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Comparative Evaluation of NFC Tags for the NFC-Controlled Door Lock with Automated Circuit Breaker

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***Abstract*— In the age of automation where almost all household appliances are having the term "smart", the need for a secured door system together with an automated circuit breaker is indeed a must have for being in the trend. With the use of the NFC technology, entering door hassle-free without countless keys and open any door with just a tap of a single card is possible. The NFC-Controlled Door Lock also comes with an automatic circuit breaker that activates when a person entered, and it deactivates when the person exits therefore reducing power costs due to idle appliances. Moreover, 4 NFC tags/cards were tested for its detection speed and distance to determine the most suitable tag to be used. The system prototype is evaluated, and it is 100% accurate when recognizing and authorizing an NFC card. It also comes with a database that records the person who enters and exits the room which is accessible easily thru a browser-based database.**

Keywords*— *Near Field Communications (NFC), NFC Data Exchange Format (NDEF), Automated Circuit Breaker, Room Security.

I. INTRODUCTION

According to NFC Forum, Near Field Communication (NFC) is a standard-based short-range wireless connectivity technology that makes life easier by making smartphone more convenient for consumers around the world [1]. The versatility of NFC technology was very wide that it can be used as a form of contactless payment, sharing of digital content, and etc. [2] As the conquest and expansion of the modern technology transform and progress, researchers have seen NFC as a secure type of communication which is used as a contactless credit card engraved in smart phones because of its speed and security [3]. On the other hand, a comprehensive survey was made by [4] and found that mass of people including consumers and retailers do not accept the technology for a few reasons. Since NFC technology are used in contactless payment systems, customers think twice before buying by using their smart phones, people are now concerned about their bank account details, as well as they are doubtful of its security.

People in the university placed their equipment, tools and devices in a certain room for safe keeping. Traditional room security uses a mechanical lock that does not tell us who uses the room, also; the key for the mechanical lock can be duplicated. Professors, including some of the students, can access those rooms if they have a key. People tend to blame, based on intuition, when their things had gone missing and as a result, this can cause some sort of misunderstandings. Person in charge in the classroom often forgot to switch off the lightings when they leave. Some people also forgot to switch off the air-conditioner and other devices. Leaving these devices, an air-conditioner for example, for one or more day will result in over consumption of energy, large amount of greenhouse gas emission, and deterioration of equipment [5].

This study focuses on the improvements of classroom security of ECE department, and to conserve energy by using the sub-circuit breaker system to manage some of the important equipment's. By improving the security, it will aid the faculty members of knowing who the faculty in charge in a specific classroom at a specific time. Managing the power supply of the appliances via sub-circuit breaker will conserve energy whenever someone forgot to turn off any devices. To do that, the proponent needs to develop a room security with an automated circuit breaker using raspberry pi integrated with a near field communication module. To make such thing happen, the group needs to write a program using python that runs multiple tasks and an Arduino program to communicate with it, a database system that keeps track of every entry and exit in the room, a thorough selection of NFC tag by means of research and experimentation, and as well as designing a circuit that will drive the motor in the door lock for automation and a circuit that will trigger the on and off state of the sub-circuit breaker.

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II. Related Literature

This section presents the past studies using NFC Technology, the implementation of NFC in the Philippines, and the application of NFC in security locks.

Maestro, Zapata, & Dela Rosa [6] developed a system that uses NFC Technology to provide a record of time keep of a faculty and save it to the database through android app. The Android application was used to read the data from the NFC card then it will be used to connect in the database for the storage of data and the record of the time of the employee.

Zay, et al., [7] focused on the smart environment of the researcher's university by implementing NFC Technology for attendance monitoring system. The researcher's created an NFC-based monitoring system application wherein the information of the students' body is stored in their NFC compatible phones. The strong point of this project is there is not much time being consumed unlike the traditional attendance system, while its weakness is the need of NFC compatible phones of the students.

In [8], a door lock system based on NFC identification of the smartphone was designed that can both recognize a smartphone ID and avoids detection of unauthorized devices. Meanwhile, in [9], a smartphone's NFC-based door lock system can be operated in 3 modes which are through single button, the numeric keypad and a teaching guide provided by the smartphone app.

III. Methodology

A. Hardware Developments

The main idea of the study is to create a prototype smart lock, specifically made for the university classroom, which allows a professor to access it by using NFC tag. The Input-Process-Output and the Block Diagram of the project are shown below.

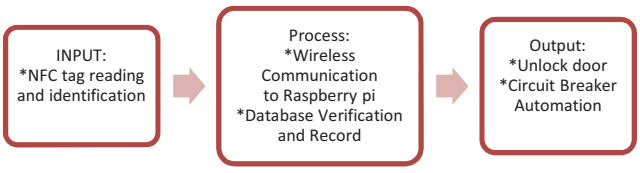

Fig. 1. The input, process, and output of the project.

The input of the project is encrypted information data of the professor that will be feed into the raspberry pi. The raspberry pi will then receive the information while the database will verify if the data is authorized. The lock/unlock door and circuit breaker automation will be the final output.

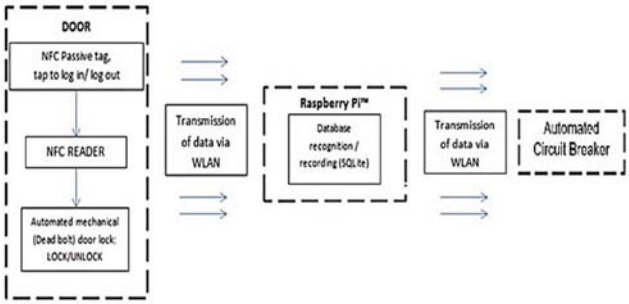

Fig. 2. The proposed block diagram for the prototype.

To further explain the IPO, figure 2 shows the Block Diagram, the system has three main stages: Detecting and reading of NFC tag at the door, processing of information authorization at the Raspberry Pi, and the automated circuit breaker. The output of the system is activation of door lock as well as the automated circuit breaker.

The following are the materials will be utilized for the systems design and structure:

i. Raspberry Pi™

This study uses a Raspberry Pi™ module, since it is a mini-computer itself, it will act as a central control of the authorization and decoding process of information.

ii. NFC Tag/Reader

In this research, the NFC tag/reader that is more suitable for secured data transfer was properly selected; this is done through the means of experimentation as well as comparing the specifications of each individual component. The NFC PN532 Breakout Board was implemented as a reader; it is the most widely used NFC chip in project prototyping. It can read and write tags, depending on the library that is supporting the chip. This NFC PN532 breakout board is mainly used as an NFC card reader. The following NFC tags were tested for its detection speed and distance Type 1- Topaz 512, Type 2 – NXP 215 & NXP 216, Type 4 – DESFire EV1. The most suitable tag among the three tags are determined to be used in the study; Type 3 were not included in the list due to its limited commercial availability.

iii. NodeMCU ESP8266

NodeMCU was chosen as the microcontroller of the system. This device was also used as the communication media between Raspberry Pi and NFC controlled door

lock because it has an ESP 12E that can connect to the Wi-Fi and can act as a microcontroller as well.

iv. Deadbolt Lock

Traditional deadbolt locks were used because doors installed in the classrooms are best suited with this kind of door locks since incase of system failure it can be easily overridden by simply using a key or switching the knob inside.

v. Automated Circuit Breaker

The specific purpose of this automated-circuit breaker is to reduce the stand-by power consumption that typically consumes 10-15W per device. Since the prototype is wirelessly controlled, a circuit was designed that controls its on/off state.

vi. WLAN Repeater

Since Raspberry Pi 3b has a specification of built in 802.11n wireless LAN, the need of WLAN repeater for extending the range of signal is needed.

vii. Servo Motor

The servo motor serves as the *opener* of the NFC controlled lock. A circuit was designed that controls the servo motor for the automation.

viii. 3D Printed Chassis

The chassis of the project were printed part by part using a 3D printer with a PLA filament. The 3D printers were available for students in the Center for Engineering Design, Fabrication, and Innovation of the College of Engineering, Technological University of the Philippines which were donated by Department of Science and Technology (DOST).

B. *Software Development*

i. Programming Language

The software of the prototype was developed using Arduino IDE for subsystems, Python for its main system, and MySQL for the database.

ii. Software Structure

The overall system flowchart is shown below:

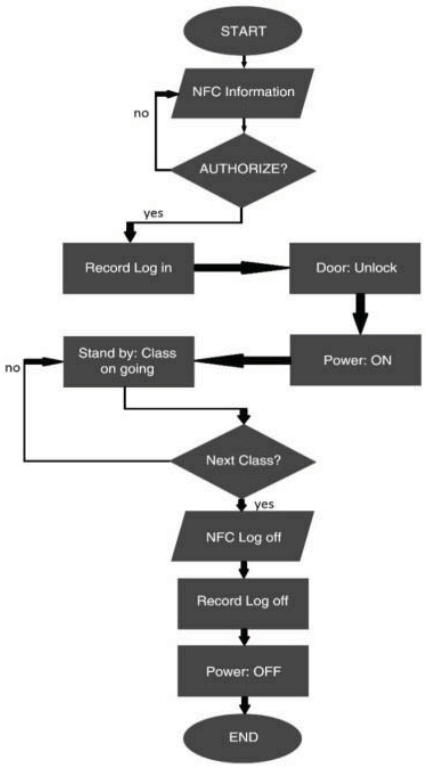

Fig. 3. The overall system flow chart.

At the start, the NFC card will be read by the NFC reader; if the card that is detected is authenticated then proceed, if not then read again. In proceeding block, after the authorization has been confirmed, the system will record the log, will open and on the automated door lock and circuit breaker respectively. If the professor is done teaching, then tap again the card to the reader and it will and the automated door lock and automated circuit breaker will be close and switch off.

C. *Testing Procedure*

Before testing the whole program for the NFC controlled door lock, the researcher has tested which tags were the most suitable for usage. The tags were tested by its detection distance with the Elechouse PN532 NFC module as well as its orientation whether it is horizontal, vertical or diagonally placed and tapped in the system. Since NFC is known for its short distance communication less than 10cm, the proper selection of NFC tag is still needed to match its specifications to the application of it in this study. For the measurement of detection distance, three trials were conducted according to its orientation, each for the available tag types; type 1, type 2 and type 4.

i. Testing the NFC Tags

The testing used the 3 NFC tag types, Elechouse PN532 NFC module and an Ultrasonic sensor. The ultrasonic sensor served as the distance measurer for the testing procedure.

ii. Database Testing

The database stores the data coming from the ESP8266 clients. Each NodeMCU was assigned to four rooms of ECE Department, which are the Department Office, the Graduate Programs Room, Accreditation Room, and COE 43. The group tested their ability to communicate with other.

iii. Authentication Accuracy Test

The group tested the accuracy of the authentication ability of the NodeMCU. Each authorized and unauthorized tag has been scanned.

IV. Results and Discussion

A. *Hardware Results*

i. The NFC Controlled Door Lock Prototype

The front and back of the device are to be shown; also, the function of its parts.

a. Frontal/Exposed View

1. Battery Indicator – The function of battery indicator is to show what current level of charge the battery has. Each LED means a 25% percent of a battery charge, hence, if all the LED is ON then it is 76% to 100%, if only three LED from the bottom is lit, it is 51% to 75%, if two LED is ON then it is 26% to 50% and so on.
2. Protective Cover – protects the interior of the device from dust and other external interruptions.
3. Nuts, Bolts, and Plastic Latch Hook – If the user unhooked the plastic latch, he or she can then manually operate the deadbolt lock.
4. Back of the Servo Motor – This means that the servo motor that automates the deadbolt lock is detachable.

b. Internal of the Device

1. Threaded Hole – To attach the NFC controlled door lock, the proponents need to screw the device on the door and to do that a threaded hole is needed.
2. Charging Port – In case the battery is out of charge, the user will only detach the protective cover, no need to screw out the whole device.

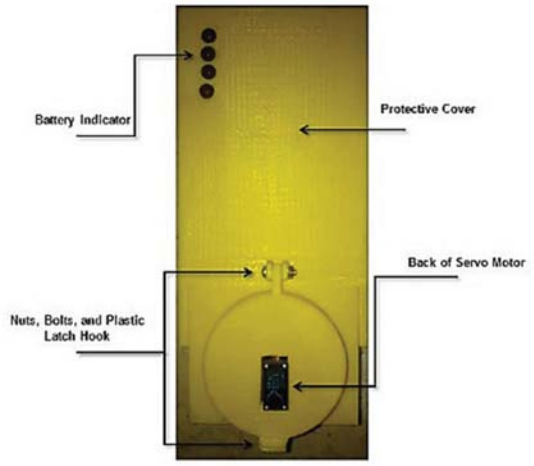

Fig. 4. The frontal/exposed view of the prototype with the lable of parts

3. Regulator – Since the voltage of the battery is too much for the components to handle, the regulator controls excess voltage supplying only 5V output for the components.
4. PN532 Breakout Board – The PN532 Breakout Board reads the incoming information from NFC tags or cards. It can be said that this is where you put your input to produce the specified output.
5. NodeMCU – The nodeMCU is the device that will be deciding of whom is authorize and is not. This component also sends the serial number of the authorize person to the database.

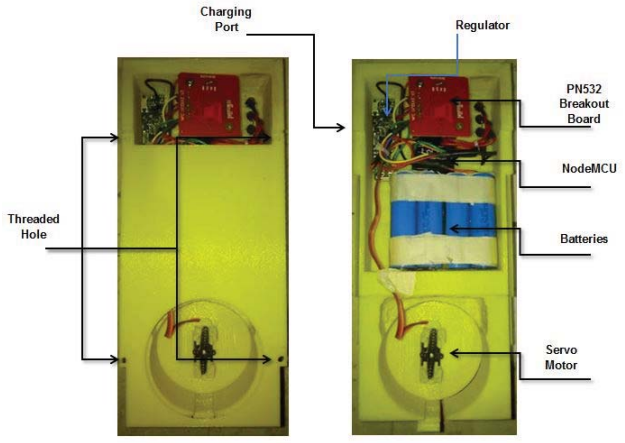

Fig. 5. The internal view of the prototype with its part and functionality.

6. Batteries – It is a lithium ion battery and it acts as a supply for this stand-alone device.
7. Servo Motor – With the aid of 3D printed support, the servo motor is now the responsible for the automation of the deadbolt lock. It can be said that this is the final output of all components.

All in all, a code has been written to control the servo that was attached on the knob of the door lock to be able to control its locked/unlocked function and to control the switches of the sub-circuit breaker. If the scanned tag is authorized, the servo will turn from 0° to 90°. The servo motor is then connected to the NodeMCU. On the other hand, the sub-circuit breaker is wirelessly connected to the NodeMCU. Its communication and triggering function operate like that of the servo motor. After reading a registered tag, the sub-circuit breaker will latch open/close.

B. Testing Results

i. Testing the NFC Tags

The proponents tested the different NFC tags and have come up to these results shown below.

TABLE I. NFC TAGS/CARDS SUMMARY OF RESULT

Tag type	Data format	Orientation (Parallel to the module)	Mean Range (cm)	Mean Time (ms)
NXP MIFARE DESFire EV1	NFC Forum Type 4	Vertical	2.70	124.00
		Horizontal	2.60	139.90
NXP MIFARE (Ultralight C) – NTAG215	NFC Forum Type 2	Vertical	5.00	148.40
		Horizontal	4.10	173.40
NXP MIFARE (Ultralight C) – NTAG216	NFC Forum Type 2	Vertical	6.00	98.00
		Horizontal	5.20	197.90
NXP MIFARE Classic 1k	N/A	Vertical	2.70	162.90
		Horizontal	2.60	90.00

The type 2 tags specifically the NXP 215 / 216 were the best to use with the Elechouse PN532 NFC module for it offers distance up to 6.00 cm that is enough to be detected within the width of the door. Unfortunately, type 1 tags, Topaz 512, aren't compatible with the Elechouse PN532 module for it cannot be detected at all.

While other tags like the Mifare Ultralight 1k and EvE Desfire offers detection distance less than 2.70 cm therefore it is not suitable for the said project because the signal will not penetrate in the door itself.

i. Database Testing

This subsection shows the result of the database, the data from the NFC cards were recognized and has been recording at the databases. Table II and III represents the rooms with installed prototype tested.

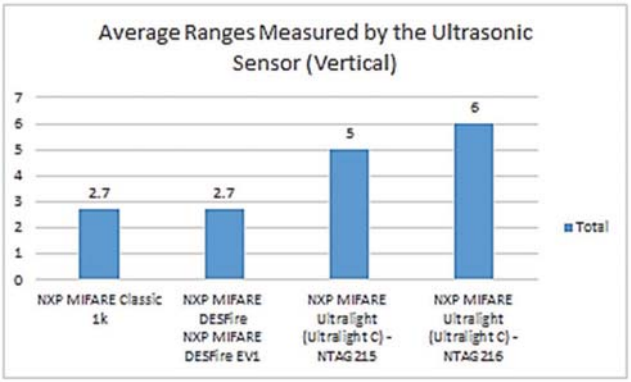

Fig. 6. Mean Ranges(Vertical)

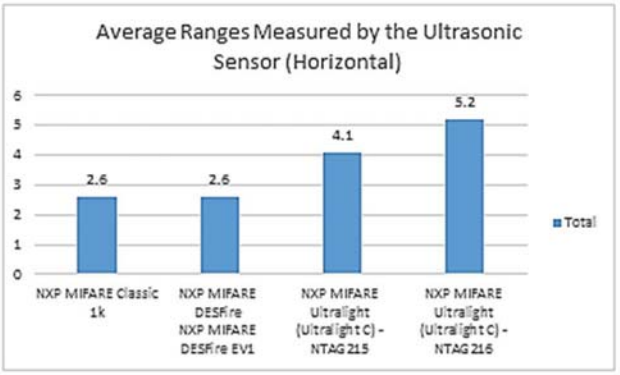

Fig. 7. Mean Ranges(Horizontal)

TABLE II. DATA RECORDED FROM ROOM A

last_name	first_name	nfc_serial	room	date ▲ 1
ALBA	YUGEL RUDOLF	326012036	GRAD	2018-02-07 18:01:23
AMADO	TIMOTHY M.	325346052	GRAD	2018-02-07 18:03:30
AQUINO	AARON U.	327119876	GRAD	2018-02-07 18:04:30
ARAGO	NILO M.	326133636	GRAD	2018-02-07 18:05:38
FERNANDEZ	EDMON O.	326156676	GRAD	2018-02-07 18:06:09
GALIDO	EDGAR A.	325200388	GRAD	2018-02-07 18:07:15
JORDA	ROMEO L., Jr.	323808900	GRAD	2018-02-07 18:07:45
MADRIGAL	GILFRED ALLEN	324331652	GRAD	2018-02-07 18:09:22
PADILLA	MA. VICTORIA	324233732	GRAD	2018-02-07 18:09:53
PUNO	JOHN CARLO	325269508	GRAD	2018-02-07 18:11:47
THIO-AC	AUGUST C.	323725956	GRAD	2018-02-07 18:12:22
TOLENTINO	LEAN KARLO S.	324466436	GRAD	2018-02-07 18:13:30
VALENZUELA	IRA C.	324135044	GRAD	2018-02-07 18:14:05
VELASCO	JESSICA S.	322988292	GRAD	2018-02-07 18:14:59

TABLE III. DATA RECORDED FROM ROOM B

last_name	first_name	nfc_serial	room	date ▲ 1
ALBA	YUGEL RUDOLF	326012036	DEPT	2018-02-07 18:02:13
AMADO	TIMOTHY M.	325346052	DEPT	2018-02-07 18:03:04
AQUINO	AARON U.	327119876	DEPT	2018-02-07 18:04:40
ARAGO	NILO M.	326133636	DEPT	2018-02-07 18:05:33
FERNANDEZ	EDMON O.	326156676	DEPT	2018-02-07 18:06:16
GALIDO	EDGAR A.	325200388	DEPT	2018-02-07 18:07:10
JORDA	ROMEO L., Jr.	323808900	DEPT	2018-02-07 18:07:51
MADRIGAL	GILFRED ALLEN	324331652	DEPT	2018-02-07 18:09:11
PADILLA	MA. VICTORIA	324233732	DEPT	2018-02-07 18:09:58
PUNO	JOHN CARLO	325269508	DEPT	2018-02-07 18:11:41
THIO-AC	AUGUST C.	323725956	DEPT	2018-02-07 18:12:30
TOLENTINO	LEAN KARLO S.	324466436	DEPT	2018-02-07 18:13:24
VALENZUELA	IRA C.	324135044	DEPT	2018-02-07 18:14:10
VELASCO	JESSICA S.	322988292	DEPT	2018-02-07 18:14:53

ii. Authentication Accuracy Test

The data as shown below tells that the prototype project is 100% accurate in recognizing and authorizing an NFC Card.

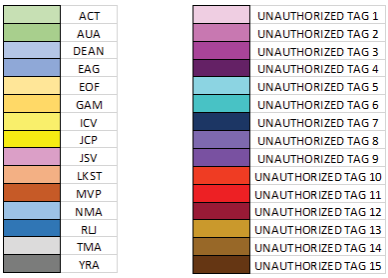

Fig. 8. Legends

TEST 1		
Trial	Authorized Tags	Unauthorized Tags
1	UNLOCKED	NO ACTION
	LOCKED	NO ACTION
2	UNLOCKED	NO ACTION
	LOCKED	NO ACTION
3	UNLOCKED	NO ACTION
	LOCKED	NO ACTION
4	UNLOCKED	NO ACTION
	LOCKED	NO ACTION
5	UNLOCKED	NO ACTION
	LOCKED	NO ACTION
6	UNLOCKED	NO ACTION
	LOCKED	NO ACTION
7	UNLOCKED	NO ACTION
	LOCKED	NO ACTION
8	UNLOCKED	NO ACTION
	LOCKED	NO ACTION
9	UNLOCKED	NO ACTION
	LOCKED	NO ACTION
10	UNLOCKED	NO ACTION
	LOCKED	NO ACTION
11	UNLOCKED	NO ACTION
	LOCKED	NO ACTION
12	UNLOCKED	NO ACTION
	LOCKED	NO ACTION
13	UNLOCKED	NO ACTION
	LOCKED	NO ACTION
14	UNLOCKED	NO ACTION
	LOCKED	NO ACTION
15	UNLOCKED	NO ACTION
	LOCKED	NO ACTION

TEST 2		
Trial	Authorized Tags	Unauthorized Tags
1	UNLOCKED	NO ACTION
	LOCKED	NO ACTION
2	UNLOCKED	NO ACTION
	LOCKED	NO ACTION
3	UNLOCKED	NO ACTION
	LOCKED	NO ACTION
4	UNLOCKED	NO ACTION
	LOCKED	NO ACTION
5	UNLOCKED	NO ACTION
	LOCKED	NO ACTION
6	UNLOCKED	NO ACTION
	LOCKED	NO ACTION
7	UNLOCKED	NO ACTION
	LOCKED	NO ACTION
8	UNLOCKED	NO ACTION
	LOCKED	NO ACTION
9	UNLOCKED	NO ACTION
	LOCKED	NO ACTION
10	UNLOCKED	NO ACTION
	LOCKED	NO ACTION
11	UNLOCKED	NO ACTION
	LOCKED	NO ACTION
12	UNLOCKED	NO ACTION
	LOCKED	NO ACTION
13	UNLOCKED	NO ACTION
	LOCKED	NO ACTION
14	UNLOCKED	NO ACTION
	LOCKED	NO ACTION
15	UNLOCKED	NO ACTION
	LOCKED	NO ACTION

Fig. 9. NFC Cards/Tags Accuracy test

V. CONCLUSION

NFC compared to RFID is more practical when it comes to security, since NFC offers short distances communication than RFID it offers best security when it comes to door locks and electronic payments.

In this paper, it is concluded the best tags to be used were the type 2, NXP 215 and NXP 216 tags, since these tags offers the best detection distance suitable for the NFC controlled door lock. The NFC reader can detect these tags whenever it enters within the 5-6 cm range.

ACKNOWLEDGMENT

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REFERENCES

[1] "What is NFC?," [Online]. Available: http://nfc-forum.org/what-is-nfc/. [Accessed 25 february 2017].

[2] R. P. Sabella and J. P. Mueller, NFC for dummies, Hoboken, New Jersey: John Wiley & Sons, Inc., 2016.

[3] R. Karim and H. Al-Fakhri, "Smart Door Lock: A first prototype of a networked power lock controller with an NFC interface," *KTH Information and Communication Technology,* 2013.

[4] S. Ghosh, J. Goswami, A. Kumar and A. Majumder, "Issues in NFC as a Form of Contactless Communications: A Comprehensive Survey," in *International Conference on Smart Technologies and Management for Computing, Communication, Controls, Energy and Materials (ICSTM),* pp. 245-252, 2015.

[5] @bsolute Aircon, "About Us: @bsolute Aircon," 2015. [Online]. Available: http://www.absoluteaircon.com.sg/articles/why-running-aircons-24-7-is-a-bad-idea.html. [Accessed 15 January 2018].

[6] M. S. M. Maestro, J. V. E. Zapata and R. D. B. Dela Rosa, "Near Field Communication (NFC) Technology Based Faculty Attendance Monitoring System," De La Salle University-Dasmariñas, 2015.

[7] Z. Zay, A. Zuhra, M. Razi, M. Jalaldeen, and T. Mantoro, "Nfc Based Attendance: More Than Jus t A Touch," in *4th International Conference on Research and Innovation in Information Systems – 2015 (ICRIIS'15),* pp. 69-78, 2015.

[8] C.H. Hung, Y.W. Bai, and J.H. Ren, "Design and implementation of a door lock control based on a near field communication of a smartphone," in *2015 IEEE International Conference on Consumer Electronics-Taiwan (ICCE-TW)*, June 2015, pp. 45-46.

[9] C.H. Hung, Y.W. Bai, and J.H. Ren, "Design and implementation of a single button operation for a door lock control system based on a near field communication of a smartphone," in *2015 IEEE 5th International Conference on Consumer Electronics-Berlin (ICCE-Berlin)*, September 2015, pp. 260-261.