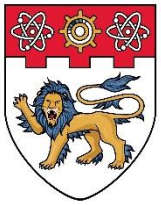

NANYANG TECHNOLOGICAL UNIVERSITY SINGAPORE

IEEE

Final Student Application Paper

Tracking Vulnerable People Using Body Worn QR Code

Faculty Advisor:
Dr. Sinha Sharad *sharad_sinha@ieee.org*

Student Project Leader:
Goh Khai Hong *gohk0062@e.ntu.edu.sg*

Year 2018

SCHOOL OF COMPUTER SCIENCE AND ENGINEERING
NANYANG TECHNOLOGICAL UNIVERSITY

A Final Student Application Paper Presented to IEEE Standards Association in Partial Fulfilment of the Requirements for the IEEE Standards University Student Grant Application

Tracking Vulnerable People Using Body Worn QR Code

Goh Khai Hong and Sharad Sinha
School of Computer Science and Engineering,
Nanyang Technological University, Singapore 639798
gohk0062@e.ntu.edu.sg sharad_sinha@ieee.org

***Abstract*—**This project designed a QR Code tracking system to integrate into a law enforcement agency's system to track vulnerable people. An efficient way to secure user data in QR Code, called HQR Code, using hash function is proposed. In the HQR Code, a user's Personally Identifiable Information (PII) is hashed to safeguard privacy and stored for tracking purpose. The tracking system provides QR code-based user location tracking alerts and a user identification system. Every user of the tracking system is assigned a unique QR Code t-shirt with unique identification number. The QR Code shirt can be worn and washed and is more reliable and durable compared to QR code stickers. Users must always wear the QR Code shirt wherever they go. These QR Code shirts link to the QR Code tracking system website, where detailed information is stored. A mobile application or a standalone QR code scanner can be used to scan the code for retrieving hash value in the code. The retrieved hash value is sent along with the geo-location of the mobile device to the system server. Authentication and geo-location mapping is done by the system. The design of this system allows authorized personnel (e.g., system administrator or police) to access detailed user information. System administrators are authorized to access users' personally identifiable information to improve the accuracy of location tracking. The tracking system has been tried out by 3 participants in Singapore. To analyse the QR Code tracking system's usability, the participants also completed the System Usability Scale questionnaire after using the system.

Keywords*—*QR Code; HQR; hash value; tracking system; QR Code shirt

I INTRODUCTION

Nowadays, QR Codes [1] are used for a variety of tasks in commercial settings. The most popular commercial use for QR Code is in the telecommunications industry, where the increasing usage of mobile phones seems to be the largest driver of their popularity [2] [3] [4]. QR Codes have already overtaken the traditional 1-D barcodes in popularity in some domains. This is due to the fact that the size of data that can be stored by traditional 1-D barcodes is very much less than that of the data that can be stored by a QR Code [5]. A typical 1-D barcode can only store less than 100 bytes of data whereas as QR Codes can store up to 2953 bytes [6].

With the extensive use of mobile devices like smartphones by people in their day-to-day lives, especially for mobile internet access, QR Code is an adequate way to communicate information rapidly and efficiently. By scanning a QR Code with a mobile device, users can be connected to a relevant web page or receive information such as special offer, discount voucher, product or location information, etc. These days, QR Codes are used everywhere starting from products to webpages, advertising, manufacturing, retailing, healthcare, transportation, e-payment transactions, inventory tracking etc. This allows offline media such as journals, newspapers, business cards, public transport vehicles, signs, t-shirts or any other medium that can hold the print of a QR Code to be used as carriers for advertisements [7]. Apart from that, QR Code can be used as ID tag or sticker for tracking and tagging purposes [8].

In Australia, QR Code technology is used for identifying and tracing livestock with ID numbers [9]. A QR Code tag is carried by livestock on the tail. The tag is then used for tracing of its movement in stock farms. In this case, error correction feature facilitates dirty label reading. When diseases like the mad cow disease (BSE) break out, a unique ID allocated to each stock farm is used to trace the source of the disease.

The most noteworthy advantage of the utilization of QR Code from the aspect of person identification comes from its simpler technology. QR code-based technology is much more accessible for the users since it does not require any special tags like the radio-frequency (RF) tags. QR codes can also be generated and printed effortlessly on practically any surface.

II CURRENT USES OF QR CODE

The QR Code technology is in use in many medical facilities, mainly in Asia-Pacific domain, mostly for accessing and controlling patient related processes and data. In 2008, the health care centres located in Hong Kong, Japan and Singapore, have implemented a system known as Unique Patient Identification (UPI) which achieved a fruitful technology transition from barcode-based system to QR code-based system [10].

Addenbrooke's Hospital in Cambridge makes use of the QR codes in compliance with its policy about the patient safety. Apart from other personal information, the QR code is printed onto a bracelet which is then carried by the patient on wrist. Originally, the tagging system was in use only for tracking blood transfusions and for controlling the coincidence between patient and blood type. Nowadays, the QR codes are employed much more extensively to minimize occurrence of some other types of failures observed in hospital or medical environments [11].

Houston's Methodist Hospital System, utilizes a patient data electronic verification system, named KBMA, based on the reading of bar codes. The system is connected online to the medical record documentation database system, called "MethOD". An upgrade of Houston's Methodist Hospital KBMA barcode-based ID system has been suggested, by transitioning from old barcode-based patient identification system to a QR code-based system [12].

A Iruma-based company, located in north Tokyo, has introduced a QR Code tagging system for the rising population affected with dementia in Japan [13].The system is used for keeping track of dementia patients with QR codes attached to fingernails. The QR code sticker holds details of a user such as address, emergency telephone number and unique ID. If a user is disoriented, police can obtain details of the user's local city hall, its telephone number and the user's ID, simply by scanning the code.

However, since the QR Code can be read at a glance by mobile devices, many users consider data privacy an important concern because the personal information or other sensitive information stored in QR Code is accessible by everyone. In the work presented in this paper, SHA-1 [14] is used to overcome data privacy concerns so that QR codes can be generated in a way to achieve data privacy and security as well. SHA-1 is a hash function designed by the United States National Security Agency, published on 1995 and approved as U.S. Federal Information Processing Standard. It has been replaced by SHA-2 or SHA-3 since 2010 as it has not been considered secure against malicious attack [15]. However, the git source code management system uses SHA-1 hashes extensively as identifiers and consistency checks even though Google has now demonstrated a collision attack on SHA-1. This is because there is a difference between using a hash for purposes like security signing and using one for creating a "content identifier" for a content-addressable system like git [16]. In this project, hash is mainly used for creating an "user identifier" for the end user.

The QR code technology, its variants, types of data it encodes, data storage capacity and efficiency, data density and its benefits are studied in this project. A well thought of plan to select, implement and use QR codes can help in tracking vulnerable people. By the end of this project, a QR Code tracking system and an Android app (QR Tracker) is developed to attain this tracking purpose.

III PROJECT OBJECTIVE

The goal of this project is to use an appropriate QR code type in the context of Singapore to help track vulnerable people. A web and mobile application is also developed and implemented for the public usage for customized QR code-based human-tracking. The QR codes created through the process presented in this paper is printed on a plain T-shirt to be worn by vulnerable people. The concept of QR Code on t-shirt is used to promote "*user adoption*" of QR-code based tracking systems. This is aesthetically appealing, more durable and much less intrusive compared to QR Code stickers on finger nails etc. The rationale of selecting a hash function and a QR code type is also presented with sufficient technical analysis.

IV PROPOSED SYSTEM

Although the Google Play Store offers a few QR generator and scanner applications, users cannot hash the data with a hash function before encoding it as a QR code. The objective of this project is to allow users to hash the data on their own with a hash function on Android app (QR Tracker) or Web application. User can generate or scan Model 2 QR Code without Internet connectivity. They can enter the data they wish to encode. A default hashing algorithm (SHA-1) is used to hash the data. System will first hash the data and the hash value is then encoded as a QR Code. Hashing process ensures that data is secure. Finally, user can choose to send the generated QR code to their email or save it to their camera roll. A QR Code tracking system is developed for tracking the location of the user using hash value that is stored in the QR Code. The figures below show the tracking system use cases.

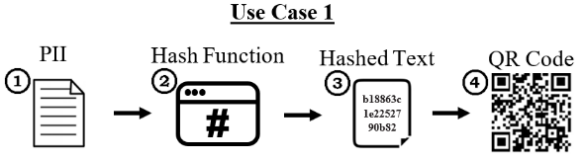

Figure 1: Data hashing and encoding of HQR code

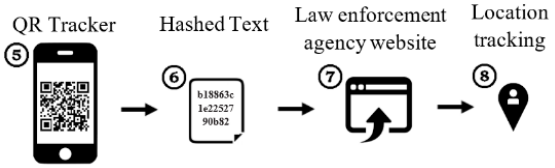

Figure 2: Data decoding of HQR code and location tracking

Figure 3: Data encoding and decoding of QR code

V RELATED WORK

This section summarizes the work that has already been done to hash a QR Code and how the work proposed in this paper relates to it.

A. Storage Capacity Planning for User PII.

Table 1: Number of characters to be encoded

PII	Detail	Sub-fields	Storage Capacity Required
Name	Goh Khai Hong	▪ Name (40 character) ▪ Separator (1 character)	41
Age	24	▪ Age (3 character) ▪ Separator (1 character)	4
Gender	M	▪ Gender (1 character) ▪ Separator (1 character)	2
Name of Next of Kin	Lim Git Ching	▪ Name of Next of Kin (40 characters) ▪ Separator (1 character)	41
Local Home Address	Blk660A, Jurong West Street 64, #05-398, S641660	▪ Block Number (7 characters) ▪ Street Name (30 characters) ▪ Street Number (3 characters) ▪ Floor and Apartment Number (7 characters) ▪ Building Name (30 characters) ▪ Postal code (7 characters) ▪ Commas (3 characters) ▪ Spaces (3 characters) ▪ Separator (1 character)	91
Contact Number	+6585808979	▪ Country Code (3 characters) ▪ Phone Number (8 characters) ▪ Separator (1 character)	12
ID	A1001011	▪ ID (8 characters)	8
Total number of characters			199

Table 1 shows the information that needs to be used to uniquely identify a Singapore based user and storage capacity required (in terms of the number of characters) for encoding each field in QR code for tracking purpose.

B. Hashing Algorithm Selection

The algorithm used for hashing user PII is Secure Hashing Algorithm 1(SHA-1). SHA-1 hashing algorithm is a weak hashing algorithm, but it can produce a hash with shorter length compared to other SHA family hashing algorithms such SHA-256 and SHA-512. By using SHA-1 hashing algorithm, a smaller QR code can be used to store the user information.

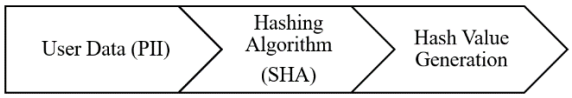

Figure 4: Hashing Process

Table 2: Original plain text and the hashed text

Hashing Algorithms	User PII	Storage Capacity Required
Plain text	GOH KHAI HONG_24_M_LIM GIT CHING_BLK660A, JURONG WEST STREET 64, #05-398, S641660_+6585808979_A1001011	199
SHA-1	17357f9620b4b124d264b18863c1e2252790b828	40
SHA3-224	3282c4bc8525016051e617f53725e9094dc930b6f4b23befa32245fc	56
SHA-256	19f6683d8c08aa5f80fa8e94c2881099744587132d34ffbabe18eb60ec81fcfb	64
SHA3-384	6a983f4dd365e1dcccec7a09c6e65960dd47a05075592a12a70cd634caad12a3c3f5ec94e21b4c8be9e25557124a23b5	96
SHA-512	de99bef2883c037a7561e4378c5f288c3f8c0ffb0798ce677d87cba02044ac18c6731f1c626aee17b056d18556a1ed685afcbaff5f2adeae3453809e3840127c	128

C. QR Code Analysis and Selection

Model 2 QR Code Version 4 – Q and Version 12 – Q are selected to be used for storing user PII in this project. Model 2 QR Code Version 4 – Q is used to store hash value of user PII whereas Version 12 – Q is used to store original user PII. The user PII and its hash value can be stored efficiently with these two versions of QR Code.

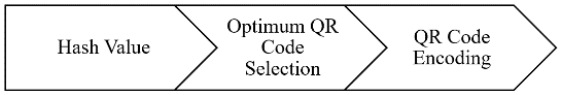

Figure 5: Optimum QR Code selection and generation process

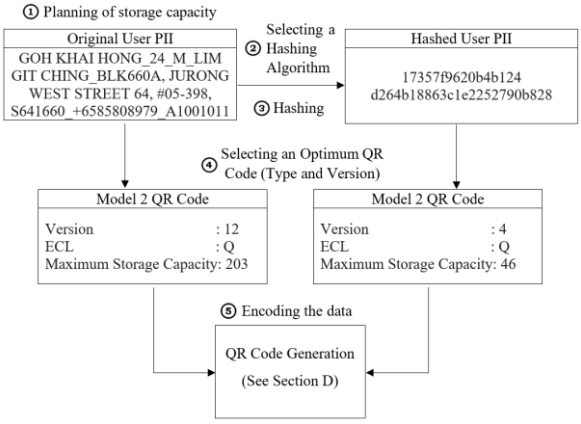

Figure 6: Pre-processing for QR Code generation

D. User PII Encoding and Hashed QR Code Generation

After finishing pre-processing steps, the next step is to encode user PII or its hash value into a QR code symbol. The following steps are the encoding steps for user PII.

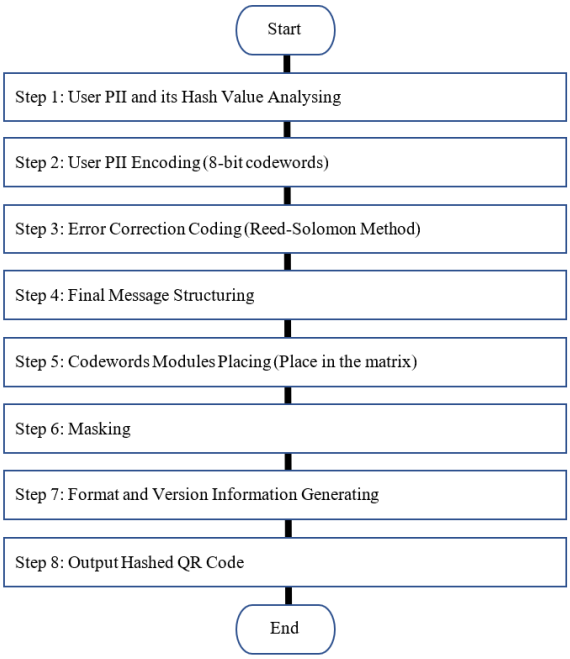

Figure 7: HQR Code encoding process

The Hashed QR Code (HQRC) encoding procedure is shown below:

1. Data hashing (User PII hashing – use case 1)
   a. Hash the arbitrary length of user data string into a fixed-length hash value using SHA-1 algorithm, which is an irreversible one-way function.
2. Data analysis (User PII analysing)
   a. Analyse the user data string and select a data encoding mode for it. In this project, Binary Mode is used for encoding user data string at a density of 8 bits per characters. Maximum number of characters that can be stored in Model 2 QR Code in Byte Mode is 2953 characters.
   b. Select an Error Correction Level. There are four user-selectable levels of error correction offering approximately up to 30% of recovery capacity. Four levels of error correction allowing recovery of the QR Code symbol codewords as shown below. Level Q is selected to be applied on the QR Code.

Table 3: Error Correction Level

Error Correction Level	Recovery Capacity % (approx.)
L	7
M	15
Q	25
H	30

   c. Select QR Code symbol version to be used. Model 2 QR Code is used in this project.

Table 4: Types of QR Code and Versions

Types of QR Code	Versions
Model 1 QR Code	1 – 14
Model 2 QR Code	1 – 40
Micro QR Code	M1 – M4
Square IQR Codes	1 – 61
Rectangular IQR Codes	R1 – R15

3. Data encoding (User PII encoding)
   a. Encode the user data string into a string of bits in accordance with the rules for the mode in force.
   b. Split the string of bits into 8-bit codewords.
   c. Padding Characters are added as necessary to fill the number of data codewords required for the version.
4. Error correction coding
   a. Divide the codeword sequence into the required number of blocks.
   b. Reed-Solomon Error Correction algorithm is used to generate error correction codewords from the 8-bit codewords of the input data.
   c. Figure 8 shows that there are 2 modules down in the bottom left-hand corner of every QR code. They display what the error correction level used in that QR code is.

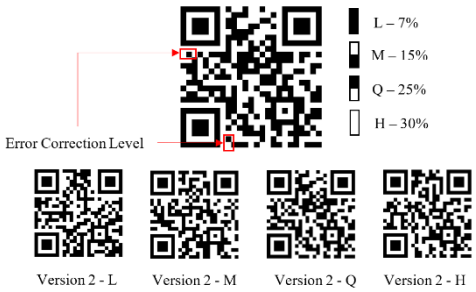

Figure 8: QR Code error correction level modules for Model 2 symbol

5. Structure final message
   a. Interleave the data and error correction codewords from each block.
   b. Remainder bits are added as necessary.
6. Module placement in matrix
   a. For Model 1 QR Code symbol, the codeword modules is placed in the matrix together with the Extension Patterns (for right-hand and lower sides), Finder Pattern, Position Detection Patterns, Separator, and Timing Pattern.

b. For Model 2 QR Code symbol, the codeword modules is placed in the matrix together with the Alignment Patterns, Finder Pattern, Position Detection Patterns, Separator, and Timing Pattern.

7. Masking

a. Apply the masking patterns successively to the encoding region of the QR Code.
b. Evaluate the mask pattern results.
c. Select the mask pattern which has lowest penalty score, optimizes the dark/light module balance and minimizes the occurrence of undesirable patterns.

8. Format and Version Information

a. For Model 1 QR Code symbol, generate the Format Information.
b. For Model 2 QR Code symbol, generate the Format and Version Information (where applicable).

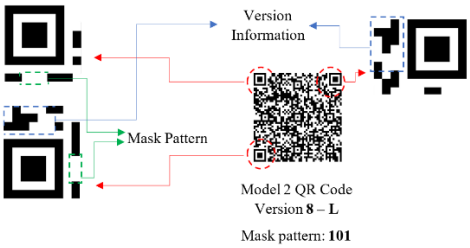

Figure 9: Format and Version Information

E. Original and Hashed User PII in QR Code

The figures below show the Model 2 QR Code symbol with user PII (Figure 10) and its hash value (Figure 11).

Figure 10: QR Code Model 2 version 12 - Q

Figure 11: QR Code Model 2 version 4 - Q

Figure 12 shows an example of user PII stored in the QR code. The underscore ('_') symbol is used to split up the fields of user PII. Figure 13 shows a hash value of user PII.

Figure 12: Example of user PII stored in QR Code

Figure 13: Example of hash value of user PII stored in QR Code

VI QR CODE SELECTION

A. Overview of Data Capacity and Maximum Size of QR Codes

Table 5 shows maximum data capacity (number of characters that can be stored) and maximum size of standard QR Codes (Model 1 and Model 2), Micro QR Codes, and iQR Codes (square and rectangular). A Model 1 QR Code can be used to store up to 7,089 characters of numerical data or 2935 characters in Byte Mode, a Micro QR Code can store up to 15 characters in Byte Mode and a square iQR Code a massive 16932 characters whereas a rectangular iQR Code can store up to 500 characters in Byte Mode.

Table 5: Maximum data capacity for various types of QR Code

Types of QR Code	Model of QR Code	Sample	No. of Modules and Code Area (mm^2)	Maximum Data Capacity			
				Numeric Mode	Alphanumeric Mode	Byte Mode	Kanji Mode
				Text Encoding: Japanese (SHIFT-JIS) Error Correction Level: L – Recovery 7%			
Standard QR Codes	Model 1		73x73 (37.1^2)	1167	707	486	299
	Model 2		177x177 (89.9^2)	7089	4296	2953	1817
Micro QR	Square		17x17 (8.6^2)	35	21	15	9
iQR Code	Square		422x422 (214.4^2)	40635	24628	16932	10419
	Rectangular		43x131 (21.8x66.5)	1202	727	500	307
* module size: 0.51 x 0.51 mm^2							

Based on analysis in this project, Figure 14 shows that the square iQR Code has highest capacity (and maximum size) and followed by Model 2 QR Code.

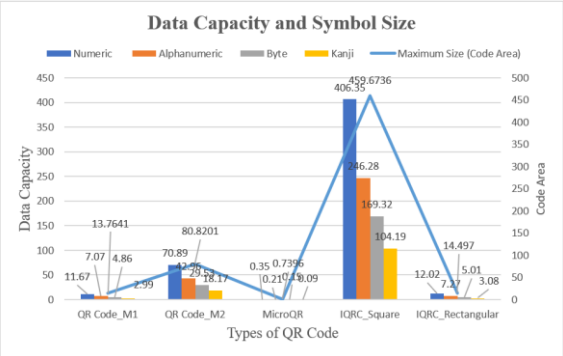

Figure 14: Data capacity and symbol size (in cm^2)

VII QR CODE T-SHIRT DESIGN PROPOSAL

A. QR Code T-shirt Replaces Sticker

In the past, there was an attempt by Japanese firm to attach QR code stickers on the human body, for example on the fingernail, for tracking the whereabouts of dementia patients. However, this approach is not feasible because the user needs to repeatedly attach and detach the stickers from the body for an average of every two weeks which will make the use of stickers more cumbersome. *Also, QR code sticker quality will be compromised because it might crack, fade, and deteriorate over time. Hence, printing the QR code on T-shirt is being proposed as a better alternative to use QR code stickers.* Firstly, T-shirt is more durable than stickers and can be worn at will. Besides, QR code has been increasingly used as a creative idea which effectively incorporating into T-shirt design work today. It is a great idea and just one more awesome way to engage people to use this QR Code tracking system.

B. The QR Code T-shirt Logo

In this project, QR Code act as a GPS-like symbol that can be used to locate and track the user location.

Figure 15: Design of QR Code T-shirt

VIII WEB-MOBILE APPLICATION

1. QR Code T-shirt Replaces Sticker

The use case diagram of QR code tracking system is illustrated in the figure below:

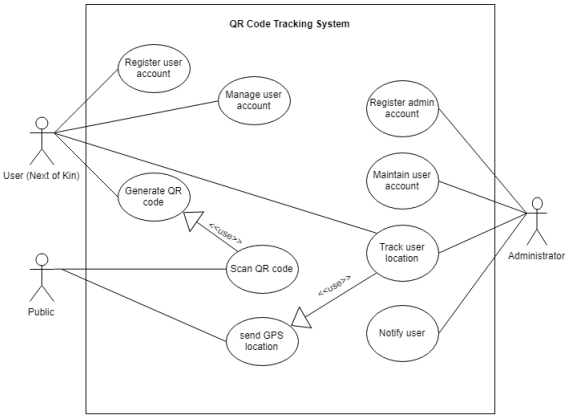

Figure 16: Use case diagram of QR Code tracking system

2. Dialog Map

Figure 17 shows the dialog map of the QR code tracking system.

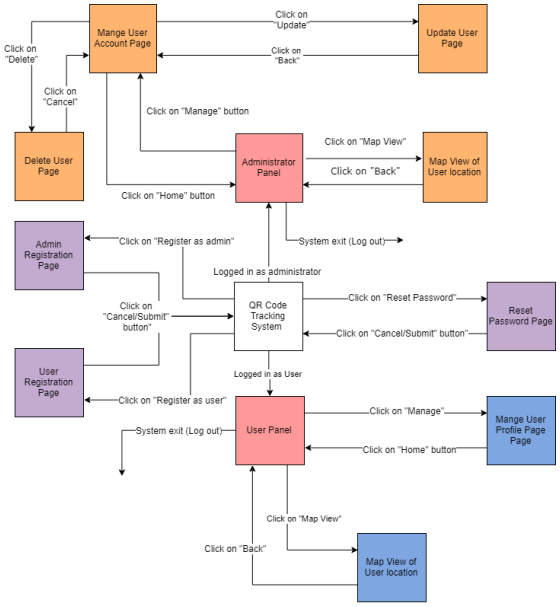

Figure 17: Dialog Map of QR Code tracking system

IX STANDARDS APPLIED

The standards supported in this project include the ISO/IEC 18004:2015, Information technology – Automatic identification and data capture techniques – QR Code Bar code symbology specification standard for generating QR Code to store the hash value of user PII. QR Code Model 2, its data storage capacity and efficiency are analysed and implemented to achieve the project goal.

X CONCLUSION

In conclusion, this project presents a system for tracking vulnerable people by using QR Code T-shirt. A new type of QR Code (HQRC) is created using SHA-1 for improving data protection and privacy. The reason for using SHA-1 is because it can be used to produce a unique, more secure and shorter hash value among all other cryptographic approaches. In the data storage efficiency analysis, iQR code has been found to have highest data storage efficiency compared to standard QR code and Micro QR Code. However, not many mobile apps in the market today can decode iQR Code as can decode standard QR Code even though iQR Code is standardised and freely available. Therefore, standard QR Code is selected as a medium for tracking purpose. In the storage capacity utilization analysis, when comparing the standard QR Code version 1 to version 14, it was found that version 4 with error correction level Q is most suitable for storing hash value of user PII whereas version 12 with error correction level Q is most suitable for storing user PII.

This proposed QR Code tracking system is using a simple technique by applying hash value of user PII as user identifier which will be sent to the system server along with the geolocation of the QR scanner. The geolocation of the vulnerable user will be updated once the retrieved hash value matched with the hash value in the system. It is convenient for police officer or agency personnel to locate the person who is getting lost based on the location updates from the mobile device. It has been shown that this system could be used for tracking people as a practical, effective and reliable alternative in all kinds of tracking system. It can be further used for keeping track personal belongings and valuables by making QR Code into a durable sticker. Instead of printing QR Code on T-shirt, bracelet or necklace can be used as QR tag for tracking and tagging purposes in the future.

XI ACKNOWLEGEMENT

The authors would like to thank IEEE Standards Association for supporting this project through an IEEE Standards University Student Grant 2018.

REFERENCES

[1] ISO/IEC 18004:2000, Information technology - Automatic identification and data capture techniques - Bar code symbology - QR Code, ISO, 2000.

[2] S. Lisa and G. Piersantelli, “Use of 2d barcode to access multimedia content and the web from a mobile handset,” in *GLOBECOM*, 2008.

[3] J. Gao, V. Kulkarni and R. Himanshu, “A 2d barcode-based mobile payment,” in *MUE*, 2009.

[4] J. Gao, L. Prakash and R. Jagetesan, “Undersanding 2d-barcode technology and application in m-commerce - design and implementation of a 2d barcode processing solution,” in *COMPSAC 2007*, 2007.

[5] A. R. Wane, S. P. Jamankar and O. V. Chandure, “An Effective mechanism for Ensuring Security of QR Code,” *International Journal of Advanced Research in Computer Science*, vol. 4, no. 6, pp. 175-179, 2013.

[6] “TEC-IT Barcode Software - Barcode Overview - Reference,” 15 January 2018. [Online]. Available: http://www.tec-it.com/download/PDF/Barcode_Reference_EN.pdf. [Accessed 2018 February 1].

[7] G. J. Z. , V. H., S. S. and X. J., “A 2d-barcode based mobile advertising solution,” *SEKE*, pp. 466 - 472, 2009.

[8] J. Sharman, “Japanese city keeps track of dementia patients with QR code nail stickers,” The Independent, 2016 December 2016. [Online]. Available: http://www.independent.co.uk/news/world/asia/japan-track-dementia-patients-qr-code-nail-stickers-a7464256.html. [Accessed 12 March 2018].

[9] “5.3 Food Safety,” GS1 Japan, [Online]. Available: http://www.gs1jp.org/2014/industry/5_3.html. [Accessed 16 February 2018].

[10] R. García-Betances and H. M.K. , “A review of automatic patient identification options for public health care centers with restricted budgets,” *Online journal of public health informatics*, vol. 4, no. 1.

[11] “SATO Healthcare ID Solutions,” [Online]. Available: http://www.satoeurope.com/. [Accessed 15 February 2018].

[12] General Data Company, “The Methodist Hospital System: Upgrade to bar code identification of patients yields significant process and safety gains,” [Online]. Available: https://www.generaldata.com/healthcare-solutions.. [Accessed 2018 February 15].

[13] “Japan tracks dementia patients with QR codes attached to fingernails,” BBC News, 8 December 2016. [Online]. Available: http://www.bbc.com/news/world-asia-38247437. [Accessed 12 March 2018].

[14] C. Veness, “SHA-1 Cryptographic Hash Algorithm,” [Online]. Available: https://www.movable-type.co.uk/scripts/sha1.html. [Accessed 5 December 2017].

[15] M. Stevens, E. Bursztein, P. Karpman, A. Albertini, Y. Markov, A. Petit Bianco and C. Baisse, “Announcing the first SHA1 collision,” Google, 23 February 2017. [Online]. Available: https://security.googleblog.com/2017/02/announcing-first-sha1-collision.html. [Accessed 12 March 2018].

[16] S. J. Vaughan-Nichols, “Linus Torvalds on SHA-1 and Git: 'The sky isn't falling',” ZDNet, 26 February 2017. [Online]. Available: http://www.zdnet.com/article/linus-torvalds-on-sha-1-and-git-the-sky-isnt-falling/. [Accessed 12 March 2018].

