing [6]. An example of a repository system is COVID-KAYA – an application developed by the Department of Health Epidemiology Bureau and the World Health Organization (WHO) that serves as the central repository for all data collected in relation to pandemic response [7].

As a step-up from the traditional pen-and-paper method, the Inter-Agency Task Force (IATF) issued Resolution No. 85 prescribing the use of StaySafe.ph in the Philippines on November 26, 2020 [8]. SatySafe.ph is an application that logs the entry of a customer via a scan of a QR code provided by the establishment [9].However, according to the developers, there are only approximately 8 million Filipinos who make use of the app as of January 2021, which is less than 10% of the total Philippine population [10].

Among the factors that may have contributed to the non-participation of most Filipinos in utilizing the StaySafe.ph app is the inaccessibility to reliable internet connection. Since the app collects data from users via the internet, many establishments resort to the traditional pen-and-paper approach due to their inability to provide a decent internet connection for their customers. Among all countries, the Philippines ranks 82nd in terms of internet service affordability, and 77th in terms of connection efficiency [11]. Mobile data is the cheapest internet connectivity option in the country, which even the general population can barely afford. This became the motivation for the development of a contact tracing device that does not require participants to have internet connection.

The device is called ConTACTS which stands for Contact Tracing Using Automated Collection and Tracking System. The system mainly consists of two (2) parts, namely: (i) the deployable unit, which is distributed and installed to each of the participating establishments, and (ii) the database which serves as the repository of data that may be accessed by authorized contact tracers. A person who enters an establishment that uses ConTACTS is required to input his/her cellphone number to the main unit. After a successful key-in, the device sends a confirmation message to the cellphone of the user via Short Message Service (SMS) and timestamps the data. The confirmation message can be used to validate the correctness of the cellphone number that was entered to the device. It is also exported to the database via the internet. Although an internet connection is still required for the main unit to transmit information, the customers are now exempted from this requirement. The acquisition and transmission of data by the deployable units are made possible with the use of a microcontroller – the main component used by the deployable units which acts like a miniature computer able to store and process data according to instructions given to it.

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## II. METHODS

Guided by Prototyping Methodology, bringing ConTACTS into fruition was a product of system implementation involving Objective Identification, Development, Refinement, Demonstration, Testing and Implementation.

*Objective Identification*

Coming up with a contact tracing system that will not require its participants to have an internet connection is beneficial for a country like the Philippines. There was already a potential for Global System for Mobile Communications (GSM) to be considered as an alternative channel for data transfer for contact tracing as most Filipinos own a mobile phone. GSM is the fundamental technology for communication of mobile phones. Considering this, the challenge therefore was to come up with a contact tracing system that mainly takes advantage of GSM, a technology that is already accessible to most Filipinos, to increase participation from the general population.

*Development*

Navigating towards the realization of ConTACTS necessitated the development of its two (2) subsystems – the deployable unit and the database. The development of the deployable unit was focused towards enabling the device to log the mobile number and other details relative to the establishment visit of a customer to the central database. Achieving this function required proper interfacing of peripherals to a microcontroller fed with appropriate instructions. The database was primarily developed to enable the acceptance and storage of transmitted data from the deployable unit. In addition, the assurance that the database can easily be accessed by authorized contact tracers warranted a user-friendly interface.

*Refinement*

The development of the deployable unit imposed device iterations, mostly aimed at component compatibility. A series of decisions had to be made relative to the choice of components, with the finalization of the mode of data transfer being the most critical. The device was originally designed to house a Wi-Fi module that will allow data transmission to the central database. However, dry runs revealed that the module was unable to receive sufficient power from the microcontroller. This was understandable as the microcontroller is already interfacing several peripherals other than the Wi-Fi module. The remedy was to enable communication between the deployable unit and the database via cellular data, and this was attained using the GSM module.

*Demonstration, Testing and Implementation*

The deployable units were installed in ten (10) participating establishments located in La Trinidad, Benguet. The key personnel assigned to the units were trained on how to operate the device so that they can properly instruct and assist the people who enter these establishments. This was done through a series of lectures and demonstrations prior to the actual start of implementation.

The effectiveness of data transmission was the ultimate litmus test to validate the core functionality of ConTACTS. The capability of the device to send confirmation messages to the visitors was tested simultaneous with the implementation phase to take into consideration the factors influential to the success or failure of transmission. This was done through data collection over a period of one (1) month across all participating establishments. The data gathering took place by tallying the number of mobile number entries against the number of instances that visitors were able to receive the confirmation message. The device was also tested in terms of its ability to forward to the central database timestamped information relative to establishment visitations. This was done concurrent with the development of the database. The experiment used five (5) test units and twelve (12) SIM cards from four (4) different network service providers. Five (5) trials were performed for each combination of SIM card and test unit, resulting to a total of three hundred (300) trials. Using the time stamps, the difference between the sending and receiving times was obtained for each trial.

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## III. RESULTS AND DISCUSSION

*The Deployable Unit*

To achieve the identified objectives, deployable units were developed such that each unit features an interconnection of six (6) components mounted on an acrylic sheet circuit board. Fig. 1 shows a simple layout of how the components are interfaced with the Microcontroller Board as the central hub. The Microcontroller Board is powered through the Universal Serial (USB) Micro-B to Dual In-line Package (DIP) Adapter Board. The Passive Buzzer provides auditory feedback while the Liquid Crystal Display (LCD) is responsible for displaying visual prompts. The GSM Module makes it possible for ConTACTS to take advantage of GSM technology to send confirmation messages and timestamped information to establishment visitor and the central database, respectively.

The link between the peripherals and the Microcontroller Board is provided by the acrylic sheet circuit board. The components mounted on the acrylic sheet are housed in an acrylic casing forming a rectangular cube. An external antenna is affixed outside the left surface of the casing for improved signal reception. The left surface also contains a port opening for the insertion of Subscriber Identification Module (SIM) Card into the GSM Module. The right-side surface contains a port opening for inserting USB Micro-B into the USB Micro-B DIP Adapter Board. The LCD is secured at the top surface. An example of a fully assembled deployable unit is shown in Fig. 2.

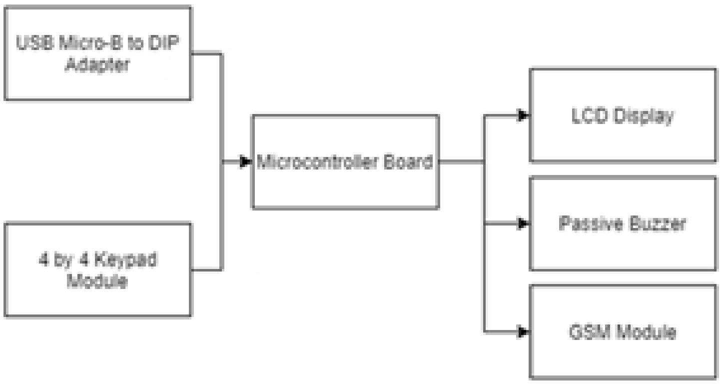


Fig. 1. Component Layout for the main unit. The microcontroller board interfaces input and output components, seen at the left and right portions, respectively.

With due consideration of market availability, product affordability and component compatibility, the units were assembled using the specific component models enumerated in Table 1. The programming of the microcontroller was done using the downloadable Arduino software.

The microcontroller program is divided into three (3) sequences, namely: (i) device initialization, (ii) mobile number collection and (iii) data transmission. In the device initialization, the microcontroller dwells in a loop state while constantly checking for GSM connectivity. The presence of signal places the device into a new state that allows it to proceed to the next sequence. In the mobile number collection sequence, the device is queued to accept digits corresponding to the mobile number of the visitor. The number entered by the visitor via the keypad will be validated in terms of its number of digits. If it is not equal to eleven (11), the visitor will be prompted to enter his mobile number again. Else, the mobile number will be displayed on the LCD with a message asking the visitor to confirm its correctness. Once the visitor affirms, the data is sent to the central database, along with the date and time when it was collected, the device ID of the unit used, and the corresponding visitor count.

 

TABLE I
SPECIFIC MODEL OF EACH OF THE COMPONENTS USED TO ASSEMBLE THE DEPLOYABLE UNITS

| Component | Specific Model |
|---|---|
| Microcontroller | Arduino Nano |
| LCD Display | LCD I2C |
| Keypad | Generic Membrane Keypad Module |
| GSM Module | SIM800L |
| USB Adapter | Generic USB Micro-B to DIP Adapter |
| Buzzer | Generic Passive Buzzer Module |

*The Central Database*

The design of the database mainly aimed at its successful integration with a website, to enable contact tracer access. This was done using WampServer, a web development software for Windows. Its phpMyAdmin feature became the primary tool for integration of database with the web application. The creation of tables was done using its graphical user interface tool while the Structured Query Language (SQL) feature was utilized to enable the incorporation of SQL statements for back-end instructions.

Authorized contact tracers will be able to access the website via their login credentials. The user will be greeted with the Message Table shown in Fig. 3, one of the five (5) tables featured by the website. This table contains timestamps, mobile number, device id and visitor count among others for each establishment visitor. The other tables can be viewed using the navigation bar. Account credentials and information of administrators and contact tracers can be found in the Accounts Table. The Locations Table and Device Info Table on the other hand both contain information relative to device deployment location, with the former showing the city/municipality, barangay, and street, while the latter specifying the establishment name, as well as the device latitude, longitude, and mobile number. The Owner Table presents the names, addresses and contact numbers of the establishment owners.

*Test Results*

Table 2 shows the summary of SMS transmission count gathered over a period of one (1) month across all participating establishments. The results show a success rate that is consistently above 80% on all devices, with 81.9% being the lowest and 98.7% being the highest. While the discrepancy between the total number of mobile entries and the total number of visitors who received the confirmation message may suggest device instability, it is also noteworthy to consider realistic factors which came into play during the implementation phase. One factor was the mobile device connectivity of each visitor as communication between mobile devices require both sending and receiving parties to be within network reach. For instance, it is possible that some of the visitors were using a SIM card that had poor network coverage where the unit was deployed. There were also cases when the unit did not have sufficient load to send a confirmation message. Another common feedback referred to occasions when there was no assistance of any form provided by the host establishment relative to how the unit should be operated. The overall success rate is 95.86%.

TABLE III
SPECIFIC MODEL OF EACH OF THE COMPONENTS USED TO ASSEMBLE THE DEPLOYABLE UNITS

| Device No. | Establishment Name | Total Mobile Number Entries | Total No. of Visitors who received confirmation | Success rate (%) |
|---|---|---|---|---|
| 1 | Justice Hall | 888 | 900 | 98.7 |
| 2 | DOST CAR | 782 | 797 | 98.1 |
| 3 | Municipal Hall | 459 | 474 | 96.8 |
| 4 | Xhyrilord Pharmacy | 243 | 274 | 88.7 |
| 5 | 7th Floor Cafe | 190 | 200 | 95 |
| 6 | The Vibe Prjct | 156 | 168 | 92.9 |
| 7 | Epiphany Clinic | 133 | 140 | 95 |
| 8 | Mylk Tea | 104 | 127 | 81.9 |
| 9 | Balili Barangay Hall | 117 | 126 | 92.9 |
| 10 | Cafe Kzar, KM. 5 | 87 | 100 | 87 |

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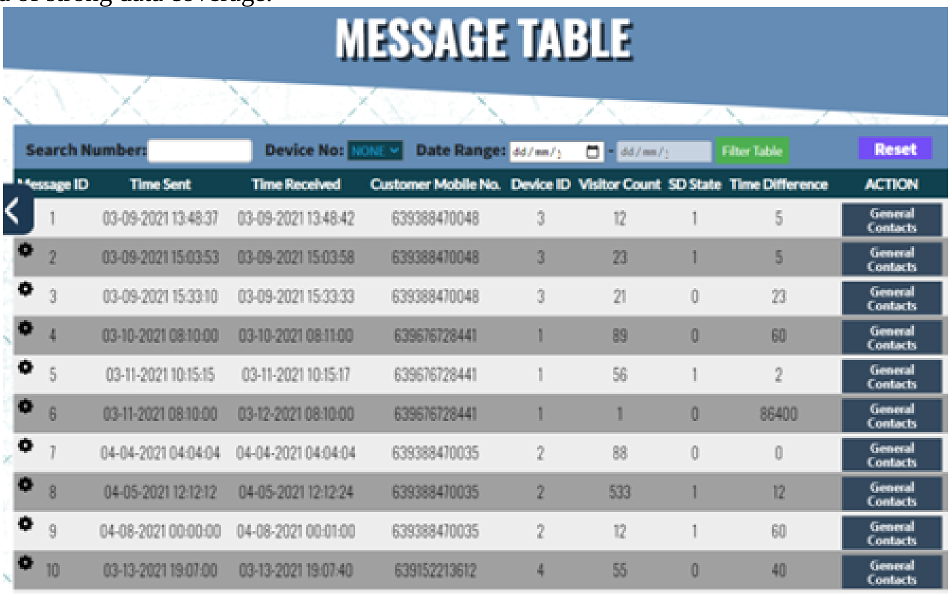
Results of the tests conducted to determine the ability of the device to transmit data to the central database revealed no issues as the database was always able to receive all three hundred (300) information lines sent with the three hundred (300) conducted trials. The largest difference between the sending and receiving times was 9 seconds, while the lowest was 1 second, and the mean was 3.15 seconds. It should be noted that the tests were done in a location where data coverage is strong for all the four (4) network service providers. This suggests that the developed deployable unit is capable of transferring data to the central database provided that it is situated within an area of strong data coverage.



MESSAGE TABLE

Search Number: Device No: NONE Date Range: dd/mm/ - dd/mm/ Filter Table Reset

| Message ID | Time Sent | Time Received | Customer Mobile No. | Device ID | Visitor Count | SD State | Time Difference | ACTION |
|---|---|---|---|---|---|---|---|---|
| 1 | 03-09-2021 13:48:37 | 03-09-2021 13:48:42 | 639388470048 | 3 | 12 | 1 | 5 | General Contacts |
| 2 | 03-09-2021 15:03:53 | 03-09-2021 15:03:58 | 639388470048 | 3 | 23 | 1 | 5 | General Contacts |
| 3 | 03-09-2021 15:33:10 | 03-09-2021 15:33:33 | 639388470048 | 3 | 21 | 0 | 23 | General Contacts |
| 4 | 03-10-2021 08:10:00 | 03-10-2021 08:11:00 | 639676728441 | 1 | 89 | 0 | 60 | General Contacts |
| 5 | 03-11-2021 10:15:15 | 03-11-2021 10:15:17 | 639676728441 | 1 | 56 | 1 | 2 | General Contacts |
| 6 | 03-11-2021 08:10:00 | 03-12-2021 08:10:00 | 639676728441 | 1 | 1 | 0 | 86400 | General Contacts |
| 7 | 04-04-2021 04:04:04 | 04-04-2021 04:04:04 | 639388470035 | 2 | 88 | 0 | 0 | General Contacts |
| 8 | 04-05-2021 12:12:12 | 04-05-2021 12:12:24 | 639388470035 | 2 | 533 | 1 | 12 | General Contacts |
| 9 | 04-08-2021 00:00:00 | 04-08-2021 00:01:00 | 639388470035 | 2 | 12 | 1 | 60 | General Contacts |
| 10 | 03-13-2021 19:07:00 | 03-13-2021 19:07:40 | 639152213612 | 4 | 55 | 0 | 40 | General Contacts |

Fig. 2. Website message table

## IV. Conclusions

In conclusion, the study successfully developed a deployable unit and central database system for contact tracing purposes. The deployable unit consists of six components mounted on an acrylic sheet circuit board, with the microcontroller board as the central hub. It utilizes peripherals such as the LCD, GSM module, and passive buzzer to provide visual and auditory feedback and enable SMS transmission to the central database.

The central database was designed for integration with a website, allowing authorized contact tracers to access visitor information. Tables were created using WampServer and phpMyAdmin, with SQL statements for backend instructions. The website featured tables such as the Message Table, Accounts Table, Locations Table, Device Info Table, and Owner Table, providing comprehensive data on visitors and establishments.

Test results showed a consistent success rate above 80% for SMS transmission, with factors like poor network coverage and lack of operational support affecting the discrepancy between mobile entries and confirmation messages received. The overall success rate for SMS transmission was 95.86%. Data transmission to the central database was successful, with no issues encountered during tests, indicating the unit's capability to transfer data in areas with strong data coverage.

In summary, the developed deployable unit and central database system demonstrated effectiveness in contact tracing, providing reliable SMS transmission and data transfer capabilities. Enhancements can be made by considering network coverage and providing operational support from establishments.

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