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Encrypted quick response scheme for hotel check-in and access control system

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Abstract

The unpleasant experience of long queue while waiting to check-in at hotel is a common problem faced by guests especially during holidays. As such, various self-service technologies (SSTs) were introduced over the years by researchers with the aim to increase the avenues of checking-in guests. Self-check-in kiosk is an invention that allows guests to check-in themselves using bar codes that were sent to them in advance. Although bar codes are able to reduce guests' waiting time, it cannot be used to unlock hotel rooms. This makes mobile device a better medium for hotel check-in and access control system. Despite mobile device is very convenient and easy to operate, guests would have to own the specific type of mobile device such as near-field communication smartphone and its customized application before using the system. This makes the solution not user-friendly to guests. Therefore, a novel encrypted quick response scheme is presented to extend the existing SST to unify the process of check-in and room access control. The proposed scheme uses quick response codes and cryptography techniques to generate secure hotel keys that can be printed or stored inside a smartphone, thus, supporting a wide range of guests.

Keywords

Raspberry Pi, Bluetooth low energy, hotel check-in, access control

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Introduction

The advancement of information and communication technology which offers compelling computing and communicating capabilities has radically changed the service delivery industries towards self-service technologies (SSTs) as way to supplement or replace the conventional ways of service delivery. SST is defined as technological interfaces that allow customers to receive services without directly involving any service employees.[1] Examples of SST application are automated teller machines,[2] airport self-service check-in systems,[3] restaurant food automated ordering systems[4] and so on. The usage of SST benefits service industries in various manners such as reduction of labour cost, improvement on operational efficiency and productivity, creation of differentiation and competitive niches and so on.[5]

Long queuing lines to check-in are common in hotels during peak time because demands exceeded supply of services by hoteliers. For example, hotel guests may encounter full lobby when check-in during school holidays. The lengthy queuing time to check-in would give negative perceptions on hotel's service quality and reduce guests'

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satisfactions. Therefore, many hotels have implemented hotel self-service applications with SSTs[6] to improve check-in and room access control, where convenience and security are of importance to guests. SSTs have surfaced in hotels as alternative ways for guests to check-in conveniently without any form of assistances from service employees. Past and recent studies[6–8] have mainly focused on using self-service kiosks (SSKs) and self-service mobile devices (SSMDs) to increase hotel capacity to check-in guests, hence reducing guests' waiting time and frustration caused by long queues at reception counters, while minimizing operating cost for hoteliers.[7] Moreover, the adoption of SSKs at hotel provides guests with more privacy and autonomy as to how and when they check-in to hotel, whether through hotel employees or SSKs. For instance, if there is a long queue in front of the reception counter, hotel guests can opt to check-in via SSKs and obtain the activated hotel key cards without having to interact with the service employees.[9]

Nevertheless, the adoption of SSKs into hotel could transform a simple check-in process at lobby that is assisted by hotel employee into a complex cumbersome self-service conditional logics and interactions. For instance, guests would have to follow the SSKs' on-screen instructions to check-in, such as key in the unique identification codes that were sent to them ahead of their arrival. Once successfully checked in, guests would need to wait for the activation of the hotel key cards and collect it.[10] Some guests may not be comfortable to check-in through SSKs because they are lack of proficiency in using the technology and are afraid of making mistakes.[11] Thus, to enhance the usability of SSKs, barcodes such as quick response (QR) code were introduced to store identification codes for guests' to check-in easily.[9] The use of barcodes eliminates the process of entering the identification codes manually. Guests simply tap the barcodes on the SSK's scanner to check-in. Although barcodes could make the check-in process via SSK easier, it cannot be used to unlock hotel rooms. Hence, guests would still have to wait and collect the activated key cards through the SSKs before proceeding to their hotel rooms. This could result to long queues being built up at SSKs if the number of SSKs is limited especially during peak seasons.

The infusion of smartphone technology in the recent years has opened up the opportunity to further reduce guests' check-in times through SSMDs, utilizing mobile devices to check-in and unlock hotel rooms.[8] For example, Clarion Hotel Stockholm has implemented near-field communication (NFC) check-in and room access control systems that allow guests to perform self-check-in as well as hotel key activation using customized NFC smartphone applications.[12] Once guests are checked in through NFC smartphones, they can proceed to the reserved room and unlock the room by tapping their NFC smartphones on the door. Although the use of mobile devices is able to unify hotel check-in process and room access control, specific type of mobile devices are required before using the system, such as NFC smartphone along with the customized applications. As such, SSMD may not be a viable solution for wide variety of guests, particularly for those who are not well versed with mobile technology. The advantages and disadvantages of using different types of SSTs to check-in and gain access to hotel rooms are summarized in Table 1.

Table 1. Summary of advantages and disadvantages of utilizing various SST to check-in and unlock hotel room found in the literature and in the commercial market.

Self-service technologies (SSTs)	Advantages	Disadvantages
Self-service kiosk (SSK)	Convenience; easy to operate	Require separate key cards to unlock hotel rooms
Self-service mobile device (SSMD)	Convenience; easy to operate for guests who are familiar with mobile technologies; one device to check-in and unlock hotel room	Require specific mobile device and its application; not easy for guests who are not familiar with mobile technologies to operate
Proposed system (SSK + SSMD)	Convenience; easy to operate; one secure key to check-in and unlock hotel room; option to use mobile device or physical print out as key	Require mobile device to store the key or print out of the key

To address the gap in the literature, a novel design and development of encrypted quick response (EQR) scheme is posited to renew the interest of using SSK to check-in and unlock hotel rooms. The EQR scheme is designed through innovative integration of two imperative techniques, namely, (1) cryptography and (2) QR code to generate EQR keys that are secure and can be digitally transmitted to guests in advance upon successful booking of rooms. The proposed EQR scheme extends the existing SST by unifying the process of check-in and room access control with integrated EQR keys. The aim is to let guests check-in securely through SSKs using the received EQR keys and thus, eliminate the need of queuing in front of reception counter. Besides, guests can use the same EQR keys to securely unlock the hotel rooms. The EQR keys are designed to meet the needs of guests with different digital lifestyles. Those who prefer mobile technologies can opt to store digital copies of their EQR keys on mobile devices like tablets or smartphones, while others can print out the physical EQR keys. The EQR keys facilitate guests in speedy and secure checking-in as well as unlocking hotel room which are particularly timely and relevant to the hotel industry.

Related work

In this section, related work on check-in and room access control systems in hotels is discussed with respect to the proposed EQR scheme, namely, cryptography and QR code. A typical hotel check-in process at reception counter entails two important steps. First, guests register themselves with the help of servicing staff and second, obtain the activated keys to their rooms from the staff. Generally, check-in process consumes a considerable amount of time and, therefore, might cause bottleneck during peak seasons, which result to long queues especially if only limited reception counters are available. Thus, commercial interests in adopting SSTs, such as SSK and SSMD in hotel industry, become popular and gain strong acceptance in marketplace because it can reduce long queues at the reception counters while minimizing the operational cost.[9,10]

Hotel room access control refers to the mechanisms of authenticating guests and subsequently translating it to unlocking hotel rooms. Most of the existing hotels are using magnetic stripe (Magstripe), radio-frequency identification (RFID) and NFC key cards for room access control.[12–18] For example, Great Wolf Resorts in Pennsylvania's Pocono Mountains has its guests wearing an RFID-enabled wristband to unlock room doors and make payment.[14] This keyless room entry using RFID-enabled wristband technology has also been implemented in Walt Disney World with its MagicBand,[17] Royal Caribbean Cruises with its WOW band[18] and Carnival Cruise line with its Ocean Medallion.[18] As for NFC technology, Clarion Hotel Stockholm has implemented room access control systems using NFC smartphone.[12] However, assessment of the existing literature studies on SSK implementations in hotel industry yields a research gap between check-in and room access control. Apparently, recent developments of SSK have been focusing on utilizing barcodes for the purpose of guests' check-in but using separate key card technologies for room access control. As a result, the keys are not compatible between the check-in system and the room access control system. Although SSMD was introduced to unify check-in process and room access control, guests have to own the specific devices, such as NFC or Bluetooth low energy (BLE) smartphones and its application, before using it. Thus, not all guests are benefited from the SSMD implementations.

QR codes are static and non-powered two-dimensional matrix of black and white pixels that store data which can be retrieved optically.[19] Characteristics of simplification in storing, distributing and retrieving of information using QR code make it particularly suitable for hotel check-in and room access control. This has opened up an emerging trend to integrate QR code into SSKs for speedy and easy check-in. For example, Thailand's Royal Cliff Hotels Group and Jurys Inn Hotel Group are using personalized QR code for guests to perform express check-in and collect room keys through SSKs.[9] The potential of adopting QR code into hotel industry is tremendous. One compelling reason is to integrate hotel check-in process and room access control together that can be accessed with secure digital keys stored in QR codes to supply a more dynamic environment where guests have more degrees of freedom and privacy in deciding the way to check-in and access to hotel rooms. As such, a new scheme is required to store digital key securely in QR codes that can be read and decoded by both SSKs and door locks.

Cryptography is the imperative security primitive that can be used to securely store digital keys in QR code to unify hotel check-in process and room access control. Cryptography is a method to jumble up information known as plaintext using a secret key to form an unintelligent format known as ciphertext.[20] To restore back the original plaintext, the same secret key is required to decipher the ciphertext, hence the term symmetric-key algorithm. To the best of our knowledge, there is no other related work on storing digital keys securely in QR code through cryptography technique for the purpose of universal hotel check-in and room access control.

System design and implementation

In this section, design of the EQR scheme is presented with the aim of reducing the waiting time to check-in, through SSKs and conveniently unlock the hotel room using the EQR keys that they received digitally in advance. The proposed solution comprises a hotel booking management system, which enables guests to book rooms through a web browser and serves as centralized room access control system, an EQR encoder to generate unique hotel keys for guests, SSKs to facilitate guests in checking-in and EQR door panels to decode EQR keys and unlock hotel rooms. The process of booking rooms through the hotel booking management system, checking-in via the SSK and unlocking the hotel room's door through the proposed system is depicted in Figure 1. At the heart of the proposed system is the EQR scheme that unifies the process of check-in and room access control using EQR keys. EQR keys are designed to be secure and convenient through innovative integration of cryptography technique and QR codes. Figure 2 shows the processes of generating an EQR key for each guest using the proposed system.

The first step in booking hotel rooms through the proposed system is to use a web-enabled computer or mobile device to access the hotel booking management system. Then, select a desired date and room, provide personal credentials such as identification card or passport number and make necessary payment to confirm a booking. Based on the guest's credentials given, EQR encoder residing at the hotel server will generate unique EQR keys for the guests. First, guest's credentials are used by the one-time password (OTP) and access code module to derive an exclusive OTP and access code, which will be used in the check-in process. The generated OTP is only valid for one check-in session to prevent replay attack.[21] Then, it is encrypted through the encryption module that serves as a security protection, using Advanced Encryption Standard

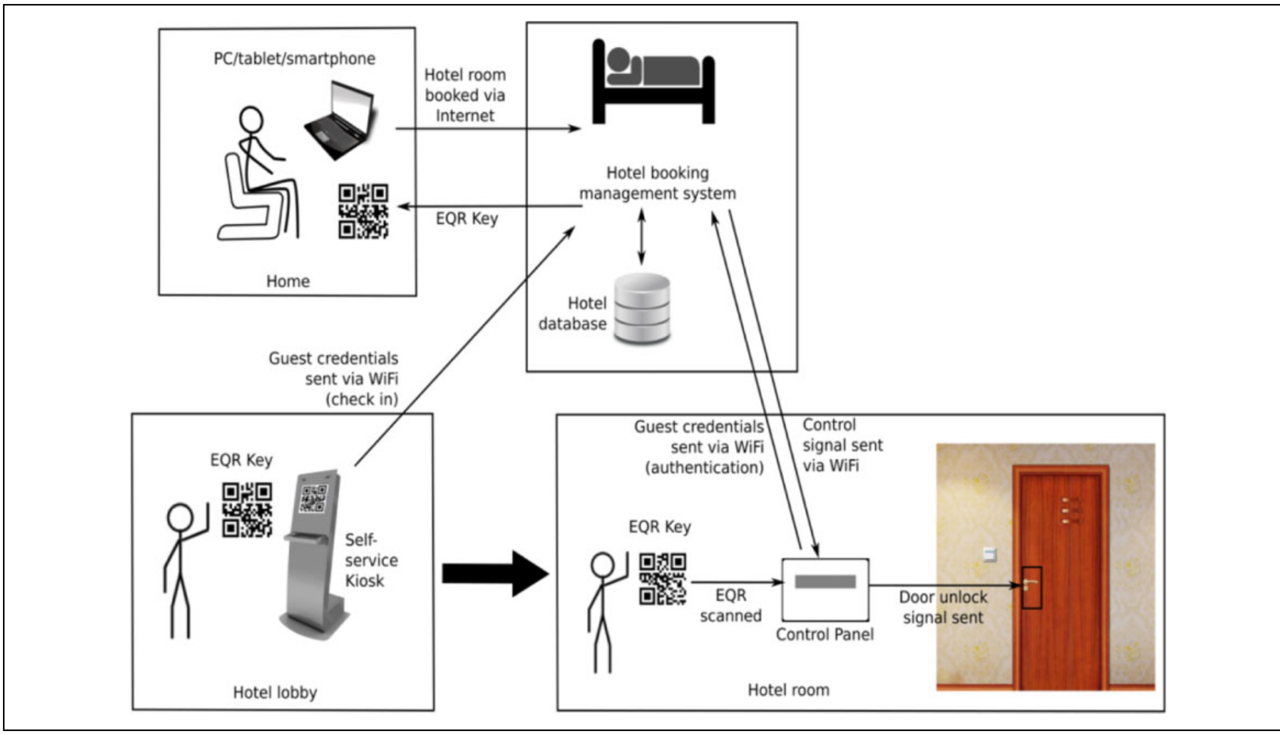

Figure 1. Booking, checking-in and unlocking hotel room with the EQR key. EQR: encrypted quick response.

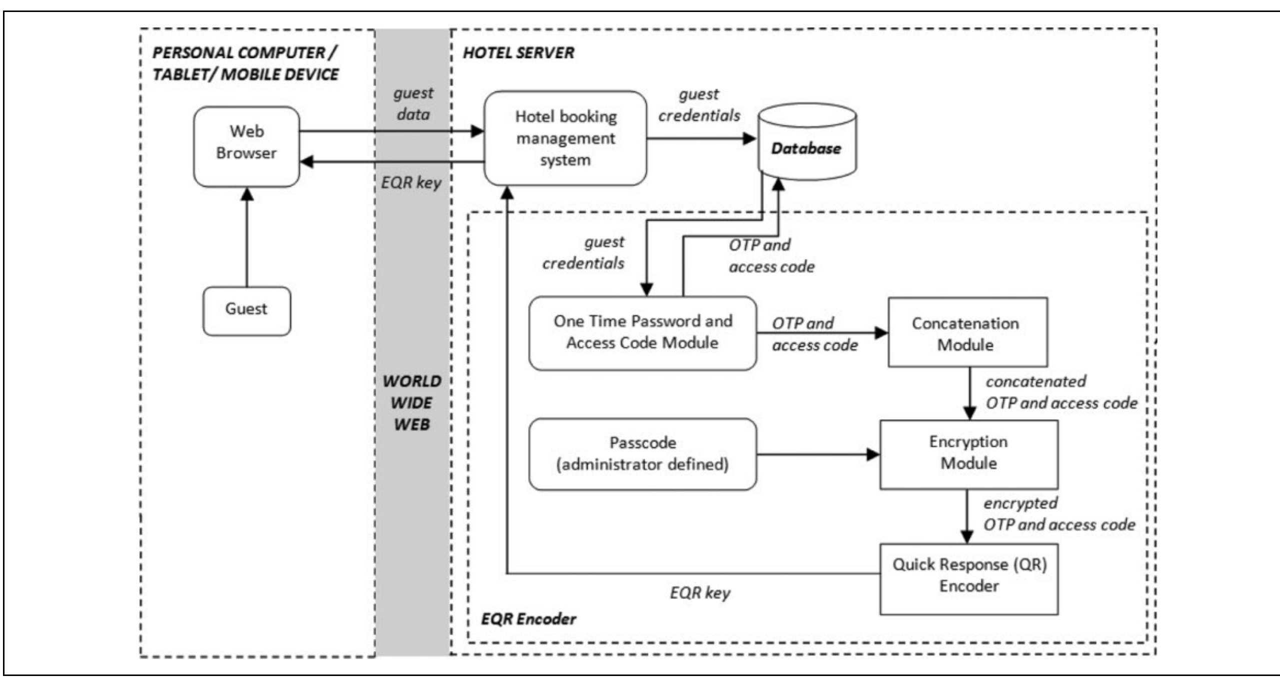

Figure 2. Processes of generating an EQR hotel key. EQR: encrypted quick response.

(AES) with a key size of 256 bits along with a passcode defined by server administrator. Although other cryptography technique such as Triple Data Encryption Algorithm (3DES)[22] can be used, AES is recommended. This is because AES is the de facto encryption standard for secured data encryption and decryption where it has been adopted by the US government.[19] The key size of 256 bits is chosen as compared to the key sizes of 128 and 192 bits to better resist brute force attack.

On the actual day of staying, guest has the choices of either printing out the EQR key or storing it inside a mobile device as illustrated in Figure 3 to check-in using any SSK

Figure 3. Physical printed copy of EQR key. EQR: encrypted quick response.

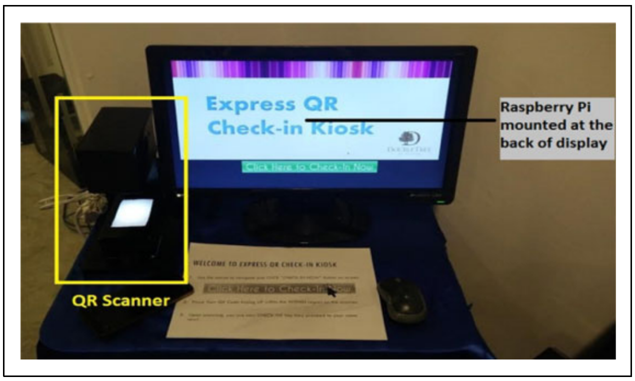

Figure 4. Prototype of the EQR check-in SSK. EQR: encrypted quick response; SSK: self-service kiosk.

located at the hotel through a simple tap-to-check-in interaction. Using the EQR key and SSK, guest can conveniently bypass any long queue at reception counter especially during holiday seasons. Figure 4 depicts a low-cost implementation of SSK using a standard monitor, a Complementary metal–oxide–semiconductor (CMOS) camera as QR scanner and a single-board computer known as Raspberry Pi (RPI) that is connected to a network module. Customized applications written in C code and python are run on top of Raspbian operating system within the RPI to scan and decode EQR keys. If valid EQR keys are determined by the SSK, it will check in guests via the network module through local area networks (LANs). By tapping an EQR key on the SSK's check-in panel, the embedded camera will capture the EQR key and pass it to the EQR decoder to obtain the OTP and access code. The processes of decoding an EQR key and checking-in a guest through an SSK are depicted in Figure 5. The QR reader within the EQR decoder first acquires the encrypted OTP and access code from the EQR key. Then, the decryption module extracts the concatenated OTP and access code using the passcode defined by the server administrator. After that, the decatenation module will start to segment out the OTP and access code. Both the segmented OTP and access code are subsequently sent to the check-in verification module residing at the hotel booking management system through LAN connection for checking-in a guest.

Upon receiving guest's OTP and access code, the check-in verification module retrieves the guest's check-in status and room information from the hotel database. If the access code is usable, then the guest check-in status is retrieved from the hotel database. However, if the access code is not valid, then the process will stop. If the check-in status reveals that the guest has already checked in, then the room information such as the room number, the associated floor plan and so on will be sent back to the SSK's display module and shown on the SSK's screen. On the other hand, if the check-in status indicates that the guest has yet checked in, then the received OTP is passed to the check-in module to update the guest's check-in status on the database. Once the check-in process is completed, the room information is sent back to the SSK's display module and displayed on the SSK's screen to assist guest in locating the reserved room.

Guests upon reaching their reserved room can unlock the door by tapping the EQR key on the EQR door panel installed outside the room as shown in Figure 6. The EQR door panel consists of a camera board module to capture EQR keys, an RPI for decoding EQR keys, a network module to communicate with the hotel server which authenticates guests and a BLE module that sends control signal to unlock the BLE motorized door lock. The requirement of operating the EQR door panel is a power supply of 5 V along with 2 A of current and can be connected to the hotel network through either LAN or WiFi. Whenever the CMOS camera detects an EQR key, it captures and passes the key to the EQR decoder that retrieves the guests' access code. The processes of decoding an EQR key, authenticating the guest and unlocking the door are summarized in Figure 7.

Similar to the check-in process, the encrypted OTP and access code are first acquired from the EQR key through the QR reader. Then, the decryption module is started using the passcode provided by the administrator to obtain the concatenated OTP and access code. After that, the decatenation module is initiated to spit the OTP and access code. Next, the access code and unique room ID are sent to the door authentication module residing at the hotel booking management system for guest authentication purposes.

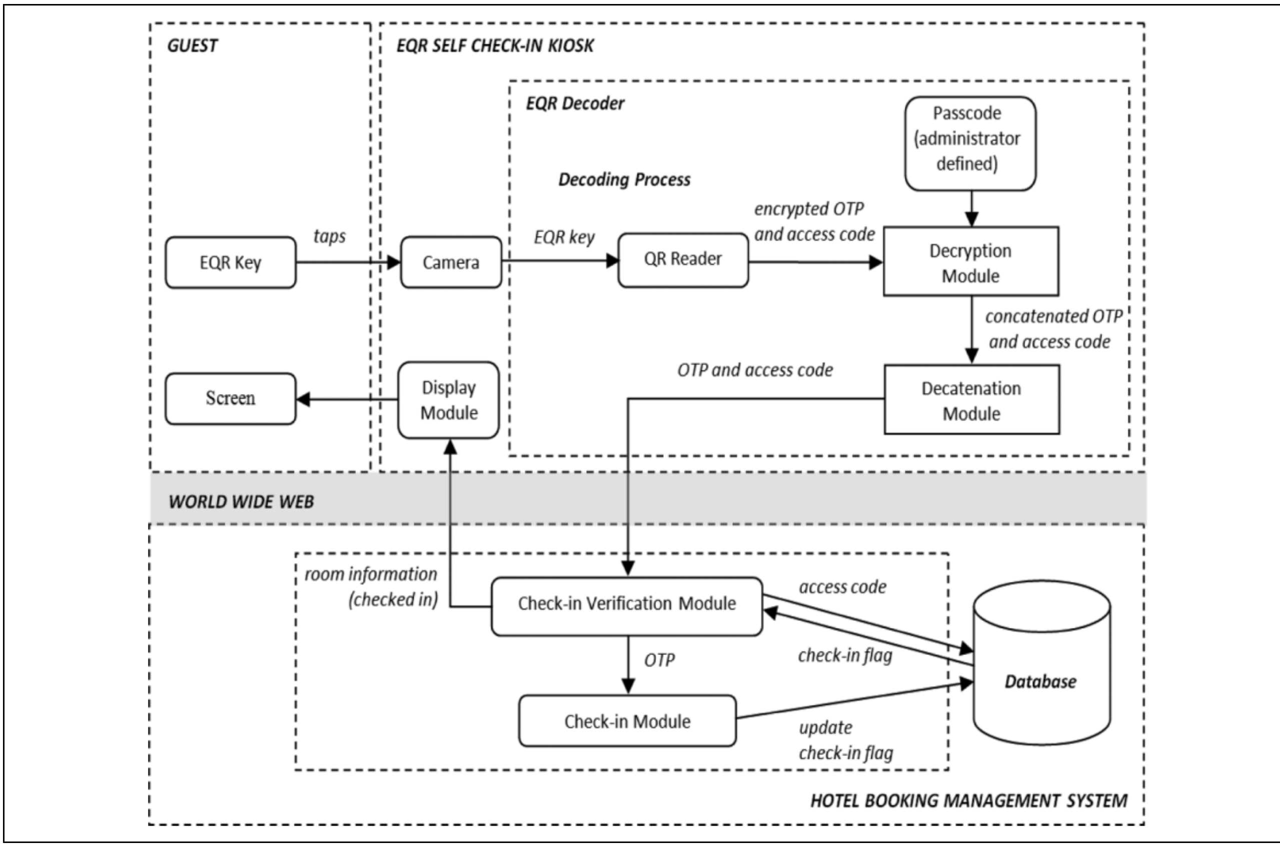

Figure 5. Processes of decoding an EQR key and checking-in guest with EQR SSK. EQR: encrypted quick response; SSK: self-service kiosk.

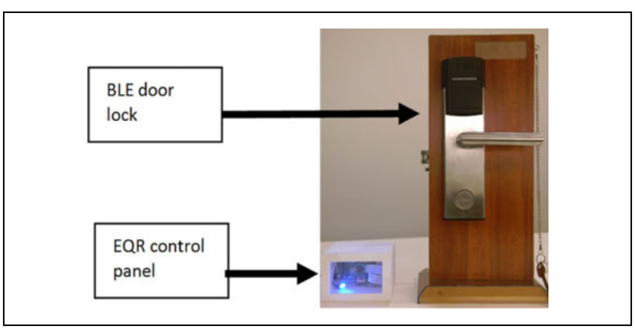

Figure 6. Prototype of the EQR door panel and BLE motorized door lock. EQR: encrypted quick response; BLE: Bluetooth low energy.

Once the door authentication module received an access code and room ID, it retrieves the guests' check-in status and room ID from the hotel database. If an invalid access code is provided or the check-in status shows that the guest has not checked in, the operation will end and the door remains locked. Otherwise, if the check-in status indicates that the guest has already checked in, the room ID retrieved from the hotel database is compared with the received room ID. If both are matched, an unlocking flag is sent back to the unlocking module located at the door panel through network connection. Finally, the unlocking module sends a control signal to BLE motorized door lock via BLE connection to unlock the door.

System evaluation and discussion

An evaluation was conducted at Digital Home, Multimedia University, to assess the perceived usefulness, perceived ease of use and behavioural intention to use the proposed system. The laboratory experiment was conducted in the bedroom setting of Digital Home, which was deemed appropriate to simulate the hotel room setting in the real environment (see Figure 8). Forty participants were recruited to participate in the experiment and evaluation. During the experiment, each of the participants was requested to check-in and unlock the room with the prototype of EQR check-in SSK. After the product-trial session, participants were required to complete a survey questionnaire.

In the survey questionnaire, seven-point Likert-type scale survey items were adapted from the previous studies of hotel check-in system[23,24] and are tabulated in Table 2. All survey variables were verified by reliability and validity. Reliability and validity of the variables were assessed using Cronbach's α and the average variance extracted (AVE). As shown in Table 3, all values of Cronbach's α and AVE met the desirable value, indicating that reliability

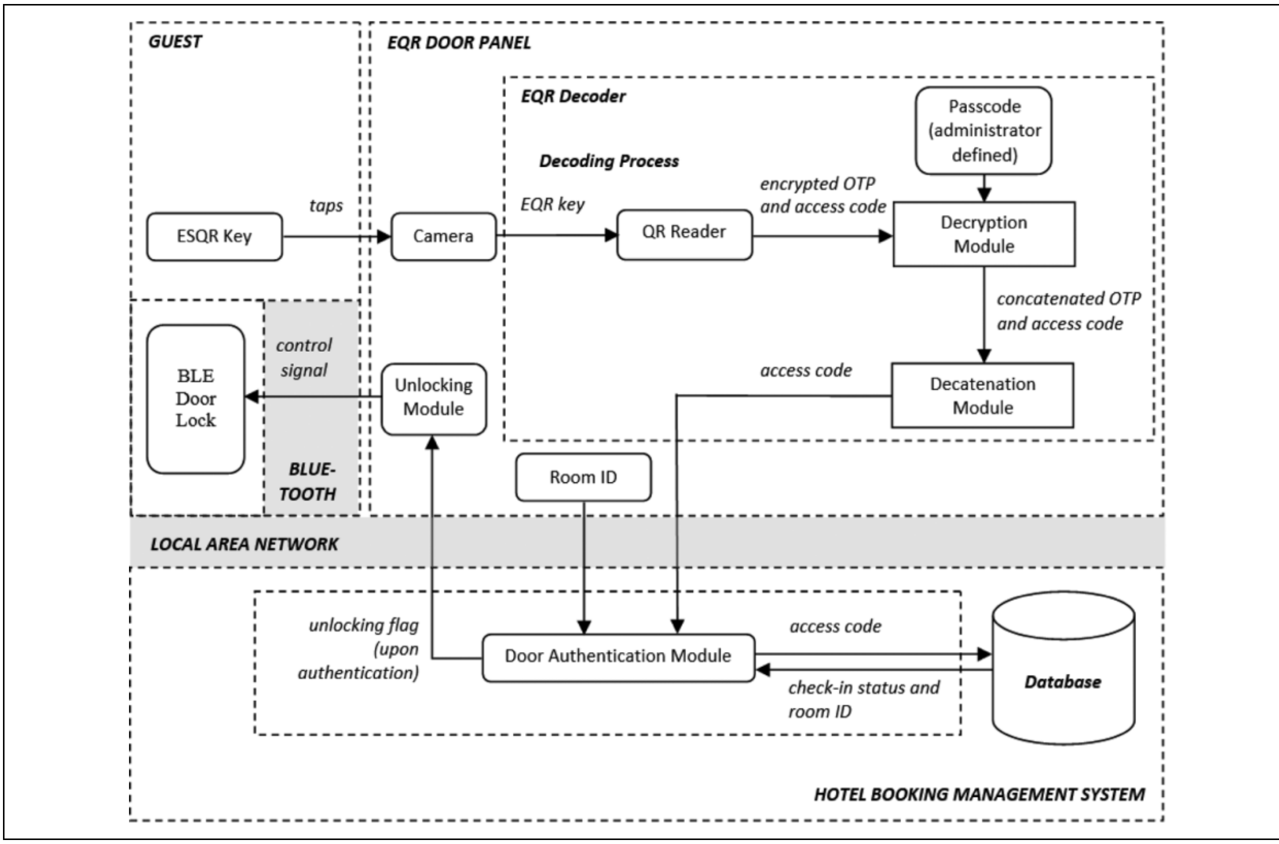

Figure 7. Processes of decoding an EQR key, authenticating guests and unlocking the BLE door. EQR: encrypted quick response; BLE: Bluetooth low energy.

Figure 8. Bedroom setting of Digital Home, Multimedia University.

and convergent validity were established. For discriminant validity, the square roots of the AVE values in each variable were compared with the correlation values between

Table 2. Items used to evaluate the EQR system.

Construct	Measure items
Perceived usefulness[23]	PU1: Using the check-in kiosk enables me to accomplish check-in more quickly. PU2: Using the check-in kiosk improves my check-in process. PU3: Using the check-in kiosk enhances my effectiveness on check-in to hotel.
Ease of use[24]	EoU1: Using the QR code at check-in kiosk requires little work. EoU2: Easy to get the kiosk to check-in with QR code. EoU3: Overall, QR codes are easy and convenient to use as check-in token.
Behavioural intention to use[23]	BI1: I will use the check-in kiosk rather than through reception counter to complete my check-in process. BI2: My intention is to use the check-in kiosk, which enables me to accomplish my check-in process more quickly. BI3: My intention is to use the check-in kiosk, which enables me to enhance my effectiveness on check-in process.

EQR: encrypted quick response; QR: quick response; PU: perceived usefulness; EoU: ease of use; BI: behavioural intention.

Table 3. Descriptive, reliability and validity analyses.

		Descriptive analysis		Reliability and validity	
Scales	Number of items	Mean	Standard deviation	Cronbach's α	Average variance extracted
Perceived useful	3	6.083	0.711	0.848	0.774
Perceived ease of use	3	6.092	0.830	0.690	0.633
Behavioural intention to use	3	6.100	0.709	0.898	0.836

Table 4. Correlation matrix of variables.[a]

	Perceived useful	Perceived ease of use	Behavioural intention to use
Perceived useful	**0.774**		
Perceived ease of use	0.483**	**0.633**	
Behavioural intention to use	0.397*	0.274	0.836

[a]Values in bold are square roots of the average variance extracted.
*Correlation is significant at the 0.05 level (two-tailed).
**Correlation is significant at the 0.01 level (two-tailed).

Table 5. Results of regression analysis.[a]

	Beta coefficient	Standard error
(Constant)		
Perceived useful	0.409*	0.188
Perceived ease of use	0.146	0.191
R^2	0.413	
Adjusted R^2	0.171	
F	3.808	
Significance	0.031*	

[a]Dependent variable is the behavioural intention.
*$p < 0.05$.

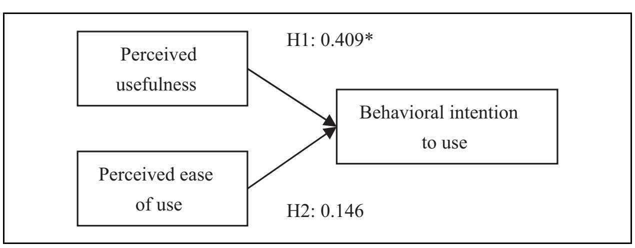

Figure 9. Results of evaluation.

two variables. As presented in Table 4, discriminant validity was confirmed as all the square roots of AVE values were greater than the off-diagonal values in the correlation matrix.

Multiple regression analysis was conducted to assess the research model. As shown in Table 5 and Figure 9, perceived usefulness ($b = 0.409$; p-value < 0.05) is found to have a significant positive relationship with their behavioural intention to use EQR system. However, perceived ease of use ($b = 0.146$; p-value > 0.05) has no effect on the behavioural intention. These results indicate that the proposed system is regarded as useful, and it leads to higher levels of users' intention to check-in and access room via the QR code. However, users' behavioural intention to use the self-service check-in kiosk at the hotel system was not influenced by perceived ease of use. The attribute of easy-to-use will be further examined by follow-on qualitative research to assess the users' requirement more closely.

Conclusion

This research work extends the boundaries of SSK technology capabilities by creating a new and secure EQR scheme, enabling guests to check-in and access to their rooms conveniently and securely. Numerous existing applications of SSKs have largely focused on using digital keys to check-in guests.[9] However, research on securing the digital keys in unifying the check-in process and access control system has been significantly neglected. The primary contribution of this research is the new innovative design of EQR scheme that utilizes cryptography technique and QR code to deploy a secure hotel check-in and access control system. From the viewpoint of convenience, the proposed system enables guests to conveniently check-in and unlock the doors through the EQR keys that they received digitally in advance. From the perspective of security, the encryption scheme provides a higher degree of security to hotel check-in and access control system. In short, the proposed system is an innovative cutting-edge solution that provides end-to-end security protection from check-in to unlocking the hotel rooms. More importantly, guests have the flexibility to use the EQR keys as printed copies or digitally stored inside their smartphones. The EQR hotel check-in and access control system has been deployed successfully to demonstrate its effectiveness. Two key issues surface from our system evaluation. First, our findings showed that users' intention to use EQR system is influenced by the attribute of usefulness. In practice, our research work contributes in the development of design principles and methodologies for developing a unified QR-enabled hotel check-in and access control system that is valuable for hoteliers. The proposed system has three research limitations that should be noted. First, although the process of check-in and unlocking hotel rooms has been unified through the EQR scheme, guests would need to check-in separately through SSK, then only can proceed to unlock the hotel room. Therefore, an integrated check-in and access control system is suggested for future work which enables guests to bypass the SSK and check-in in front of their hotel rooms while unlocking the doors simultaneously. Second, as the EQR scheme is built on top of the QR code, EQR keys inherited the shortcomings of QR code. For example, guests can duplicate the EQR keys using a camera. As such, intruders may use this approach to steal the EQR key from guest if it is not kept properly. Therefore, it is suggested for future research to include dedicated smartphone application to safeguard the EQR keys with password so that it is not easily accessible by unauthorized users. Lastly, this study only evaluated the EQR check-in SSK system. It is suggested for future research to conduct evaluations on SSK and SSMD and comparison studies regarding the processing time and successful rate between the proposed system and the conventional check-in system.

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Declaration of Conflicting Interests

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