ICIC Express Letters
Volume **15**, Number **6**, June **2021**

 ISSN 1881-803X
pp. **595–603**

ADAPTIVE DESIGN OF TWO-PHASE QUICK RESPONSE CODES FOR CONTACT TRACING AND SURVEILLANCE APPLICATION: A CASE STUDY OF COVID-19

Jaruwat Pailai[1,*], Warunya Wunnasri[2], Siriporn Sansri[1] and Manit Chaipayuan[3]

[1]Department of Computer and Information Science
Faculty of Science and Engineering
Kasetsart University
59/5 Moo1 Chiangkrua, Muang, Sakon Nakhon 47000, Thailand
[*]Corresponding author: jaruwat.pa@ku.th; siriporn.san@ku.th

[2]Department of Computer Science
Faculty of Science
Khon Kaen University
123 Moo 16, Mittraphap Road, Nai-Muang, Muang, Khon Kaen 40002, Thailand
waruwu@kku.ac.th

[3]Sakon Nakhon Provincial Public Health Office
1859 Soonrajchakan Road, Tatchungchoom, Muang, Sakon Nakhon 47000, Thailand
offside49@hotmail.com

Received October 2020; accepted January 2021

Abstract. *The contact tracing aims to identify all potential contacts of the infection, while the surveillance is utilized to track and monitor the local quarantined individuals. This paper proposes an adaptive design of quick response codes that integrate the contact tracing and surveillance into two phases. The aim is to prevent the COVID-19 outbreak in Sakon Nakhon by providing the local quarantine information, which the public health staff investigated. Especially, the primary policy of the local public health office is to prevent the spread of infection to public health officers. The quick response codes were applied to identifying the locations and representing visitor's identification information through an electronic ticket (e-ticket). The frontline inspector can examine the local quarantine status of the visitor by scanning the e-ticket immediately. A million local quarantine information records were classified into four statuses. Each status was illustrated by the color code with its suggestion as the useful information to the inspector with contactless activity. This proposal's primary goal is to prevent the infection of public health workers by providing crucial information with touchless interaction. The preliminary use interval time demonstrates that most of the interaction time from contact tracing task to surveillance task can be completed in 30 seconds.*
Keywords: COVID-19, Contact tracing, Surveillance, Quick response codes

1. **Introduction.** The contact tracing aims to identify all potential contacts of the person when s/he is identified as an infected individual. The objective is to interrupt ongoing transmission and reduce the spread of infection. The notification will be sent to all potential contacts of the infected individual for early care and self-isolate. The information of all potential contacts should be provided to the local public health officers who have to periodically follow up them for the symptoms and test illness [1]. On the other hand, the surveillance concept is to monitor and provide the local quarantine information to the local public health officers. The surveillance holds an important role in monitoring the progress of the spread of infection [2]. The monitoring of quarantined individuals is also

DOI: 10.24507/icicel.15.06.595

necessary for tracking them in public areas. However, the contact tracing avoids using personally identifiable information (PII), but the surveillance application requires the PII in its identification and monitoring processes.

The Thai public applications for contact tracing and surveillance were developed separately, for example, ThaiChana was implemented for contact tracing without surveillance. Thus, the frontline workers cannot access the visitors' quarantine status and cannot distinguish the quarantined individual from the others. In this paper, the integration of contact tracing and surveillance is proposed as the two-phase quick response (QR) codes. The primary goal is preventing the infection of public health worker by providing the useful information with contactless activity. The system architecture was designed with concern about security and privacy via generating the pseudo-number for exchanging information. The e-ticket is applied as visitor identification in contactless activity, which is one strategy of physical distancing to reduce the risk of infection between the frontline workers and the visitors.

This paper's remaining details are organized as follows. Section 2 reviews related works of the contact tracing and surveillance implementation. The specific requirement of the local public health office is also demonstrated in this section. Section 3 describes the two-phase QR codes with distributed databases design, while Section 4 and Section 5 are the preliminary use result and its discussion, respectively. Finally, the conclusion is presented in Section 6.

2. **Related Works.**

Many contact tracing applications were implemented with several techniques and concerns of data privacy based on each specific environment and specific limitations. This section presents the implementation of contact tracing and surveillance applications. The requirement and limitations of this work are described in this section.

2.1. **Contact tracing and surveillance implementation.**

2.1.1. *Contact tracing application.* The contact tracing is the identification process of the persons who may have contacted the infected individual and subsequent collection of further information about their contacts. Several techniques are applied to developing the contact tracing for collecting the user information such as QR codes, Bluetooth, GPS, WIFI based, and combination of them with centralized and decentralized databases regarding each purpose [3-6]. However, tracing apps have generated much discussion around their key attributes, including system architecture, data management, privacy, security, proximity estimation, and attack vulnerability [7]. The tracking and traceability system was also utilized to detect any serious outbreaks of disease early in several domains, such as using the livestock iris code in the food safety domain [8]. Physical distancing is an important strategy to limit the potential spread of COVID-19, which utilizes the technology for creating the activities without direct touching with any people or surfaces. For example, Bluetooth technology was applied to controling the disinfection robot [9].

2.1.2. *Surveillance application.* The surveillance's definition in the public health domain is the ongoing, systematic collection, analysis, interpretation, and dissemination of data about a health-related event for using in public health action to reduce morbidity and mortality and improve health [10]. Several sorts of information are required to develop surveillance for a specific problem in the local area [11]. Firstly, the objectives of surveillance should be specified clearly, which will affect the source of data. The more precise the goals are, the more significant the data source can be defined. Next is to determine the methods following the objectives, such as the order of resources, which should be reviewed [12], and which the attributes that should be paid the most attention [13].

The examples of private applications in Thailand are DDC COVID-19, COSTE, and DDC-Care for contact tracing of the infected individual and epidemiologic investigation

[14], while the public applications are also available such as MorChana for mobile-based contact tracing [15], and ThaiChana for location-based with QR codes [16]. However, these applications are able to trace the contact of the infected visitor after his/her infection was confirmed from the epidemiologic investigation. The local quarantine information is useful information that can be provided to the frontline workers who have responsibilities to scanning symptoms and measuring temperature of the visitors. Thus, the adaptive design of two-phase quick response codes aims to integrate both contact tracing and surveillance application where the visitor's visited location was collected, and the visitor's quarantine status was informed to the frontline worker. Moreover, the local quarantine information of this proposed application was investigated by the public health staff differently from self-reporting in the other applications. The encrypted pseudo-number is utilized in the contact tracing phase for preventing random access, which is different from ThaiChana where the location parameter can be random by increasing the shop identification.

2.2. **The local public health office requirement and limitation.** In response to the COVID-19 pandemic, the Sakon Nakhon public health office aims to prevent infection spread to public health officers who are the frontline workers. There are three primary objectives as the following: 1) the ongoing investigation of the local quarantine information (also known as knocking the door project by the village health volunteers); 2) zero death due to the COVID-19 coronavirus; and 3) the non-infection of indirect contact through public health worker. Moreover, the application should be compatible with the general smartphone that means the application does not require additional or special devices. This is a limitation of the application designing for reducing the cost when using the application in many locations.

Accordingly, a proactive policy is the investigating quarantine information. The cooperation between the village health volunteers and the public health officers can gather a million quarantine information records from 18 districts regarding the first primary objective. However, the local quarantine information was not utilized to prevent infection spread to public health officers. This paper proposes two-phase quick response codes for encouraging the remaining primary objectives, which is the cooperation between the academic and the public health office.

3. **The Two-Phase Quick Response Codes.** The cooperation and exchange of information are described in this section. Many operations were conducted by the collaboration between Sakon Nakhon Provincial Health Office (SKHO) and Kasetsart University, Chalermphrakiat Sakonnakhon Province Campus (KUCSC). The application is deployed on the KUCSC server, where the contact tracing information is also stored in KUCSC database. On the other hand, the quarantine information is investigated and collected in the SKHO database.

The exchange of information between KUCSC and SKHO contains the identification data and the local quarantine information by requesting web application programming interfaces in the SKHO server. Figure 1 demonstrates the design of contact tracing and surveillance application using two-phase QR codes with distributed databases.

3.1. **Local quarantine information.** The local public health office takes responsibility to investigate personal health information and monitor the movement of people in their area during the outbreak of the COVID-19 pandemic. "Thailand's village health volunteers are unsung heroes, working to support the prevention, detection and reporting of COVID-19" [17]. The SKHO is the local public health office in this context which can gather and store a million quarantine information records from 18 districts in Sakon Nakhon province.

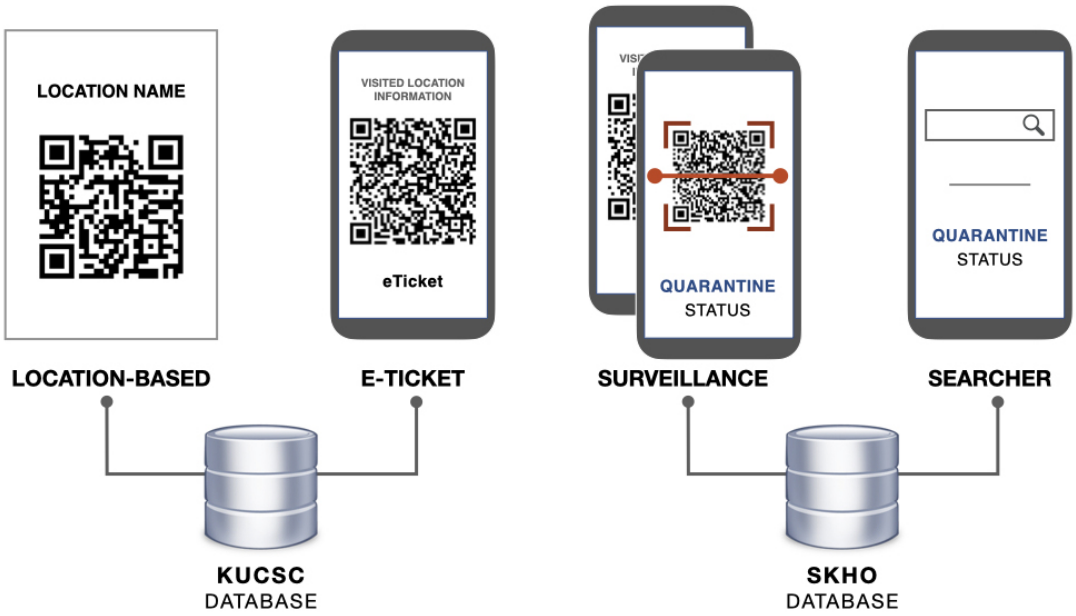

FIGURE 1. An adaptive of two-phase QR codes design with distributed databases

The four statuses of the local quarantine information are defined by using the color code as the following. The red status is assigned the quarantined individual who comes from the high-risk states or high-risk province. Concurrently, the yellow status is assigned to direct contact of the quarantined individual, such as everyone who lives in the quarantined individual's house. The green status is assigned to contactless of the quarantined individual, and the gray status is used for representing an uninvestigated visitor by the village health volunteers or the public health officers. This quarantine information was stored in the local health organization server under the ministry of public health working.

3.2. **User roles.** Even the contact tracing phase and surveillance phase were integrated into this proposed application, the roles of users are separated into two groups regarding their activity on this application to prevent accessing sensitive personal health information. The general user role is able to use the contact tracing phase for tracing his/her visited locations and generating his/her e-ticket to identify the user identity with the current location and visited time. On the other hand, a frontline worker role can access the quarantine information in the surveillance phase by scanning the visitor's e-ticket, and also can use the contact tracing phase as same as the visitor in the general user role.

3.3. **Contact tracing phase.** This proposed application consists of the contact tracing phase and surveillance phase, which these phases were implemented on distributed databases. In the contact tracing phase, identification data comprise a user identification, a location identification, and a scanning timestamp as a visited timestamp of each location. The national identification number is required for the registration as PII, and then a pseudo-number is generated to represent the visitor identification. On the other hand, a pseudo-number of each registered location is generated after the location registration process. The pseudo-number is also utilized to create the QR code as the location identification. The technical details of this step are thoroughly described later in Section 3.5, the exchanging information.

Subsequently, the movement of each person can be traced by scanning location identification in the form of the location's QR code. Visitors are the users who scanned the location's QR code using their device, while the visited location and timestamp are collected in this step. Simultaneously, the visitor's pseudo-number is applied with the scanned location's pseudo-number and the scanned timestamp for generating the e-ticket.

The example of an e-ticket is shown in Figure 1, in which the identification data were embedded in this contact tracing phase.

The remaining process of contact tracing is to trace the contact when finding an infected individual. The contacted infected individual identification is an offline process by using all infected individual's visited locations and its timestamp for identifying the direct contact of the infected individual. Moreover, the contact tracing of those direct contact infected individual is also possible with the visited locations and its timestamp of them. These processes will be executed when the epidemiologic investigation is requested. The contact tracing phase is available for the general user role, which this contact tracing design can be operated standalone without the surveillance phase. The visitors can trace their visited location via scanning the location's QR code.

3.4. **Surveillance phase.** The surveillance phase is integrated into this application for utilizing the local quarantine information. The aim is to inform each visitor's quarantine status to the inspectors, such as public health workers, village health volunteers, and nurses. The frontline worker role of the surveillance phases is assigned to the inspector who was approved by SKHO. The first task of the inspectors in this surveillance phase is tracing themselves and registering their working location. The inspectors have to scan a location's QR code to trace their visited location and simultaneously register their surveillance location. Afterward, the inspector can use the application to examine the visitor's quarantine information by scanning their QR code. The application verifies the current location between the inspector and the visitor which should be the same place by matching their pseudo-code numbers. The application also checks the timestamp of the e-ticket that should be generated in less than an hour.

A quarantine status of the visitor is displayed on a screen of the inspector's device after verifying the e-ticket. The location information and the visitor information also appear together. Figure 2 demonstrates examples of the inspector's screen after scanning the visitor's e-ticket. The suggestion of each status comprises the COVID-19 related recommendation from the Department of Disease Control (DDC) and the contact of SKHO. Moreover, the inspector can examine a visitor status by searching his/her national identification number. These surveillance processes are the exchange quarantine information between KUCSC and SKHO.

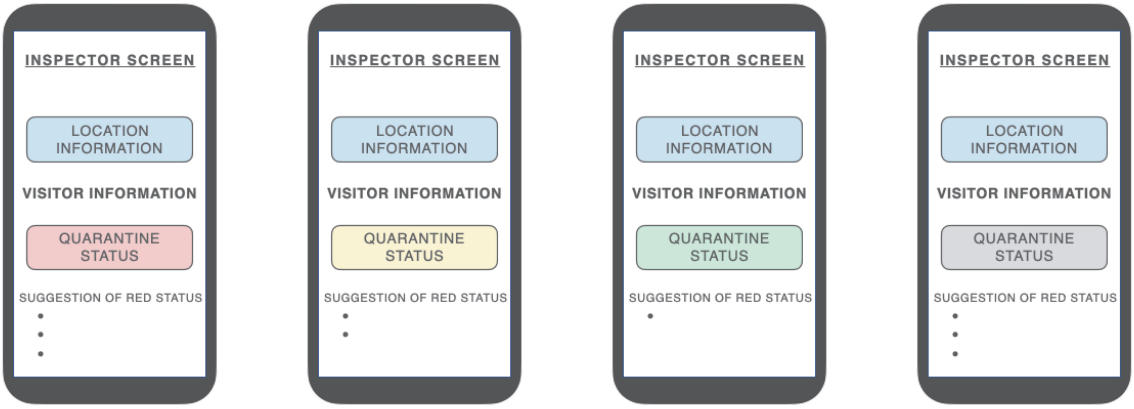

FIGURE 2. The examples of an inspector's screen after scanning the e-ticket

3.5. **Exchanging information.** The contact tracing phase avoids to use PII by generating pseudo-number to represent user identification and location identification. These pseudo-numbers were encrypted and utilized to create the e-ticket to exchange the identification information from the visitor to the inspector. The inspector has informed only

the local quarantine status without visitor's PII and other health information after scanning his/her e-ticket. In other words, the embedded data in the e-ticket consists of a set of encrypted pseudo-number that includes encrypted pseudo-number of visitor and visited location. Another embedded data is a scanned timestamp for verifying the timing of visiting. Thus, the inspector cannot access the PII and other health information of each visitor from the e-ticket of this proposed application.

Another exchange of information is the cooperation between SKHO and KUCSC for informing the local quarantine status to the inspector after scanning the visitor's e-ticket. The web application programming interfaces (APIs) were developed for exchanging the essential information. The application was deployed on the KUCSC server and will send the requests to API on the SKHO server. There are two information exchanges between these servers as shown in Figure 3: 1) a verification task is required for all inspectors while entering to surveillance phase; 2) a surveillance task is sending the PII of a visitor after scanning the e-ticket. The response data of the SKHO server is only the code number that the application will retrieve the meaning of the response code on the KUCSC server.

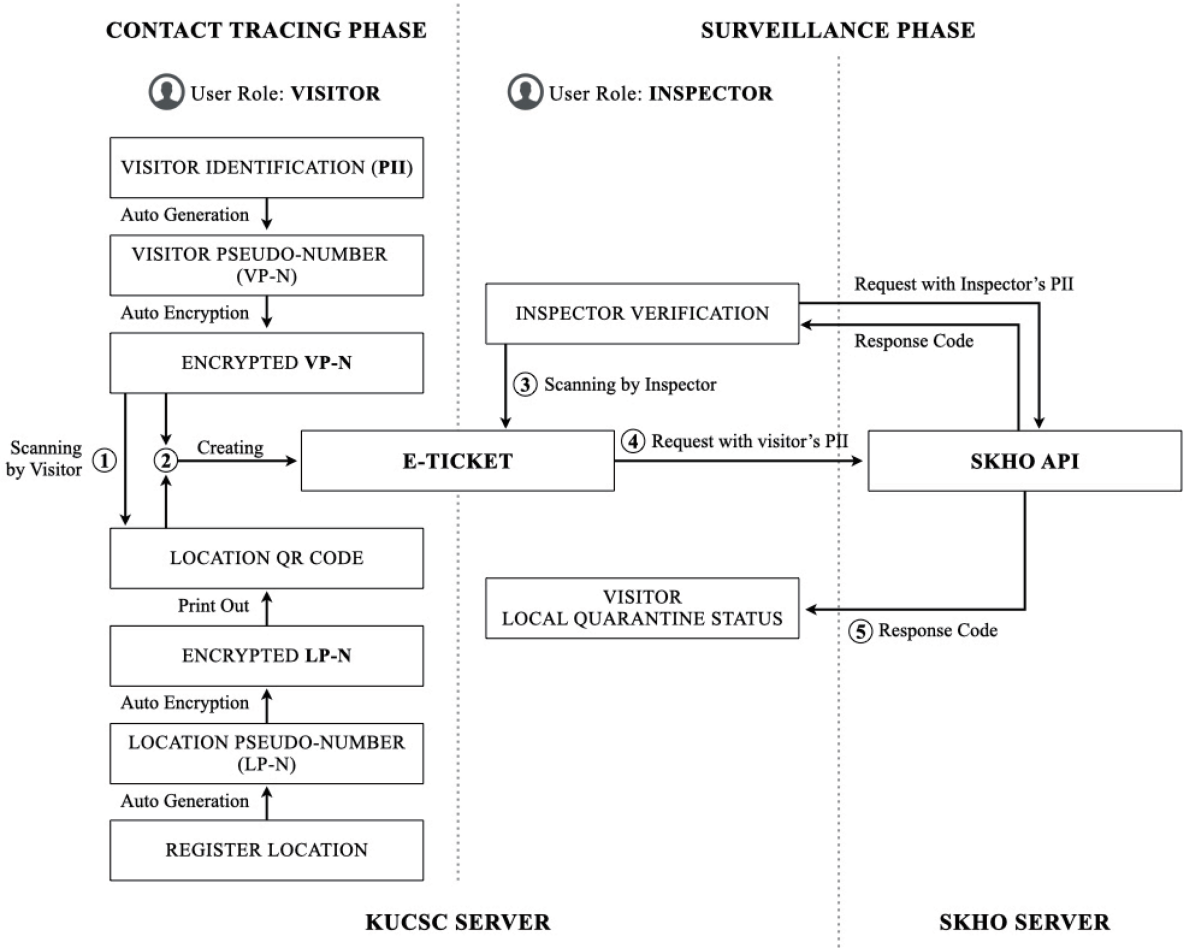

FIGURE 3. The exchange of information in each phase

Figure 3 demonstrates the exchange of information in each phase. The information exchanging between the visitor and the inspector is designed with touchless interaction to prevent the spreading of COVID-19. The encrypted visitor pseudo-number was created from the visitor's PII to represent the visitor's identification. Meanwhile, the encrypted registered location's pseudo-number is utilized for creating the location's QR code as location identification. The e-ticket is generated after the visitor scanned the location's QR, as demonstrated with number ① and number ② in Figure 3. The exchange of information between the visitor and the inspector will be completed after the inspector

scanned the visitor's e-ticket, as demonstrated with number ③ in Figure 3. Afterward, the application on the KUCSC server sends the request to SKHO API for retrieving the quarantined status code of the visitor, as shown as number ④ in Figure 3. The application displays the meaning of the response quarantined status code from number ⑤ in Figure 3 with its related DDC recommendation.

4. **Preliminary Use.** A preliminary use of two-phase QR codes with distributed databases was conducted for illustrating potential of the application. The first activity is scanning the location's QR code of visitors for getting their e-ticket. Subsequently, the frontline workers have to scan symptoms and measure temperature regularly. An additional task of the frontline worker is scanning the e-ticket of visitors, which the frontline worker will be the inspector in this second activity. These activities are a general procedure to use two-phase QR codes. Three different location types cooperated in this preliminary use, which include hospital, public health office, and academic. However, some data without PII and visitor's health information is presented in this paper due to the data privacy policy. The preliminary use result illustrates the contact tracing phase of 2,612 visitors of the academic area in five days. The surveillance phase result shows 74.27% of e-ticket utilization, while 25.73% were examined via the searching method.

Furthermore, the interval time between the QR code location scanning of the visitor and the e-ticket scanning of the inspector is observed as demonstrated in Figure 4. The mode of interval time is less than 30 seconds that means most of the contact tracing and surveillance processes can be completed within 30 seconds via the two-phase QR codes with distributed databases. Even the use of the application is an additional activity from scanning symptoms and measuring temperature processes at each checkpoint, all activities can be completed in a short time. In addition, the head of public health officer can monitor only the number of visitor and the number of each status without PII in the application.

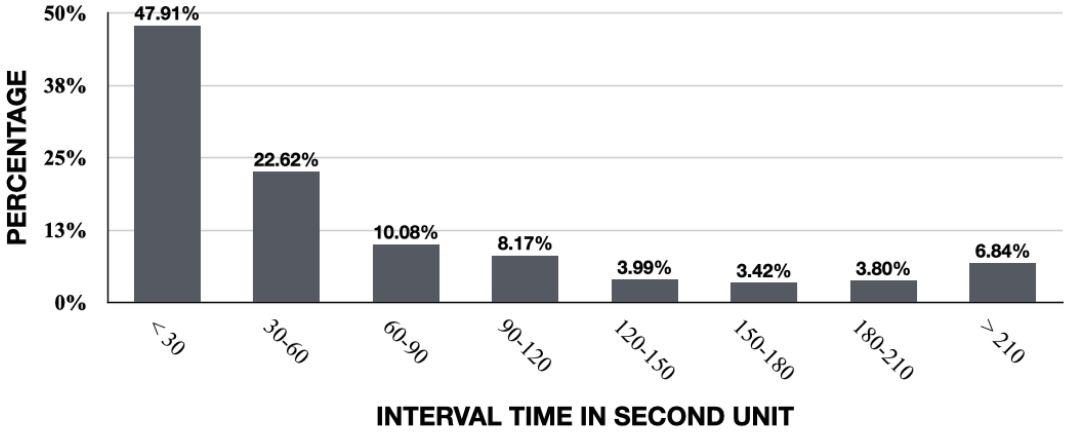

FIGURE 4. The interval time between location's QR code scanning and e-ticket scanning

5. **Discussion.** The local quarantine information is crucial information that can be utilized for preventing the COVID-19 outbreak in Sakon Nakhon. The cooperation was conducted to respond to the remaining primary objectives, including zero death due to the COVID-19 coronavirus and the non-infection of indirect contact through public health workers. However, there are several points to the concern about data privacy, such as the required data contrast of contact tracing and surveillance, which was mentioned before in the introduction section. Thus, the encrypted pseudo-number can be used in the contact tracing phase, while the PII is essential information in the surveillance phase. There is one

additional concern about providing sensitive personal health information. It is possible to immediately display the quarantine status on the visitor's screen, but it might spread panic about COVID-19. Accordingly, this proposed application informs the quarantine status on the inspector's screen only.

The integration of gaining contact tracing information and providing local quarantine status is different from available public applications for Thai. For example, the ThaiChana is majorly used as the contact tracing application for the visitors but cannot provide the quarantine information to the frontline workers. The location parameter of ThaiChana is the shop identification number without encryption. On the other hand, the quarantine information of people around the user can be accessed using the MorChana, but the quarantine information is gathered by self-reporting. The two-phase QR code for contact tracing and surveillance application is designed to prevent public health workers' infection by using the local quarantine information, which the village health volunteers or the public health officers investigated. All parameters in this proposed application were encrypted for information security.

There is one more substantial advantage of the two-phase QR code for contact tracing and surveillance application, which supports the protection of epidemic tasks over the checking-in by scanning the QR code, which is the primary method for regular tracking people's locations. The interval time demonstrates that most of the interaction time can be completed in 30 seconds. In this short time, all necessary information (user-, location-, timestamp-information) is tracked and collected for supporting the surveillance procedure in the future. Besides, the quarantine status, which the application displays, helps the on-site workers deal with surveillance at that current time. Especially, the frontline workers have to treat or take care of the patients or even the workers who have to scan symptoms and measure temperature. The quarantine information can encourage them to treat the people carefully. On the other hand, the exchange of information can inform the public health worker about the people who did not complete their 14 days self-quarantine. The public health officers can monitor them and investigate why the refusal to cooperate with mandatory self-quarantine.

During the preliminary use, there are misunderstandings of mandatory self-quarantine for 14 days in some groups of people. Typically, visitors who have red status during operation are people from high-risk states or high-risk provinces. Nevertheless, the public health worker reported that some people who belong to red status thought they had already completed 14 days of quarantine. Another situation is the yellow status identified. The people who have yellow status said that they did not come from the high-risk province, which means they thought they are not necessary to self-quarantine. However, the yellow status is assigned to a direct contact person and everyone who lives in the same house with the red status person. Following these situations, the surveillance phase can check the visitors' quarantine status who might misunderstand their quarantine status and helps the workers protect against the epidemic.

6. **Conclusion.** We proposed the two-phase QR codes with distributed databases. The contact tracing can be utilized whenever the SKHO requests an epidemiologic investigation. The proposed concept of this application is not only able to trace the contacts of an infected individual but is also utilized to prevent the spread of COVID-19. In addition, the application can provide the information for monitoring the local quarantined individuals. Many operations were conducted from the cooperation between KUCSC and SKHO regarding the COVID-19 pandemic. The encrypted pseudo-number was utilized in the contact tracing phase for generating the e-ticket. Furthermore, the preliminary use illustrates that the two-phase QR codes with a distributed database is the promising method to exchange the information with touchless interaction within 30 seconds. The

exchange of information was developed for retrieving the quarantine status of each visitor, which is an alternative method to apply for utilizing the existing data.

Acknowledgment. This work was supported by Faculty of Science and Engineering and Sakon Nakhon Provincial Public Health Office. We also appreciate the help of the persons-in-charge who cooperated in this work for keeping people safe.

REFERENCES

[1] WHO TEAM, *Department of Communications, What Is Contact Tracing and Why Is It Important?*, http://who.int/news-room/q-a-detail/contact-tracing, Accessed in September 2020.
[2] A. W. Hampson, Surveillance for pandemic influenza, *Journal of Infectious Diseases*, vol.176, no.Supplement 1, pp.8-13, 1997.
[3] F. Lucivero, N. Hallowell, S. Johnson, B. Prainsack, G. Samuel and T. Sharon, COVID-19 and contact tracing apps: Ethical challenges for a social experiment on a global scale, *Journal of Bioethical Inquiry*, pp.1-5, 2020.
[4] M. Cunche, A. Boutet, C. Castelluccia, C. Lauradoux and V. Roca, *On Using Bluetooth-Low-Energy for Contact Tracing*, Research Report, Inria Grenoble Rhône-Alpes, INSA de Lyon, 2020.
[5] M. Paul, Z. Raymond and K. Aaron, In coronavirus fight, China gives citizens a color code, with red flags, *New York Times*, https://www.nytimes.com/2020/03/01/business/china-coronavirus-surveillance.html, Accessed in September 2020.
[6] T. Martin, G. Karopoulos, J. L. Hernández-Ramos, G. Kambourakis and I. N. Fovino, Demystifying COVID-19 digital contact tracing: A survey on frameworks and mobile apps, *Wireless Communications and Mobile Computing*, 2020.
[7] N. Ahmed, R. A. Michelin, W. Xue, S. Ruj, R. Malaney, S. S. Kanhere, A. Seneviratne, W. Hu, H. Janicke and S. K. Jha, A survey of COVID-19 contact tracing apps, *IEEE Access*, vol.8, pp.134577-134601, 2020.
[8] R. R. German, J. M. Horan, L. M. Lee, B. Milstein and C. A. Pertowski, Updated guidelines for evaluating public health surveillance systems, *Morbidity and Mortality Weekly Report*, vol.50, no.RR-13, 2001.
[9] L. Zhao, S. Sun and X. Wang, Tracking and traceability system using livestock iris code in meat supply chain, *International Journal of Innovative Computing, Information and Control*, vol.7, no.5(A), pp.2201-2212, 2011.
[10] W. Budiharto, Development of disinfection robot for handling spreading of COVID-19 in Indonesia, *ICIC Express Letters, Part B: Applications*, vol.12, no.1, pp.75-81, 2021.
[11] S. M. Teutsch and R. E. Churchill, *Principles and Practice of Public Health Surveillance*, Oxford University Press, USA, 2000.
[12] S. Tangsawad, S. Buntrai and W. Klangburum, Development of migrant surveillance system in public health region 7 and 8, *Journal of the Office of DPC7 Khon Kaen*, vol.27, no.2, pp.12-20, 2020.
[13] A. Karnjanapiboonwong, P. Sanchaisuriya and S. Srivanichakorn, Data system for surveillance of cardiovascular disease, diabetes and related risk factors in Thailand during 2010-2015, *Disease Control Journal*, vol.43, no.3, pp.220-232, 2017.
[14] *DDC-Care*, http://ddc-care.com, Accessed in September 2020.
[15] *MorChana*, https://www.morchana.in.th, Accessed in September 2020.
[16] *ThaiChana*, https://www.thaichana.com, Accessed in September 2020.
[17] *World Health Organization*, https://www.who.int/thailand/news/feature-stories/detail/thailands-1-million-village-health-volunteers-unsung-heroes-are-helping-guard-communities-nationwide-from-covid-19, Accessed in September 2020.