International Journal of Engineering Research and Technology. ISSN 0974-3154, Volume 12, Number 11 (2019), pp. 1841-1846
© International Research Publication House. http://www.irphouse.com

Design and Implementation of a OTP-based IoT Digital Door-lock System and Applications

Joongjin Kook[1*]

[1]Assistnat Professor, School of Information Security Engineering, Sangmyung University, Korea.

**Corresponding Author*
ORCID: 0000-0002-0033-388X

Abstract

With the rapid increase in the proportion of single households, vulnerability to crime is emerging as a new social problem. Especially for single female families, the anxiety of stranger visitors is known as the biggest problem.

In this paper, we propose an OTP-based IoT door-lock system to enhance the security of digital door-locks. The system consists of a door-lock with features such as OTP password generation, lock remote control, image storage and live streaming, and a smartphone app with features such as real-time video monitoring, door lock control and event logging.

Keywords: Digital Door-lock, Door-lock, IoT, Security, OTP

I. INTRODUCTION

Recently, South Korea has seen the number of single households growing at a fast pace due to the economic crisis and changes in social structure, and as of 2019, the number of single-person households in the country is close to 29% of all households. Korea is rapidly transforming itself both socially and economically due to the weakening of traditional family values, the improvement of average education level, the increase of female participation rate in economic activities, and the entry of the baby boomers into the aged population [1].

Fig 1 shows the proportion of single-person households in OECD countries in 2013 [2].

In Korea, the increase in the number of single-person households has increased the demand and supply of houses for single-person households, and apartments such as small apartments, officetels[1], and studios are the main residential environments. The statistics on single-person households in Korea showed that for residents in their 20s and 30s, the proportion of small-sized homes under 50m^2 was high at 74.5% and 62.3%, respectively. The share of apartments such as multi-unit houses and officetels accounts for more than 80% [3].

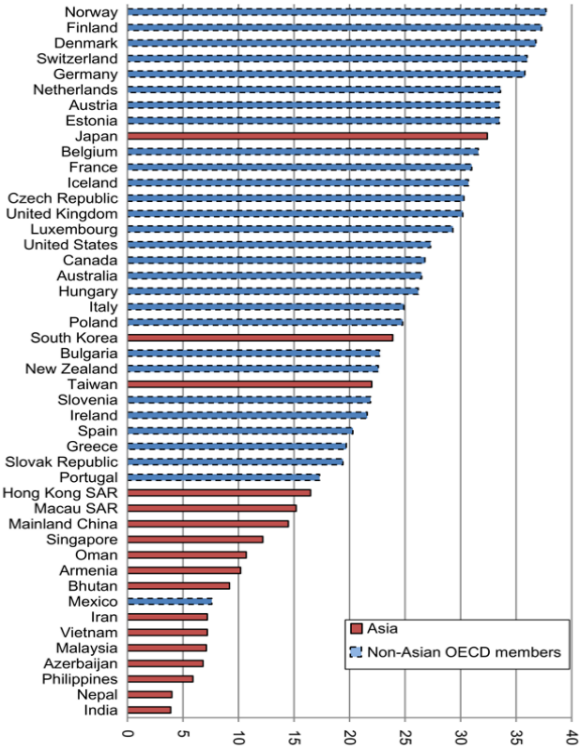


Fig 1. The Proportion of single-person households in OECD countries (Source: OECD (2013), United Nations (2014))

The increase in the number of single-person households is causing various new social problems. In particular, problems such as rescue activities in emergencies, housebreaking, and theft are serious [3].

The entrance doors to multi-unit houses, which are the main residential types for single-person households, are mostly composed of digitized common/individual entrance locks, and the authentication is done through passwords, RFID tags, and biometrics, etc. However, in most cases, passwords are often used for reasons of price and convenience, and password functions are basically provided even if they have RFID or biometrics. Therefore, it is necessary to pay extra precaution

[1] *Officetel* is a multi-purpose building with residential and commercial units in south Korea.

not to leak the password, and it is recommended to change the password periodically, but it is not done well due to the inconvenience and the insensitivity to security. The password of the door can also be leaked by the use of UV light or hidden cameras [4].

In this paper, we apply OTP (One Time Password) technology, which is against the password leakage, and the real-time monitoring function using the camera module to the password-type digital door locks, enabling to prevent the crime and relieve the anxiety to unfamiliar visitors. In addition, in order to have IoT functions, we study the design and the implementation of the IoT-based remote authentication door lock system, which can check the issuance/change of passwords, images and the event logs of digital door locks through the smartphone apps, and we develop the prototype.

II. RELATED WORK

Recently, major Asian countries such as Korea, Japan, and Hong Kong have seen the increase in the proportion of single-person households due to aging, late marriage, and nuclear family. It is rapidly changing socially and economically due to the weakening of traditional family values, the improvement of the average education levels, the increase in women's participation in economic activities, and the entry of the baby boom population into the aged population. As a result, the number of housing environments for single-person households such as studios, officetels, and small apartment has soared, and various new social problems occurs.

'The study on single-person households and crime occurrence' analyzed the effects of Seoul's population/ regional characteristics, especially among single-person households, on the five major crimes including murder, robbery, rape, theft and violence. The panel regression analysis was conducted using data from 25 autonomous districts in Seoul for three years from 2014 to 2016. According to the analysis, the number of five major crimes increased by 0.81% when the number of single-person households increased by 1%. Single-person households are more likely to be exposed to crimes than multi-person households, which can be attributed to the family disorganization and the weakening of social networks [5]. Also, women were 2.276 times more likely to be victimized by crimes than men [6].

Most apartments such as studios, officetels, and small apartments, which are the main types of residence for single-person households, are equipped with digital door locks at their common/ individual entrances, and visitors' authentication is performed through passwords. In the case of single-person households, O2O services combined with IoT technology and unmanned delivery services have been used in order to solve inconveniences when visiting outsiders such as home delivery or mail delivery while away from home [7].

The development of IoT technology and the spread of open hardware platforms have created an environment to produce various IoT project outputs, and the DDiT project implemented digital door locks using Arduino [8]. Arduino used in DDiT is used for the wireless communication with smartphone using bluetooth and the control of doorlocks, and requires a separate server for data exchange with a smartphone.

Major companies related to digital devices have released many products, and Samsung SDS released the SHP-DR900, which provides remote control and remote authentication [9]. SHP-DR900 prepares against the leakage of passwords by sending visitors-only access keys through smartphone apps. In addition, the company uses its own security technology to prevent information leakage and hacking. The data stored in door locks is encrypted with Samsung SDS's own algorithms, S-WBC (Samsung SDS-White Box Password). However, the product can send a password only to those who have installed the app using a dedicated mobile app, and monitoring function using a camera is not available.

KT's 'Giga IoT Door Lock' enhances security by preventing password leakage by setting different passwords for each user. Through the application, you can check the status of your entrance outside your home, and you can check the information of accessors such as who opened the door and when it opened. In addition, if an abnormal state is detected, a push notification is sent to the user [10]. However, the use of multiple passwords makes its management difficult, increases the likelihood of password exposure, and lacks real-time monitoring.

S1, which is well-known as an unmanned security system, supports the dispatching security system nationwide, and allows users to easily remove or resume the security services with NFC function on smartphones, and provides differentiated services through interactive safe services such as mobile patrol reports and criminal trends information. [11]. However, Si supports the dispatching system and needs to build several sensors for infrastructures, causing initial installation costs and continuous service costs.

Conventional digital door locks support biometric technologies such as passwords, RFID, Bluetooth, and fingerprints, but two or three of the methods are used to complement each other, rather than being used alone due to the risk of exposure. However, among them, passwords, which are the weakest method are commonly used. Keypads with a fixed numerical arrangement have security problems because numeric buttons frequently used worn out or they are exposed to UV rays. So, their safety against the password leakage has increased by using keypads that change the positions of numbers every time [12]. However, the resident's password is usually fixed and therefore it is vulnerable to the exposure of the password itself.

In this paper, we propose an IoT-based remote authentication door lock system using OTP to solve crime exposure damage, to relieve anxiety, and to offer the convenience of visit in absence. It consists of a door lock with functions such as OTP password generation, remote control of locks, image storage and real-time streaming, and a smartphone app with real-time video monitoring, door lock control and event logging. The IoT-based remote authentication door lock system proposed in this paper is expected to contribute to solving security problems and improving the quality of life for single-person residential environments for an increasing number of single-person residential environments by preventing password leakage using OTP passwords and resolving residents' anxiety using the remote monitoring based on real-time events and video monitoring. In addition, when abnormal behavior is detected inside or outside the home, a push message is sent to residents to enable real-time response.

III. OTP-BASED IoT DIGITAL DOORLOCK

III.I System Overviews

The OTP-based IoT digital door lock system consists of control systems, server, clouds, and mobile applications. Fig 2 shows the schematic of the whole system.

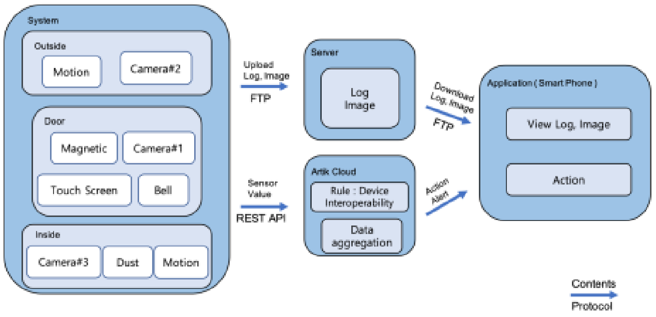


Fig 2. OTP-based IoT Digital Doorlock System

The control systems are subdivided into the door lock control system, the indoor control system, and the outdoor control system. Raspberry Pi 3 is used for the door lock control system and ARTIK7 module of Samsung Electronics is used for the indoor/ outdoor control system.

The door lock control system consists of a hall sensor that can check whether the door is opened or closed, a relay module to control the door lock. The indoor control system consists of PIR (Passive Infrared Sensor) to detect an abnormal behavior indoor/ outdoor the home, and the fine dust sensor to measure air pollution level in the house. The door lock control system consists of a touchscreen-based random keypad for users to input a password, and three camera modules to monitor CCTVs at the entrance, indoor and hallway. Each control system processes the measurements of the sensors and sends the values to smartphone applications. In the application, it is possible to know whether the door is opened or not and the air pollution level in the house in real-time, remotely monitor the images of CCTV, and remotely issue the one-time password of the door lock to a specific person in a similar way to OTP (One-time Password).

OTP (One-time Password) is a security system that uses a password that is frequently generated according to a particular algorithm, not a predetermined password, and is often used as a means for authentication in financial institutions. Google released Google Authenticator (or Google OTP) for authentication services using OTP [13].

The OTP technology in this system generates a random password in the application and sends it to the door lock to issue a one-time password that can be used for a certain time. For logging, detection records and photos are sorted in chronological order and stored on a server, which residents can check them through smartphone applications later on. In addition, it delivers push notifications according to sensor values (ring of doorbell, motion detection, door lock error, etc.). The interoperability for devices registered in the cloud can be guaranteed by using ARTIK Cloud's Rule. Through the setting of the threshold values for each sensor, it sends a push notification that can determine the security situations.

III.II OTP Generation and Authentication

Visitors can be divided into two types: authorized and unauthorized. Classify visitors who have promised with a resident in advance as the authorized. When a doorbell rings, the camera module built in the door lock captures the visitor and uploads the image file to the server. The resident checks the visitor's image stored on the server through the smartphone application, and generates and sends an OTP to the visitor through the application.

The generated OTP is sent to the door lock for immediate synchronization. When the synchronization is complete, the random keypad is activated to receive a password. When the visitor inputs the received OTP on the keypad, the password verification process checks whether the password input by the visitor is the same as the generated OTP. If the two numbers match, the door lock is set to open. If the two numbers do not match more than three times, the server records a log and sends a push notification to the residents through the ARTIK Cloud. The logs recorded on the server can then be checked in the smartphone application.

Unauthorized people are classified into those detected by the external motion sensors, those pressed the wrong password more than three times, and those detected by the internal motion sensors.

First, if the movement is detected for more than 10 seconds through the motion sensors, the camera takes a picture, and saves it on the server, and leave a log. The event information sends push notifications to the resident's smartphone via the cloud. If the door lock password is incorrect more than three times, a warning sounds, a camera takes a picture of the visitor and then sends a push notification to the resident via the cloud. Even if it is detected by the indoor motion sensor, it is processed the same as the outdoor sensor.

Algorithm 1

```
[Main procedure]
Initialization
Register callback for doorbell
Register callback for motion sensor
Register callback for doorlock
Register callback for camera
Standby

[Procedure doorbell]
if (ring a bell) {
    transmit event information to cloud and logging
}

[Procedure motion_sensor]
```

```
if (motion detected) {
  save detection time and accumulate count
  if (motion_count > MOTION_THRESHOLD) {
    transmit event information to cloud and logging
  }
}

[Procedure doorlock]
if (password mismatched) {
  accumulate mismatch count
  if (mismatch count > MISMATCH_THRESHOLD) {
    transmit event information to cloud and logging
    generate alert sound
  }
}

[Procedure camera]
if (receive a cam command) {
  if (SINGLE_SHOT) {
    take a picture and save
  } else if (STREAM) {
    streaming
}
```

Algorithm 1 shows the event-driven algorithm of an OTP-based IoT digital door lock system.

While the system is operating, the camera takes pictures indoor and outdoors to prevent accidents that may be caused by unauthorized persons inside or outside the home. This function acts as a CCTV and enables to remotely real-time monitor by requesting through a smartphone application.

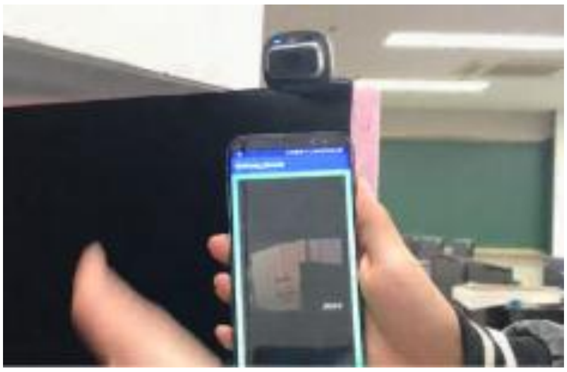
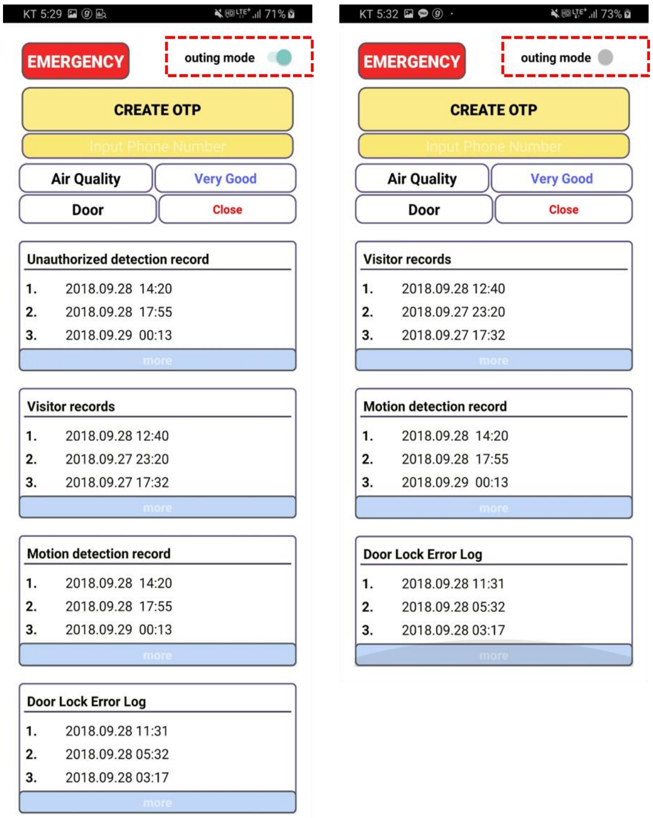


Fig 3. Realtime Remote CCTV

III.III Applications for Mobile Device

Smartphone applications provide OTP generation/ transmission, the air pollution level and door opening/ closing check, log check (non-authorization detection, visitor records, motion detection, door lock error records) and real-time monitoring. Fig 4 shows the GUI configuration and functions of smartphone applications.



KT 5:29 71%

EMERGENCY | outing mode

CREATE OTP

Input Phone Number

Air Quality	Very Good
Door	Close

Unauthorized detection record

1. 2018.09.28 14:20
2. 2018.09.28 17:55
3. 2018.09.29 00:13

more

Visitor records

1. 2018.09.28 12:40
2. 2018.09.27 23:20
3. 2018.09.27 17:32

more

Motion detection record

1. 2018.09.28 14:20
2. 2018.09.28 17:55
3. 2018.09.29 00:13

more

Door Lock Error Log

1. 2018.09.28 11:31
2. 2018.09.28 05:32
3. 2018.09.28 03:17

more

KT 5:32 73%

EMERGENCY | outing mode

CREATE OTP

Input Phone Number

Air Quality	Very Good
Door	Close

Visitor records

1. 2018.09.28 12:40
2. 2018.09.27 23:20
3. 2018.09.27 17:32

more

Motion detection record

1. 2018.09.28 14:20
2. 2018.09.28 17:55
3. 2018.09.29 00:13

more

Door Lock Error Log

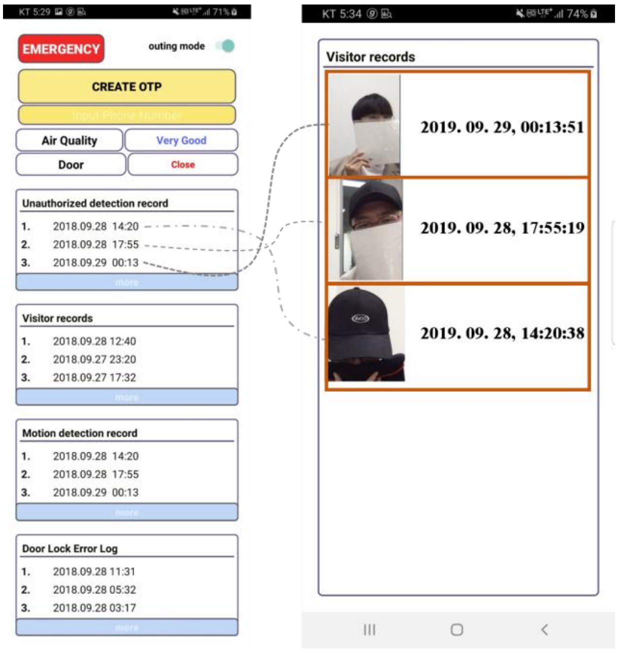
1. 2018.09.28 11:31
2. 2018.09.28 05:32
3. 2018.09.28 03:17

more

Fig. 4. Smartphone application GUI and functionalities

The outing mode can be activated when a resident goes out. When the system is in the outing mode, the motion sensor in the home is. In this case, if an abnormal behavior is detected, a push notification that there is a possibility of unauthorized and illegal access is immediately sent to the resident. This record is stored in the 'PIR' list and can be checked in the application. If the resident receives a push notification and determines it as a dangerous situation, he/she can immediately sends the notification to a security company or a designated number by pressing the emergency button at the top left of the application.

As for OTP generation, when you input the OTP recipient's phone number in the *Phone Number Input Field* in Fig 5, and click the 'Create OTP' button, a one-time password for the visitor is issued. In this case, the security of OTP was considered by setting a password through a random number generation algorithm based on Linux's entropy pool. If the door lock is opened with the generated OTP, the existing OTP is deleted, and if the OTP is not used, the door lock password cannot be used after a certain time. The resident may use a designated password rather than an OTP, which can be set remotely by the resident in the application.



Unauthorized detection record
1. 2018.09.28 14:20
2. 2018.09.28 17:55
3. 2018.09.29 00:13

Visitor records
1. 2018.09.28 12:40
2. 2018.09.27 23:20
3. 2018.09.27 17:32

Motion detection record
1. 2018.09.28 14:20
2. 2018.09.28 17:55
3. 2018.09.29 00:13

Door Lock Error Log
1. 2018.09.28 11:31
2. 2018.09.28 05:32
3. 2018.09.28 03:17

Visitor records
2019. 09. 29, 00:13:51
2019. 09. 28, 17:55:19
2019. 09. 28, 14:20:38

Fig. 5. Unauthorized Visitors on Outing Mode

Through the smartphone app, you can check the air pollution level measured by the fine dust sensor installed in your house in real-time. You can check the door opening/closing by attaching magnetic sensors to the door to prevent crimes that may occur due to door opening that residents do not recognize.

When motion sensors attached outdoors detect an abnormal behavior for more than about 10 seconds within the detection range, they determine him as a stranger and immediately capture using the camera, and send a push notification to the resident. The detected records and photos can be checked in the application's *Unauthorized Detection Record*.

When a doorbell rings, the camera module attached to the door takes a picture. You can check this photo and the time it was taken in the application's Visitor Record.

If the generated OTP or the given password is different from the door lock password more than three times, the resident receives a push notification and checks the application's *Door Lock Error Log*.

V. EXPERIMENTS AND RESULTS

In order to verify the functions of the system proposed in this paper, we set up the system in houses and conducted the experiment by distinguishing the roles of residents and visitors.

First, when a visitor rang a doorbell, a push notification was sent to a resident. The time required for issuing and transmitting OTP was slightly different depending on the network conditions, but it took about 1 second or less. The resident's smartphone application allows the user to check the event log related to the door lock and sensors in real-time, and the camera images to be remotely streamed in real-time.

If the visitor pressed wrong passwords more than three times, a camera immediately captured it, and a push notification was sent to the resident, and the photos and records were stored in the application in a time sequence.

Upon detecting movement in front of the door for more than a specified time (10 seconds), a push notification was sent to the resident, and the photos and records were uploaded normally in the application.

The keypad was randomly placed every time, and the function of modifying the password of the door lock through the application in preparation against the password exposure also worked normally, and the door was able to be opened and closed with the modified password.

In addition, when the application was activated in the outing mode, the motion sensors in the house were operating normally, and a push notification was sent to the resident. Through the application, the detection records and photos could be checked and images of CCTV in the house were monitored the in the real-time.

VI. CONCLUSION

In this paper, we designed an IoT-based remote authentication digital door lock system using OPT and implemented a prototype using Samsung Electronics' ARTIK module and Raspberry Pi. In addition, we developed a smartphone application for the management and control of the system, enabling to issue OTP to visitors and make him/ her check the situation inside and outside the house in real-time.

This system allows single-person residents to relieve the anxiety caused by the password leakage and unforeseen visitors, making solve the growing social problems occuring in single-person households.

Later, this system needs to be placed in single-person households and to be compared with various existing products, in order to verify how effective it is in increasing the convenience and relieving the anxiety.

It is expected that this system not only contributes to relieving the anxiety about the social safety for single-person households, but also be applied to various sharing economy platforms such as lodging facilities and personal lockers (vault, warehouses, garages, etc.)

REFERENCES

[1] HeeKyung, S., 2017, “The analysis of Solo Economy,” 2017 Research Report part 2, Statistics Korea, pp. 153-173,.

[2] Wei-Jun, J. Y., Adam, K. C., 2015, “Living alone: One-person households in Asia,” Demographic Research, 32(40), pp. 1099-1112.

[3] Report of the Single-person household of South Korea 2018, KB Financial Group Inc.

[4] A four-door passcode can be set in 10 minutes, http://www.mrtt.news/news/articleView.html?idxno=1479

[5] Anti-spying Kit for a Digital Door-lock, http://news1.kr/articles/?2782470

[6] Jeehyun, K., 2017, "Korean Crime Victimization Survey," Korean Criminological Review, 28(2), pp. 287-320, 2017.

[7] Wikibox, http://wikibox.kr

[8] Daegyu, S., Hanshin, G., Yongdeok, N., 2015, Design and Implementation of Digital Door Lock by IoT, KIISE Transactions on Computing Practices, 21(3), pp. 215-222.

[9] Samsung SDS SHP-DR900, https://smarthome.samsungsds.com/doorlock/product/view?prdId=137&searchWord=&searchPrdType=SD&searchCateId1=4&searchCateId2=0&locale=ko

[10] KT IoT Door-lock, Korea Telecommunications, https://shop.kt.com/iot/prodGigaIotDoorlock.do

[11] S1 , https://www.s1.co.kr/service/service01_02.do

[12] Hidekey, https://www.wadiz.kr/web/campaign/detail/10995

[13] Google OTP, https://github.com/google/google-authenticator