Integrated Laboratory Security Control System Using Near Field Communication Based on Internet of Things

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***Abstract*-- The laboratory in the university is one of the learning support facilities for students. Commonly, the laboratory room loaning system still uses a conventional method, the user fills a loan book out, takes the room key, and returns it to the admin after completion. The problems often happened, such as loss of keys or no monitoring system for laboratory usage. Therefore, this study aims to integrate the Internet of Things (IoT) based door lock control system for laboratory security. The proposed system consists of a website for monitoring, an Android application as a user interface for requesting laboratory loans, an NFC reader, and NFC on smartphones access to the room. The monitoring system has features for user registration, loan applications, viewing loan schedules, and sending loan notifications. The test results show that the NFC tag is able to read and detect NFC ID from a smartphone up to 2 cm with an average delay of 0.2686 seconds. With the proposed system, it is hoped that it can provide secure access, ease in loaning laboratory rooms and a fast and controlled process.**

***Index Term*-- Near Field Communication, laboratory, website, Android, Internet of Things, smartphone.**

INTRODUCTION

Laboratory security systems at the Faculty of Applied Sciences Building Telkom University still used conventional keys. When students will loan the laboratory room, several administrative processes must be carried out, such as ensuring the space is not used at the specified time. Fill out the room loan book and ask for the head of laboratory affairs approvals. If it is agreed, the people it may concern must first take the key in the admin room at the specified time.

Based on the procedure which has been described, there are several problems. First, the laboratory administrator and the borrower must check the schedule manually. Second, The borrower must find the head of laboratory for getting approval. Third, the room key is not always available in the admin room because the previous borrower has not returned the key, and often disorganized by not filling borrowing books out. Some of these problems caused by loaning documentation were not well structured. Besides, the loan process was less efficient because it required a long time. Therefore, we need a system that can organize the process of laboratory room loaning, which is paperless and can be accessed easily and flexibly..

Related Works

Several studies have reviewed the use of RFID (Radio Frequency Identification) technology as an automatic control and security function, for example, room controllers [1], gate security systems [2], and detecting illegal access to buildings [3]. When using RFID technology, a tag (usually a card) is needed to be identified by the reader, where the chip price on the tag is still relatively high, so it is less economical. Besides, RFID technology has some drawbacks, which is related to standardization, signal collision, frequency of work, manufacturing errors and tag detection, rapid change of technology, security and privacy, and the possibility of a virus attack [4][5].

On the other hand, there is Near Field Communication (NFC) technology, which has several advantages and has been integrated with smartphones [6], where NFC technology is also widely implemented to facilitate human activities [7]–[11]. Study by Abdel-Gaber and Ali [12], NFC technology is utilized in the university community and digital library. NFC's use for a simple door lock controller system was also implemented by Hung, Bai and Ren [13]. For the user interface, use web and android applications. This is because Android has been proven capable of being used for various needs such as project monitoring [14], vehicle tracking [15], smart city monitoring [16], social activities [17], driving safety [18], and others.

This study aimed to integrate the NFC technology-based laboratory door lock control system with the website and android application as the user interface. There are additional features in the system for monitoring room temperature because there are sensitive devices to temperature changes in some laboratories.

NFC is a communication technology using magnetic induction based on Radio Frequency Identification (RFID) technology and referred as the second generation of RFID technology. NFC operates at a frequency of 13.56 MHz with transmission speeds reaching 424 Kbit/s. NFC transmission distance of about 4-10 cm. The difference between NFC and other contactless communication technologies is that NFC devices can be active-active (peer to peer) and active-passive. Therefore, NFC always involves the initiator (reader) and the target. Active initiators produce RF (Radio Frequency) fields that can provide power to passive targets or have no resources. This allows NFC targets to have elementary forms such as stickers, key chains, or cards that do not require particular energy.

Fig. 1. Modul NFC PN532 (NFC Reader)

Figure 1 shows PN532 which is one of the NFC sensors that have a frequency at 13.56MHz for NFC or RFID applications. This sensor has four pins that are TX pin as a transmitter, RX pin as a receiver, GND pin as a ground pin, and VCC pin as pins for 5V power input. This sensor can detect devices about 1 cm to 4 cm. The detail specifications of the PN532 NFC sensor module can be seen in Table I.

TABLE I.
COMMUNICATION SYSTEMS ON PN532 SENSORS [19]

Communication Scheme		**ISO/EIC 14443A**	**MIFARE Higher Baud Rate**	
Baud rate		106 kbits/s	212 kbits/s	424 kbits./s
PN532 to ID Card	Modulation	100% ASK	100% ASK	100% ASK
	Bit coding	Modified Miller Coding	Modified Miller Coding	Modified Miller Coding
ID Card to PN532	Modulation	Subcarrier load modulation	Subcarrier load modulation	Subcarrier load modulation
	Subcarrier frequency	13.56MHz$_{/16}$	13.56MHz$_{/16}$	13.56MHz$_{/16}$
	Bit coding	Manchester coding	BPSK	BPSK

The Proposed System Architecture

The laboratory security system is designed by using NFC based on IoT so that a microcontroller device is needed as a main controller. Moreover, on the website, it also needs the Google Firebase platform, a real-time database provider, authentication, and Firestore features. The proposed system is shown in Figure 2. The designed system consists of two parts. The first part is the hardware part, which includes the design of microcontroller-based laboratory door security. NodeMCU is used as a central controller equipped with the ESP8266 wifi module.

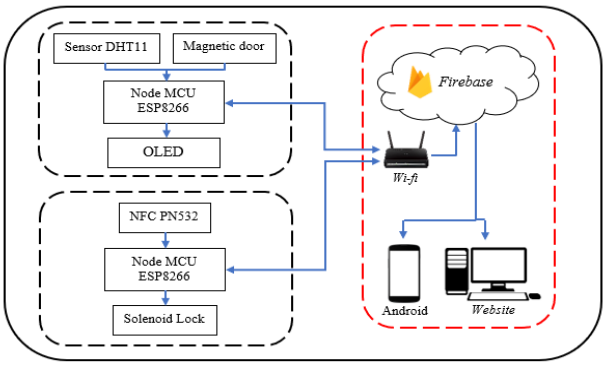


Fig. 2. Modeling of Laboratory security and room loan systems

A. Hardware Design

The ESP8266 module is used to connect the microcontroller to the Wifi network. PN532 sensor is used as an NFC reader, solenoid as a door lock actuator, magnetic door sensor as a door position detector (open or closed), and an OLED screen to display room temperature information and DHT11 as a temperature sensor. The software includes designing the backend and frontend web as an interface for monitoring laboratory room use. The system is designed based on the Internet of Things (IoT) to make a paperless system. The web database used Firebase to store sensor measurement results. The user used an Android-based application to access the room. The design for laying out the tools and their configuration describe in Figure 3.

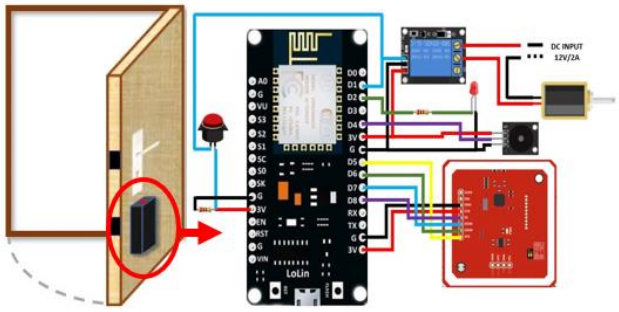


Fig. 3. Modeling of Laboratory Room Loan Systems

The system is designed to be compatible with the NFC ID of ISO/EIC 14443A type with the specifications shown in Table 1. The NFC ID is a passive component containing the hexadecimal code. When brought close to the PN532 sensor, an active component, the sensor will detect the ID. IDs are matched with data contained in Firebase. The process of sending data between the NFC ID and the PN532 sensor is shown in Figure 2. The system will send a command to the solenoid lock to open the door when the detected ID matches the one in the database, and vice versa. On the other hand, the DTH11 sensor is used to detect room temperature and the magnetic door sensor to detect the door's status, open or closed state. The sensor readings are then sent to the NodeMCU and forwarded to Firebase as data about the temperature and door status.

Students and lecturers can create accounts through the website, verify emails, and fill in identity before lending a laboratory room. When all aspects have been fulfilled, the user can make a loan application through a form available on the website. The next step is the laboratory coordinator, and head of laboratory affairs will confirm by accepting or rejecting the loan application. If approved, the system sends notifications to the borrower and updates the loan schedule through Firestore. There are features that allow for monitoring the room through a microcontroller device installed in the laboratory on the admin side.

B. Software Design

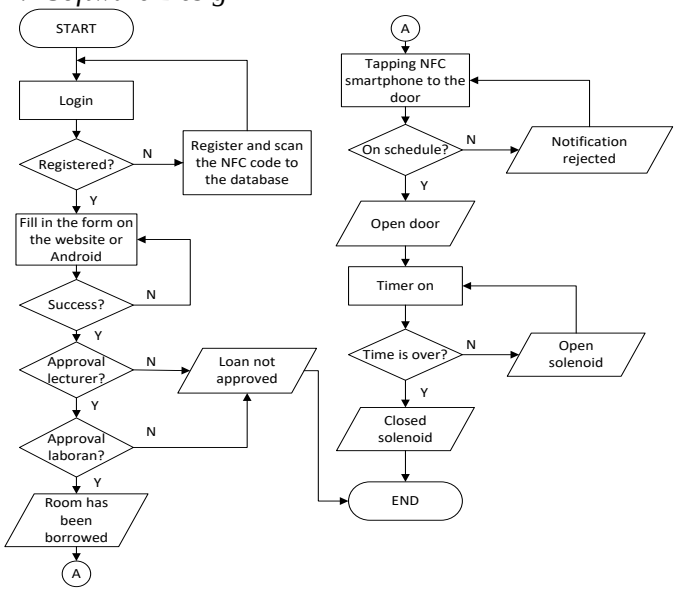


Fig. 4. Flowchart System

Based on Figure 4, the application is started by the initiation of the NFC PN532 module and is connected to the internet network. The system will always be idle until an NFC ID is detected. Users who will borrow the room must first register on the web and register NFC on their smartphone in the database. Submission of room loan must get approval from the head of laboratory and lecturer. If it has been done, then the room has been tagged by the user. At the time of borrowing, the user will scan the NFC reader. The room door will automatically open when the NFC ID matches the database and vice versa. The magnetic door sensor will check the condition of the door every ten seconds. The data obtained in the form of temperature and door condition status will be displayed on the OLED screen and sent to Firebase. The temperature alarm will be adjusted to the standards set by SNI 03.6572-2001, which is comfortable room temperature for Indonesians between 20.5ºC to 27.1ºC [20].

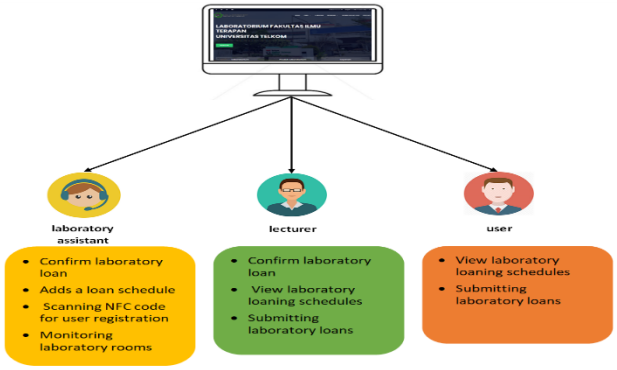


Fig. 5. Distribution of Access Rights on the Laboratory Room Loan Website

There are three access authorizations, including laboratory administrator, lecturer, and student (user) on the website. Figure 5 showed the parts that can be executed by each access authorization. The web is integrated with a Google Firebase platform that uses Firebase Authentication, Real-time database Firebase and Cloud Firestore features. Firebase Authentication provides services that can be used to authenticate users, real-time database Firebase is a database that is synchronized in real-time and receives the latest data automatically, and Cloud Firestore is a database that supports for web development. Account creation data that is carried out on the website will be stored in Cloud Firestore. Cloud Firestore itself is a database based on nonSQL and has hierarchical data compiled by collection. The features that were found on the web can be seen in Table II.

Table II.
Features on The Website

Features	Explanation
Home	Initial display of the website page.
Login Admin/ Laboratory assistant	The menu contains an email form and password for logging in with individual validated emails and accessing the admin page.
Monitoring Laboratory Room	The menu contains laboratory room monitoring displays. The displayed data includes temperature, door conditions, laboratory room names, and room conditions.
Scan NFC Code	The menu is used to scan the NFC ID to be entered into the user's biodata as the laboratory borrowers' identity.
Look at the List of Loan History in Admin	The menu contains a history of the borrowing laboratory room.
Look at the List of Loan Submissions	Menu to approve or reject the application for borrowing space contained in lecturers and laboratory assistants.
Look at the Loan Schedule	The menu is used to view the schedule for borrowing a registered laboratory room.

Features	Explanation
Look at the Registration and Loan Procedure	The menu is used to view the registration procedure and the filing for borrowing a laboratory room.
Log in as a lecturer.	The menu contains the email and password forms used to log in with individual validated emails and access the lecturer page.
Log in as a student	The menu contains the email and password forms used to log in with individual validated emails and access user pages.
User Biodata	Menu to fill in identity as one of the conditions used when applying for a room loan.
Form for Submission of Laboratory Room Loans	The menu contains the application form for borrowing a laboratory room.
Loan Submission Details	The menu is used to view the details of a laboratory room loan application.
Register as a user	Menu to register as a user.
User Account Verification	The menu used when verifying new user accounts.
User Submission History	The menu is used to view the status of room loan applications.

RESULTS AND DISCUSSION

This proposed system is simulated on a dummy door with a size of 80 cm x 50 cm as shown in Figure 6(a). The device was designed by using a case with size of 125 mm x 85 mm x 50 mm. The case contains two NodeMCUs, the first as a room door security system and the second as a room condition monitoring system. At the top, there is a push button to open the door from inside the room, and there is an OLED screen to display the temperature of the room. Figure 6(a) and 6(b) showed the installation of the device from inside and outside the door.

(a) (b)

Fig. 6. The Installation of the device (a) from the Inside (b) from The Outside

The website can be accessed online with address "www.similab-fit.online", which has the appearance shown in Figure 7. Various menus such as login, procedure, menu to download the application, and contact admin are displayed on the initial appearance.

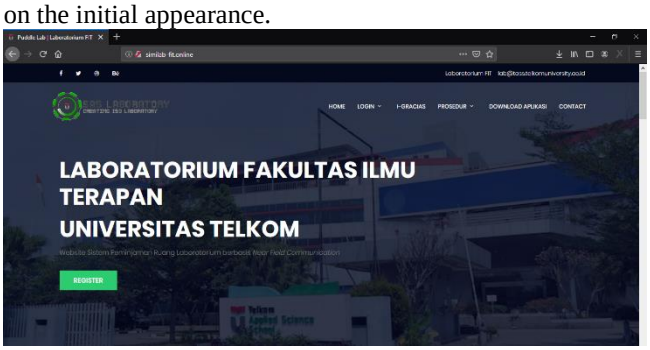


Fig. 7. Website Dashboard Display

Figure 8 shows the appearance of the user application on Android. Several menus will appear after logging in, such as a laboratory room loan submission, look at the available schedules, look at the procedures, and logout buttons.

The conducted test on the system tested the PN532 sensor read distance against NFC on smartphones, testing the sending and receiving of data from Firebase, testing the website performance, and testing the web server's endurance.

Fig. 8. Display of Android Application

The first test was the PN532 sensor reading the distance of tag. The purpose of this test is to measure how far and how sensitive the PN532 sensor is in reading an NFC ID. Testing was done by changing the PN532 sensor's distance with the existing NFC ID on the smartphone. The results of ten tests for the same distance are shown in Figure 9. From the test result found that the sensor can read at a distance of 0-2cm. The farther distance, will cause a decrease of the success rate. At a distance of more than 3.5 cm, the system could not detect the NFC ID.

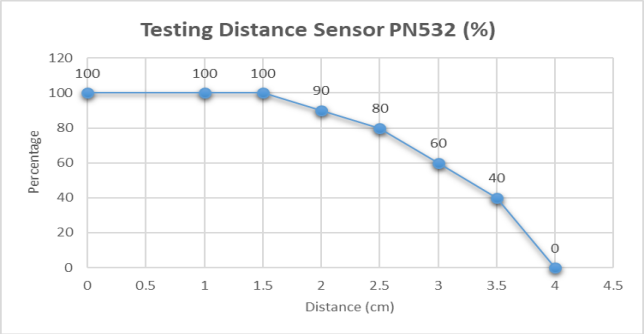
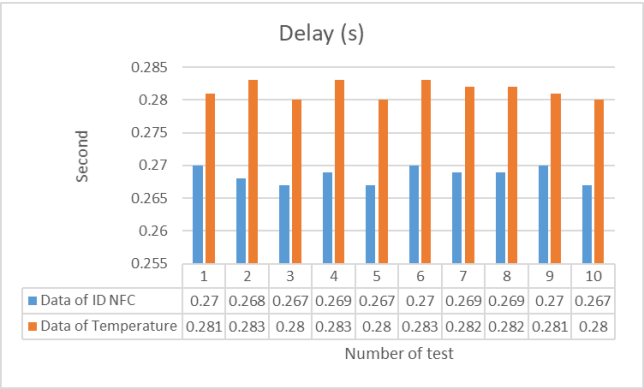


Fig. 9. PN532 Sensor Reading Distance Testing

Subsequent tests were conducted to measure the delay of sending data from the MCU device to Firebase and vice versa. The measurement was using a timestamp contained in the Arduino IDE application. The Delay test results can be seen in Figure 10. Overall, the measured delay value in all conditions was influenced by the internet connection which used in this test scenario. In the condition of sending an NFC ID, the delay was measured from the NFC tapping process to the NFC ID data to Firebase. The results showed the average delay of sending an NFC ID by 0.2686 seconds. It was influenced by the sensitivity level of the PN532 sensor when detecting an NFC ID. Furthermore, the delivery of a delay in the temperature value was measured when the DHT11 sensor got room temperature data and was sent to Firebase. The average delay in this condition was 0.2815seconds.



	1	2	3	4	5	6	7	8	9	10
Data of ID NFC	0.27	0.268	0.267	0.269	0.267	0.27	0.269	0.269	0.27	0.267
Data of Temperature	0.281	0.283	0.28	0.283	0.28	0.283	0.282	0.282	0.281	0.28

Fig. 10. Delay Testing

In the software, functional test was performed to validate all the website features according to the initial design. The validation results showed that all features could be used and run their initial function. Website performance testing is used an open-source tool, namely “Google Lighthouse”. Figure 11 shows that Google Lighthouse could measure website performance based on six parameters. Figure 11 shows that, from the six performance factors on the website, 4 points had good value, and 2 points had an average value. In the Speed Index factor, the obtained value was not included in the suitable criteria, where a good Speed Index had a value under 1 second. The First Meaningful Paint factor got a value of 1.1 seconds, where the value was in the average category as well as stated on Google Lighthouse. Figure 12 shows the total results of website performance measurements. The acquisition of value as many as 94, with a scale of 100, was included in the average category.

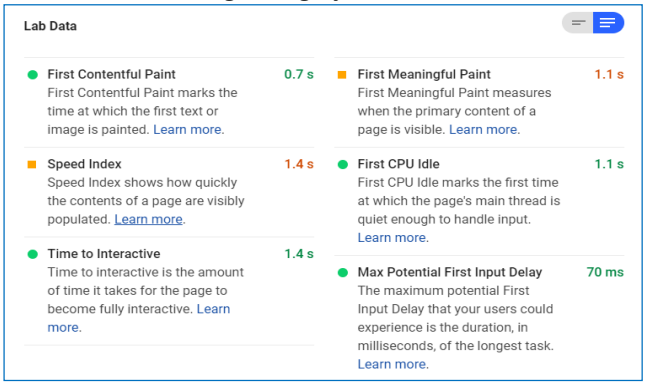


Fig. 11. Website Performance Test Results on Google Lighthouse

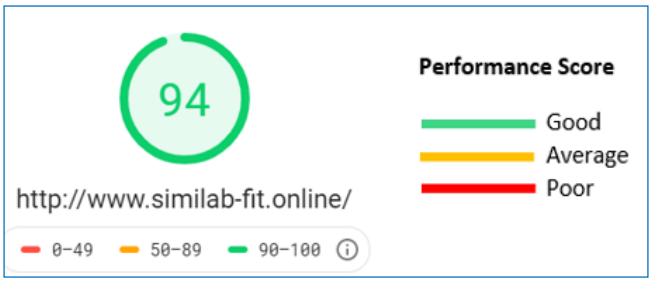


Fig. 12. Website Performance Test Results by Google Lighthouse

The final test is using the Web Stress Tool software. It used the Ramp method, where the website will flooded with requests to access in the specified time. The test using 1000 virtual users to test how many requests can be responded to within 10 minutes.

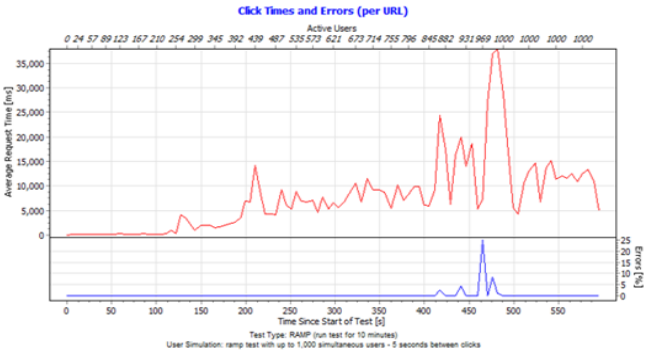


Fig. 13. Endurance Test Results

Figure 13 shows the results of website endurance testing. Based on the results obtained, it can be seen that the website was able to handle up to 1000 users with an average request time of 7995 ms. Also, from a total of 20066 incoming requests, there were only 21 errors. The website's ability will decrease when handling more than 1000 users, where the received response time increases. Based on the test results, it can be concluded that the website was able to handle 1000 users and a relatively large number of requests.

CONCLUSION

The Integrated Laboratory Door Lock Control System Using NFC Based on the Internet of Things has proven to be well implemented and replaced the loaning and security systems of laboratory rooms at universities. The NFC system capable of reading and detecting NFC IDs from smartphones up to 2 cm. On the application side, such as the web and android applications, it could facilitate students, lecturers, and administrators in borrowing, recording, and monitoring the room more efficiently. This system generates the average request processing time is 0.2686 seconds. In future work, this proposed system can be implemented in real environmental conditions. This system is then expected to provide secure access, ease in laboratory loan administration, a fast and monitorable process.

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