DESIGN AND IMPLEMENTATION OF FACILITY MANAGEMENT SYSTEM USING IOT TECHNOLOGY OF 4TH INDUSTRIAL REVOLUTION

[1]JAEEUN SEO, [2]NARAE JEONG, [3]JAEJOON KIM

[1,2,3]School of Computer and Communication, Daegu University, Korea

E-mail: [1]sjeun2003@naver.com, [2]yusinnr@naver.com
[3]jjkimisu@daegu.ac.kr (Corresponding author)

ABSTRACT

In our research, the user/client may feel inconvenienced for utilizing a facility based on current or past administration process. Because of this inconvenience, we designed and implemented smart facility management system with a digitalized new technique, Internet of Things, for comfortable and convenient use of digital door locked facility. The proposed system can make a reservation and use a facility via smartphone application. In H/W configuration, digital door lock is attached by Arduino and WiFi modules. The user's smartphone application can communicate between Apache server and WiFi module and Web Server which consists of PHP. Finally, the user can easily open and close the door lock through the application, and the facility can be used more conveniently. Furthermore, the user can conveniently manage the user information and the reservation history by using the HTML web page. In addition, the proposed system can be used for minimizing the loss of user's privacy information.

Keywords: *IoT, Arduino, Wifi, Android Studio, Facility Management System*

1. INTRODUCTION

Recently, with the development of network and internet technology, the Internet of things (IoT) is supplementing ubiquitous technology and this allows things to connect to the Internet and exchange information [1]. The Internet of Things is one of the core technologies of the 4th Industrial Revolution. Many companies are interested in investing and developing technologies using IoT and applying the technology to many products used in our life. Therefore, the Internet of things technology should continue to develop, spread and become universal, and various services will be applied in industry [2]. However, because existing facility management systems are performed through key or ID cards, users may feel uncomfortable using a smooth facility due to key or ID card loss. In addition, there are many inconveniences and difficulties in managing facilities with access security and problems with facility damage.

We developed and implemented a digitalized and smart facility management system by applying IoT to door lock facility [3]. The biggest advantage of our system is that the user can schedule the usage of the facilities through the smartphone application and can control the door lock. In addition, by simplifying the previous administrative procedure for accessing the facilities, it will reduce inconveniences of the administrator.

Our facility management system can establish a webpage to confirm user's information and reservation history, and it can help users to solve problems such as access security of facilities and equipment damage by granting authority to users. Users can easily open and close door locks through smartphone applications without lending or returning keys so that facilities can be conveniently used. In addition, direct management of the administrator is reduced and the labor cost can be saved because the reservation and use of the facilities are performed automatically.

Therefore, the facility management system that combines the Internet of things can be used efficiently and conveniently in various places such as hotels and laboratories. Section 2 briefly discusses the related works for WiFi and Arduino technology. Section 3 describes the proposed system including H/W and S/W implementation. Sections 4 and 5 conclude the paper by discussing experimental results, future works and other possible solutions.

2. RELATED WORK

2.1 Doorlock Control Using WiFi

Recently, methods for controlling door locks have been diversified in NFC tag [4], Bluetooth [5], fingerprint recognition, and face recognition in order to maximize convenience and enhance security [6][7]. The Near Field Communication (NFC) is one of radio frequency identification (RFID) technologies that allow data communication at short distances. It has a function to control the door lock using a card with an embedded NFC tag and there is no need to use a password. The door lock control using Bluetooth was developed by detecting the Bluetooth and automatically opening the door lock near the door lock. Bluetooth has cost effective, lower power consumption than WiFi technology [8][9].

However, there are many misused cases in use of NFC card because it can be easily copied and used when it lost [10]. Since mobile phones that do not use NFC functions have to use NFC cards, WiFi is preferred over NFC in our research due to inconvenient to use this system. Bluetooth is widely used because it connects with many peripherals without using wires. Therefore, it is difficult to implement high-level encryption and authentication, which can lead to various risks. In our research, we developed a door lock system using WiFi instead of NFC and Bluetooth. Although WiFi has a disadvantage of higher cost and somewhat complicated configuration, it is superior to NFC and Bluetooth in terms of functionality.

Table 1 summarizes overall specification for NFC, Bluetooth, and WiFi technology and Figure 1 shows the evolution of communication technology depending on data rate and communication distance. In Table 1, Bluetooth has a bandwidth of 800 Kbps, while WiFi has a bandwidth of 11 Mbps, which is much higher than Bluetooth. In addition, the NFC is about 10 [cm] in the communication distance, and it is about 5-30 [m] for the Bluetooth's case. In the case of the class 2, which is usually used for the Bluetooth industrial product, the maximum communication distance is 10 [m]. Compared to NFC and Bluetooth, WiFi has a much wider communication range of 32-95 [m] for 802.11b/g. Today's smartphones use 802.11ac, which has a much wider range of communication bandwidths and channel bandwidth than 802.11b. The transmission speed is about $0.1 \sim 0.85$Mbps for NFC, 24Mbps for Bluetooth, and 600Mbps for

WiFi. In our research, door locks are controlled through the flow of information in the database. As a result, we have utilized WiFi technology with high bandwidth, high transmission rate and high bit rate. Especially, in our reservation system, it is important for preventing access by people other than the reservation person for the security reason. Therefore, we use WiFi technology, which is more secure than Bluetooth.

Door lock control using biometrics such as fingerprint recognition and facial recognition has a heavy burden on costly parts and there is a big disadvantage that it is impossible to recognize when the recognition part is damaged or slightly changed.

Table 1: The Overall Comparison for NFC, Bluetooth and WiFi [11].

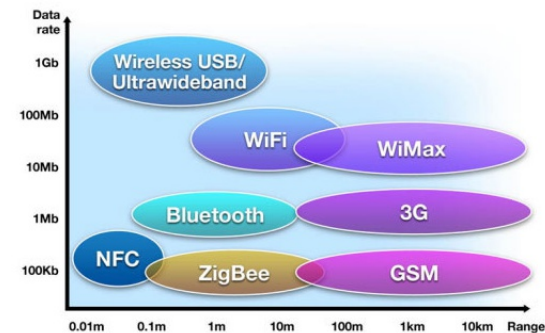|	NFC	BLUETOOTH	WiFi
Telecommunications system	P2P		
Price	LOW	MIDDLE	HIGH
Range	10cm	10m	100m
Speed	0.1~0.85Mbps	24Mbps	600Mbps

Figure 1: Communication transition via data rate and range [11],[12]

2.2 Arduino

Arduino is an open source based microcontroller developed by Arduino Software. Because it is open source, it is easy to write the source modification and access hardware. Most main controllers are of the Atmega series. Table 2 summarizes the types and specification for Arduino which are widely used [13].

In our research, we utilized WiFi module that can take advantage of open library sources supported by Arduino software. Table 3 shows the type and specification of the WiFi module.

Table 2: The Specification of Various Arduino Board [14].

Spec \ Name	Uno	Due	Simple	Pro mini
Processor	Atmega328	AT91SAM3X8E	Atmega328	Atmega168
CPU Speed	16MHz	84MHz	8MHz	16Mz
Operating Voltage/ Input Voltage	5V/7-12V	3.3V/7-12V	2.7V-5.5V	5V-12V
Digital IO/PWM	14/6	54/12	9/4	14/6
Analog In/Out	6/0	12/2	4/0	6/0
USB	Regular	2	-	-
UART	1	4	-	1

Table 3: The WiFi Shield and Module [15].

Spec \ Name	Official Wi-Fi Shield	CC3000 Wi-Fi Shield & Module	ESP 8266 Wi-Fi Module
Voltage	5V	5V	3.3V
Processor speed	2.4-2.497GHz	11Mbps+18dBm	80-160MHz
Size	55X53X11mm	60X53X12mm	30X10X11mm
Cost($)	$110	$70	$6

In Table 3, the esp8266 model was developed using a small-sized product that can be mounted on a door lock at a low cost.

3. PROPOSED SYSTEM

In modern society, the ways of opening doors of digital door locks are becoming very diverse. Among them, the method of inputting the password, the method using the NFC tag, and the method using the fingerprint or face recognition are representative. However, because of several problems in security reason, fingerprint and face recognition are often inconvenienced [16]. One of the biggest advantages of digital door lock control using APP is that it does not need any password or door lock control card since smartphones are almost always carried and used. With simple membership registration process, users can open and close the door freely in their desired space and time as well as having excellent security using smartphone application.

Figure 2 shows the overall structure of the system implemented in this paper. Part APP communicates with the PHP module in Part WEB and PHP module communicates with MYSQL module, HTML module, and WiFi module of Part DoorLock. Part DoorLock consisting of Arduino module and Wi-Fi module communicates WiFi module of Part WEB. The Arduino receives a signal from WiFi module and turns the door lock of facility on and off. It only receives the signal and is unable to transmit it elsewhere. .
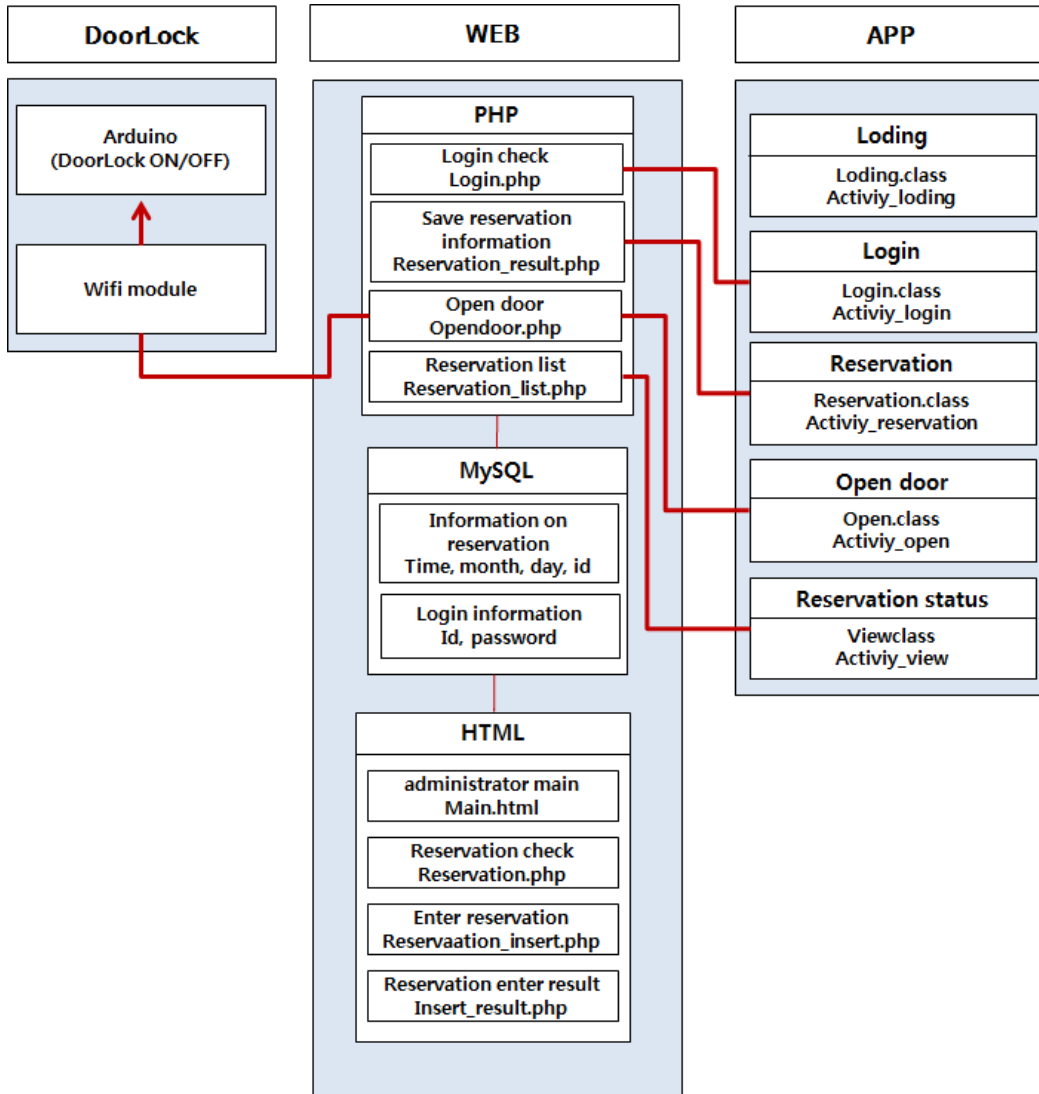
Figure 2: System Configuration Diagram of The Proposed System

3.1   H/W Configuration

In order to control the digital door lock, we adopted an open source computing platform based on a microcontroller board and C language as the control language. For communicating two systems between client (smartphone) and Arduino component, it requires a WiFi module. We can connect WiFi module to Arduino by setting up WiFi module in Arduino program. On connecting the switch line of the digital door lock to the Arduino, it does not open or close even though we press the door open/close button of the digital door

lock. As a result, open/close function of the digital door lock works only on smartphone application.

Figure 3 shows a brief overview of the process by which a user opens and closes a door lock using a smartphone. When the user opens and closes the door lock using the smartphone application, the application of the smartphone and web server communicate with each other, and the door can be opened and closed by transmitting signals to the door lock Arduino through the WiFi module.
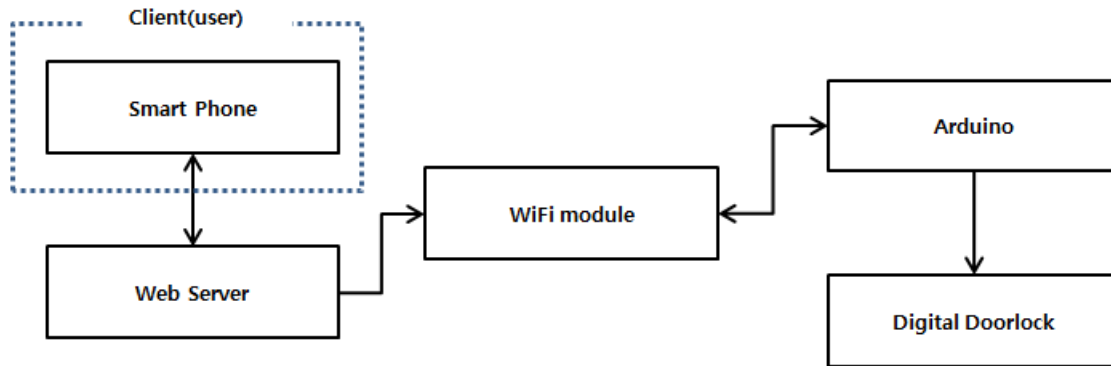
Figure 3: The Block Diagram for Door Lock's Opening and Closing Process

3.1.1 Arduino component

Since 2005, the various developments of Arduino have been created and applied worldwide. The most commonly used product name is Arduino Uno. However, due to the disadvantage of too much space in the digital door lock manufacturing process, we used the Arduino pro mini, which is a compact and easy to install product. The Arduino pro mini can be attached to the rear of the digital door lock without needing to create separate space, thus it is cost effective.

The Arduino pro mini model is smaller in function than other models. First, since USB for uploading is not supported, USB to UART module that enables communication with PC by using serial communication device. Second, since it does not support the DTR function, so users have to press the reset button every time when they upload a necessary PC program. We used FTDI (FT23RL) which satisfies both of these requirements. Once we upload the PC program to Arduino pro mini using FTDI and are followed by disconnect it, you can attach the Arduino pro mini to the digital door lock alone.

3.1.2 WiFi module

We used a typical WiFi esp8266 for our WiFi module. The WiFi esp8266 is a revised wireless module based on the esp8266 serial WiFi module and can be controlled via two serial ports (TX, RX). By connecting the WiFi esp8266 to the Arduino and setting IP address to PC program, all communication between the smartphone application, the webserver and the digital door lock is enabled.

Each of the modules described in Figure 2 can only communicate with each other using the same

IP address. However, since the IP address assigned to each module is different and can change depending on the situation, the communication error may occur. In order to solve this problem, we used port forwarding to communicate by opening a specific communication port. In our research, we set up an external IP address, not an internal IP address, to enable communication of each module.

3.2   S/W Configuration

We have used PHP as the S/W web language to implement the proposed system [17]. PHP has the advantage of being easy to use, easy to work with the database, and high efficiency at low cost [18]. The database part that manages booking information and login information is MySQL. Our proposed system has key roles for security since all access processing is performed through the user's booking information, especially, for door lock facility MySQL is one of the widely popular databases in the industry and is constantly being updated to improve performance and vulnerability. MySQL is also easy to manage, easy to integrate with PHP, and has good backup and restore capabilities. The web server used in our paper is Apache which is a popular free web server and can be used on most of operating systems. We used XAMPP software to solve interoperability issues and conflicts. Android platform was used as a mobile platform and Android Studio is free and less restrictive than Object C [19].

3.2.1 Database module

The reservation and visiting history management are performed via database information. In our research, we created a list of the information that should be stored in the database defined by experimental case. Figure 4 and Figure 5

are database formats required for reservation information for our implementation. Figure 4 consists of the user information database table. In each data field configuration, the format of the implemented data field such as userid, userpw, name and phone is used by VARCHAR, which is a character type of 15 bytes. The gender is set to 11 bytes and has the INTEGER format.

In each data field structure of Figure 5, userid is set to a character type with 15 bytes, while month, day, and time are set to an integer. The database fetches and exports reservation information at the request of PHP. The booking information should have an indirect access via PHP for security of the database. In addition to the reservation information, the database has a function for storing visitation history. It can also import and export information via PHP.

Figure 4: Database configuration of user information

Figure 5: Database configuration of reservation information

3.2.2   PHP module

Opening and closing door locks, user information and privileges, confirmation of reservation information, and confirmation of visit records are made only through PHP module. On communicating reservation information and user

information to Android studio, communication parameters are transmitted by using POST method which receives information. In PHP module, reservation information, user information and authorization, door lock opening and closing, and confirmation of visit records are all performed for requiring database information. Therefore, the user can access the database using the SQL statement to retrieve user information, reservation information, and visiting history information. The opening and closing of the door lock is performed after confirming the user's authority. When the user presses the door open button of smartphone application, the user confirms the reservation information stored in the database of PHP module and is given permission to access the door. Opening and closing of doorlock is carried out through the IP address defined by in the WiFi module and the operating electric current can be sent to the Arduino pin using Javascript language. In our research, we designated Arduino pin to 13 arbitrarily.

3.2.3   HTML module

Figure 6-(a) described the configuration of the administrator page, and Figure 6-(b) is the main page of the administrator page. A query button (★) of Figure 6-(b) can confirm the booking, including information and user information and booking history. The user can register reservation information by pressing registration button (★★). The administrator can directly manage the reservation information, the user information, and the visiting history via the administrator page. The administrator page is in HTML format, and it is processed by PHP module and displayed on the administrator page when the administrator inquires the reservation information, user information, and the visiting history through HTML.

(a)

Reservation Management

★Inquire(Request)

★★Registration

(b)

Figure 6: The Screen Shot for (a) Configuration of Administrator Page and (b) Reservation Management page

3.2.4 Application

When users use this system, they can reserve facilities and open and close doors via smartphone applications. Figure 7 shows the operation flow on smartphone application. The loading part shows the start screen to display the APP and after a delay of 2 seconds, it moves to login screen. With entering necessary information such as ID, password, date, and time, reservation screen is transmitted to PHP. The login information can be logged in PHP after checking the database ID and password in PHP, and the reservation information is stored in the database via PHP. When you press the Open Door button, user information is sent to PHP. After PHP confirms the reservation information and user information, the user is authorized to access the door. .

4.   EXPERIMENTAL RESULT

We used Evanet EN-200T as our door lock for the experimental implementation. On reviewing the control principle of the doorlock, the door remains closed when the current flows in the doorlock. Instead, the door is opened when the current is cut off. The switching wire was soldered and connected to Vcc and GND of the Arduino.

4.1   Arduino

We installed a program called Arduino pro mini to connect a serial communication device called FTDI and uploaded our application program.
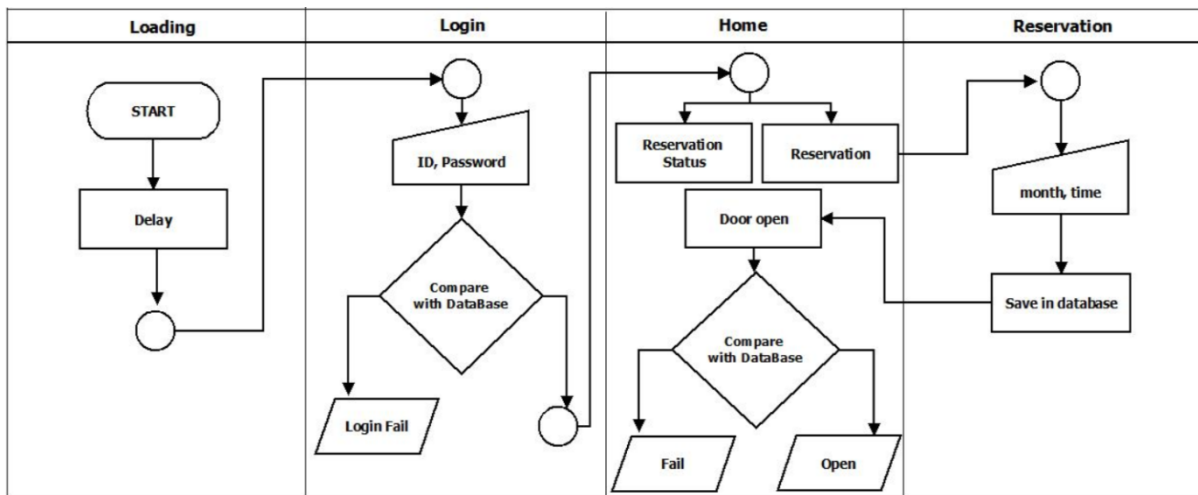

Figure 7: The Operation Flow on Smartphone Application

We programmed the membership information and the reservation time on the web server and installed Arduino pro mini to connect a serial communication device called FTDI and upload our application. Figure 8 shows the connection between the Arduino pro mini and the LED before connecting to the doorlock. We checked the control of turning on and off the LED when the button created in the webserver was pressed.

After confirming the LED turned on and off freely via data communication, it was connected to the switch line of the door lock. The smartphone application sends the data to the web and it compares current time and reserved time to the webserver. When these times are matched, a signal is sent to the specific port connected to the specific switch line.
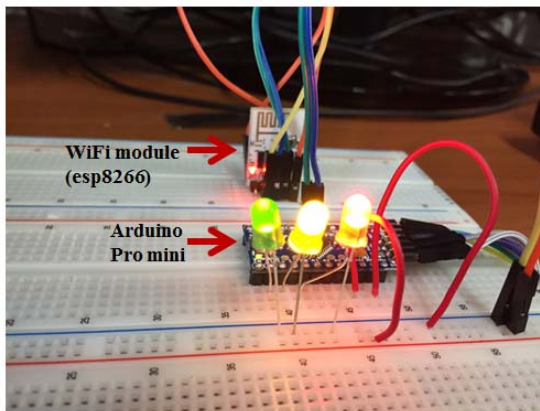

(a)

(b)

(c)

Figure 8: Checking the Operation of door lock Using LED

4.2   WiFi module

The WiFi module should write the source code in the PC's Arduino program. In order to set up the WiFi connection, it needs to open the serial port and complete the response as shown in Figure 9. Figure 9-(a) identifies the initially assigned IP address status and Figure 9-(b) shows a list of WiFi networks. Figure 9-(c) shows the input of the name and password for WiFi connection and Figure 9-(d) shows the connected status with designated WiFi. Using personal hotspot of user's smartphone, it can figure out WiFi connection with hotspot's name and password as shown in Figure 9-(d).
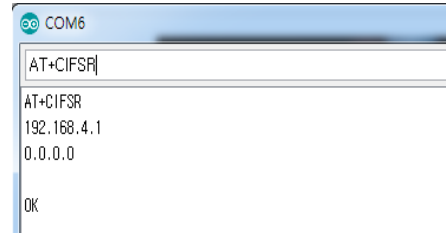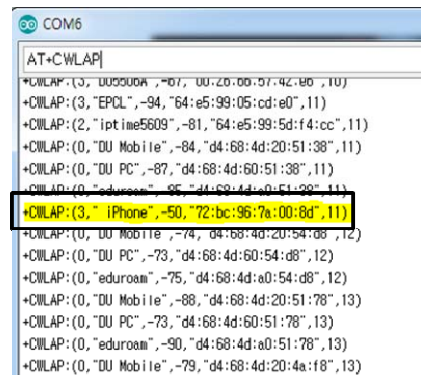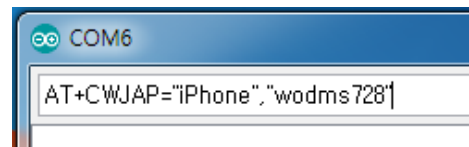
(d)

Figure 9: The Procedure for Wi-Fi Connection.

4.3   Smartphone Application

Because it is an Android studio application, we can run it Android smartphones or tablet PCs. Figure 10 shows operation results of the smartphone application. When login is performed from the login screen shown in Figure 10-(a), the main screen is displayed as shown in Figure 10-(b). The reservation information value has been stored in the database when the user clicks the reservation request after selecting the transfer date, time, and date on the reservation screen of Figure 10-(c) and (d). When using the facility, the door lock can be opened and closed with the door open button in the main screen of Figure 10-(b).

(c)

(a)

(d)
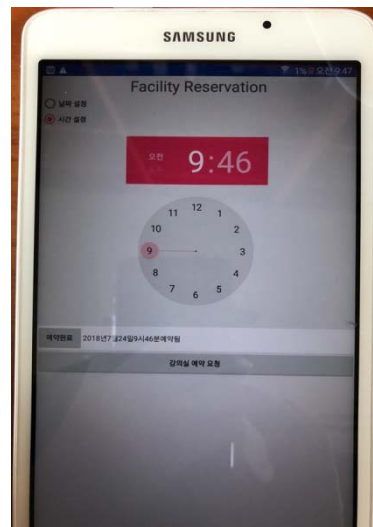
Figure 10: The Android Application

(b)

When the user's login information is input, the administrator can manage the reservation on the reservation management page as shown in Figure 11. In the main screen of Figure 11-(a), by clicking inquiry (request), it moves to the inquiry screen of Figure 11-(b). In the main screen of Figure 11-(a), it moves to the registration screen of Figure 11-(c) by clicking register. In the registration screen of Figure 11-(c), the administrator can register the reservation without using the APP for administrator's direct management.
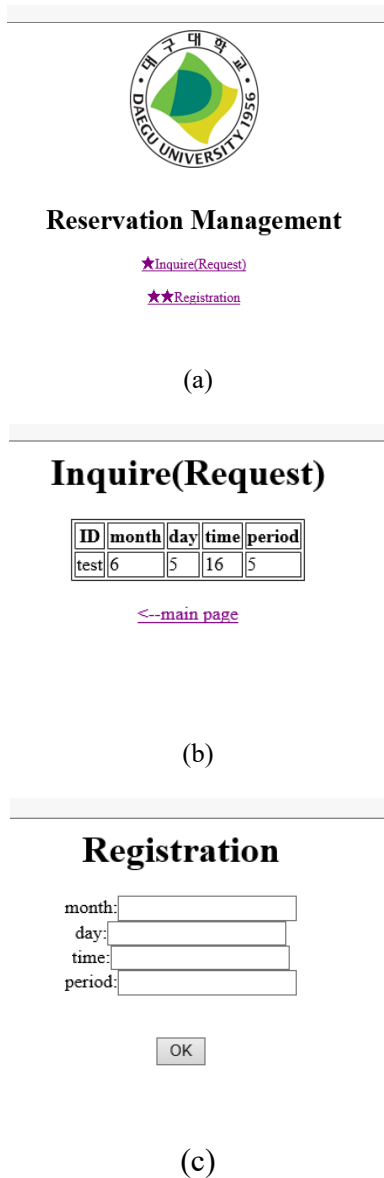
Reservation Management

★Inquire(Request)

★★Registration

(a)

Inquire(Request)

ID	month	day	time	period
test	6	5	16	5

<--main page

(b)

Registration

month:
day:
time:
period:

OK

(c)

Figure 11: The Screenshot for Reservation Management

Figure 12 shows how the door lock works using the application. In Figure 12-(a), when the open door button is pressed, Android studio passes the user information to PHP module in the smartphone application with POST parameter values. When the user information is checked and compared to the current status, the door open button is activated and the door lock is opened as shown in Figure 12-(b).
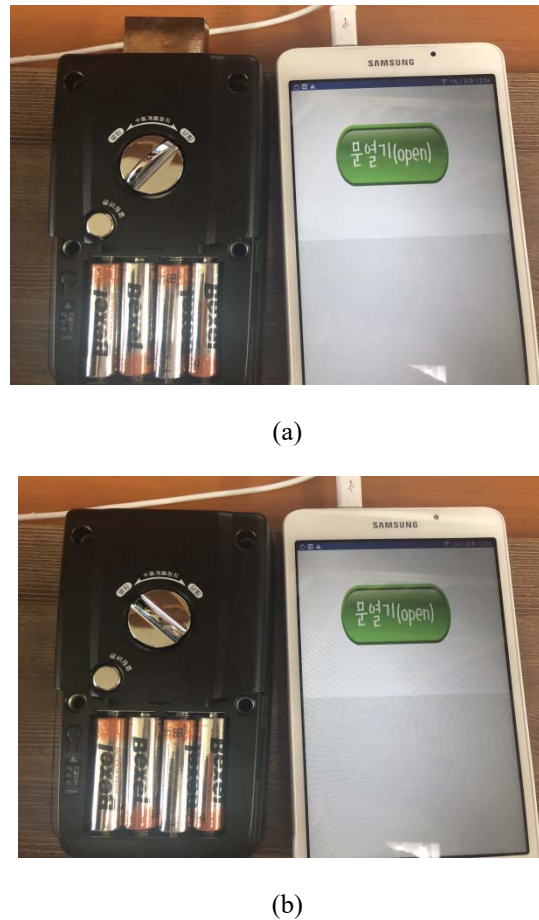

(a)

(b)

Figure 12: The Doorlock Status - (a) Closed without pressing Open Button, (b) Open with pressing Open Button.

5.   CONCLUSION

In this paper, we propose a facility management system which uses a smartphone application for the door lock system. The facility management system can control the door lock by attaching the Arduino and a converter to current digital door lock. For data communication, the operating information can be transmitted from the web to the Arduino by attaching the WiFi module. The user can open and close the facility through the smartphone application, and the administrator can manage the reservation information through the web page.

Our system has several differences from existing facility management systems. First, the door lock can be controlled by wireless digital key. Users do not need keys from the administrator and can conveniently access the door by using the smartphone application alone. Second, since the

existing digital door lock system utilizes password, it needs hardware with installed door lock with password system. Therefore, an IoT combined facility management system can be operated through a smartphone application. Finally, because the user's right to use the application's digital key is given according to the reservation, anyone who is unauthorized cannot access a facility and this makes it superior in terms of security. By applying IoT technology to reservation system, reservation system was established only through Web, app, and door lock, excluding all analog things. This research accomplished a system suitable for the IoT era that allows people who feel uncomfortable with the existing analog system to use the facility very conveniently and allows administrators to conveniently manage it through a computer.

Therefore, the facility management system that combines the Internet of things can be used efficiently and conveniently in various places where people frequently access and where security is required such as hotels and laboratories. In future works, we will work to apply various advanced technologies to the facility management system such as biometric information. In addition, we can advance our work further if an Arduino is embedded in the existing door lock, it can be developed into a built-in door lock system that can use the Internet of Things. In the future, the login process will be further strengthened by adding face recognition function that utilizes the Arduino module to the login process. Currently on the market, Apple, Samsung and others all include face recognition function, making it convenient to use this system without adding functions. Strengthening the login process through face recognition will enhance the security of the entire system. Once Arduino is built into an existing door lock, it can be developed into an IoT built-in door lock system that can be used in homes and companies by designing a reservation system that one wants.

ACKNOLEGEMENT

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