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IoT-Based Electricity and Lecture Room Usage Management Information System at State University of Surabaya

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ABSTRACT

The demand for electrical energy in university environments continues to increase in line with the growing number of students and the intensified use of various facilities. This condition has the potential to cause energy waste, especially in lecture rooms. This situation may lead to an increase in the University's operational costs, which could ultimately disrupt the allocation of budgets for various academic and non-academic activities. Therefore, a solution is needed that can monitor and control energy usage more efficiently. This study aims to design an ESP32 and RFID-based device for implementing IoT technology in classroom electricity and room management systems, as well as to develop an IoT-integrated room management system. The research method includes the design of hardware using ESP32, RFID RC-522 module, relay, push button, buzzer, solenoid door lock, and I2C LCD, connected to a web-based application built with Laravel as the backend for authentication, data management, and room usage monitoring. Tests were conducted to measure E-KTP identification accuracy, scanning speed, check-in and check-out success rates, and the integration between hardware and the web system. The results show that all E-KTPs were successfully identified with a 100% success rate, with an average scanning time of 0.682 seconds during registration, 0.728 seconds during check-in, and 0.775 seconds during check-out, with a maximum scanning distance of 1 cm. The system can also display real-time room usage data on the admin dashboard and control electrical devices according to room booking status. Thus, the developed system is not only effective in authenticating room access and monitoring electricity usage but also contributes to reducing energy waste and supporting efficient and sustainable classroom management in higher education institutions.

Keyword: Electrical Energy, IoT, NFC, ESP32, Room Management.

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1. INTRODUCTION

Electricity demand continues to increase in line with the rapid development of technology and the growing intensity of activities across various sectors, including higher education institutions, which have recently become a major focus of attention [1]. Universities, as centers of education, research, and community service, require a reliable supply of electrical energy to support a wide range of academic and non-academic activities. Facilities such as classrooms, laboratories, libraries, and administrative offices are highly dependent on the availability of electrical energy to ensure the smooth implementation of learning processes and institutional operations. Along with the increasing number of students and the intensity of facility utilization, electrical energy management has become an increasingly crucial aspect.

However, the increasing demand for energy is often not accompanied by efficient electricity usage management, leading to energy waste, particularly in classrooms [2]. Electrical energy waste is generally caused by the uncontrolled use of electronic devices, such as air conditioning systems and lighting that remain active even when the room is not in use. This condition is further exacerbated by user negligence and a low level of awareness regarding the importance of energy efficiency within the campus environment, resulting in electricity consumption that exceeds the actual needs of the room [3].

Electrical energy waste not only affects environmental aspects but also imposes a significant financial burden on higher education institutions. This issue becomes increasingly critical for universities that have obtained the status of State Universities with Legal Entity (PTN-BH), where dependence on government funding is reduced and institutions are required to be more financially independent [4]. Universitas Negeri Surabaya is one of the universities that has achieved PTN-BH status; therefore, operational cost efficiency, including electricity consumption, has become a strategic necessity to ensure institutional sustainability.

Various previous studies have examined the application of Internet of Things (IoT) technology in energy management, particularly through the use of relays as electrical flow controllers or automatic switches, which have proven effective in improving efficiency and reducing energy waste. In addition, the integration of RFID technology with IoT has been implemented to restrict access to rooms and electrical devices only to authorized users. However, most of these studies primarily focus on energy control and monitoring aspects, without considering the need for fixed and recurring room usage scheduling for academic activities such as weekly lectures. This condition indicates a research gap in the development of systems that are not only energy-efficient but also aligned with the academic operational requirements of higher education institutions.

Therefore, this study proposes an integrated system based on the Internet of Things (IoT) and Near Field Communication (NFC) to control and monitor electrical energy usage in classrooms. The system utilizes relays as the main controllers of electrical devices and electronic identity cards (E-KTP) as NFC-based authentication media to regulate room access. The novelty of this research lies in the integration of E-KTP–based NFC authentication, IoT-based electrical device control, and classroom management based on predefined academic schedules. This approach is expected to improve electrical energy efficiency, minimize energy waste, and support more structured and sustainable learning operations within the higher education environment.

2. METHODS

This study is a Research and Development (R&D) aimed at designing and implementing an Internet of Things (IoT)–based management system for electrical energy usage and classroom management. The research begins with the identification of problems related to electrical energy wastage at Universitas Negeri Surabaya, which operates as a state university with legal entity status (PTN-BH). Subsequently, a literature review is conducted as the basis for solution formulation by examining previous studies addressing energy wastage, IoT implementation, NFC/RFID technology, and web-based systems for classroom access control and electrical energy management [10]. This stage is followed by data collection through direct observation, interviews with relevant stakeholders, and literature studies to identify system requirements and the actual conditions of classroom utilization. Based on the collected data, the system is developed using the Rapid Application Development (RAD) method due to its adaptive nature and ability to support rapid development through stages of requirement planning, prototype design, system development, and testing and implementation [11]. The system implementation utilizes ESP32, an MFRC522 RFID module, a solenoid door lock, a MySQL database, and the Laravel framework. The test results are analyzed descriptively to evaluate the system's functionality, reliability, and suitability to user requirements prior to deployment in a real environment.

3. RESULTS AND DISCUSSION

3.1 System Design

This subsection describes the proposed system design by outlining the system architecture and the interaction between hardware and software components. The overall system architecture is depicted in the block diagram shown in Figure 1.

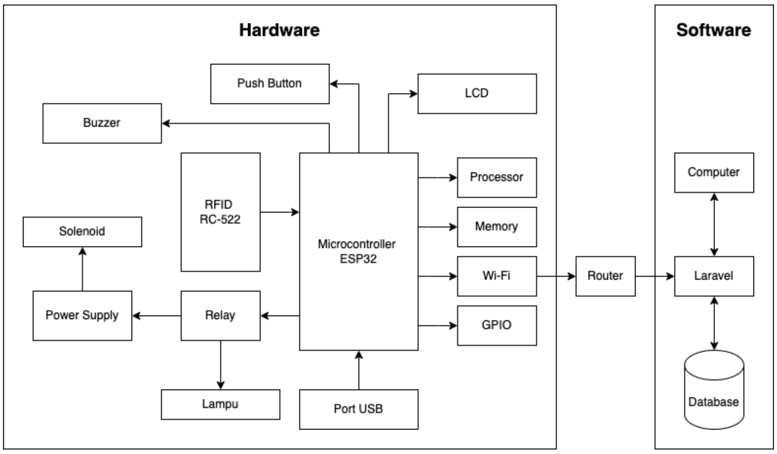

Figure 1. System Design

The system consists of integrated hardware and software components. The hardware components include an ESP32 microcontroller as the main control unit, which is connected to an MFRC522 RFID module for reading users' E-KTP, a relay module for controlling the electrical power supply, an LCD for displaying system information, and a solenoid door lock for regulating door access. The ESP32 is powered by a dedicated power supply and communicates with the server via an internet connection.

On the software side, the system is supported by a web-based application developed using the Laravel framework and connected to a MySQL database. This application is responsible for managing user data, room data, and usage schedules. RFID reading data captured by the ESP32 are transmitted to the server for authentication and decision-making processes. Subsequently, the server sends a response back to the ESP32 to enable or disable door access and electrical power flow according to the defined rules.

3.2 System Development

3.2.1 Hardware

The hardware of the proposed system is designed as an Internet of Things (IoT) configuration based on an ESP32 microcontroller integrated with identification modules, actuators, and supporting devices. This configuration functions to support user identification, door access control, and automated management of electrical energy usage.

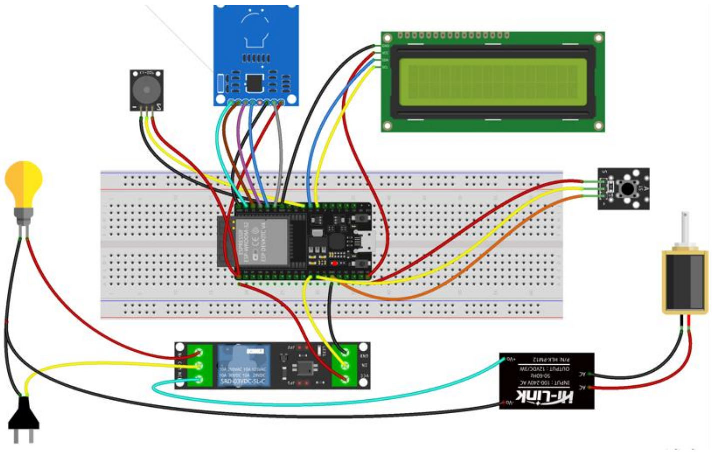

Figure 2. Hardware

The IoT hardware configuration used in this system demonstrates the integration of an ESP32 microcontroller as the central control unit with various supporting modules. The MFRC522 RFID module is utilized to read users’ E-KTP, where the acquired data are processed by the ESP32 to determine access authorization to the room. The relay module functions as a switch controlled by the ESP32 to regulate the electrical power supplied to the room, which is represented by an LED lamp as the electrical load, as well as to control the solenoid door lock as an electronic locking mechanism. In addition, an LCD is employed as an information display to present system status to users, while a push button serves as a manual input and a buzzer acts as an audio indicator to provide system notifications. The ESP32 and the solenoid door lock operate with separate power supplies, where the ESP32 is powered by an independent adapter, while the solenoid is supplied by a dedicated power source through the relay module. This configuration is intended to isolate the power paths between the logic circuitry and the inductive load, thereby minimizing electrical interference and improving system stability and reliability. Communication between the ESP32 and the server is conducted via the internet network to support centralized authentication and decision-making processes.

3.2.2 Software

The software component of the proposed system was successfully implemented to support room access control and electrical energy management. The software consists of embedded firmware running on the ESP32 and a web-based management application that communicates through RESTful APIs. This software configuration enables real-time data exchange between hardware devices and the server, ensuring that access decisions and electrical control are executed accurately.

The embedded software on the ESP32 is responsible for reading RFID card data, processing access requests, and executing control commands based on responses received from the server. When a card is scanned, the unique identifier (UID) is sent to the backend system for validation. The server evaluates the UID against registered user data and active room schedules before returning an access decision. Based on this response, the ESP32 activates or deactivates the relay to control the electrical power and displays the access status on the LCD.

The web-based management system was implemented to provide administrative control over room usage and electrical monitoring. This system includes several functional modules, such as room and user management, scheduling, and monitoring modules. The room and user management module allows administrators to manage registered users and room data, while the scheduling module defines allowable usage periods that serve as the main reference for access authorization. These modules ensure that room access and electrical activation occur only within predefined schedules.

3.3 Testing and Implementation

3.3.1 RFID Testing

RFID testing was conducted to evaluate the system's performance in processing users' E-KTP as the primary mechanism for identification and room access. This testing focused on system speed aspects, including the time required for E-KTP registration and the system's response time in granting room access after card scanning.

a. E-KTP Registration Scanning Speed

This testing aims to determine the time required by the system to register E-KTP data into the system database through the RFID module and the web application.

Table 1. RFID Registration Testing Results

E-KTP	Response Time (s)	Status	Result
1	1.182	Registered	Pass
2	0.514	Registered	Pass
3	0.802	Registered	Pass
4	0.613	Registered	Pass
5	0.419	Registered	Pass
6	0.402	Registered	Pass
7	0.814	Registered	Pass
8	0.64	Registered	Pass
9	0.855	Registered	Pass
10	0.58	Registered	Pass

Based on the results of the E-KTP reading test during the registration process, all tested cards were successfully read and registered by the ESP32-based device and the RFID module. From ten test trials, the observed response times ranged from 0.402 to 1.182 seconds. Although variations in reading time were observed, all registration processes were completed successfully, indicating that the system is capable of accurately recognizing and processing each E-KTP. These results demonstrate a 100% success rate in the card registration process as well as in data classification based on the information stored on the server. With an average response time of 0.682 seconds, the system is considered sufficiently efficient and feasible for implementation in Internet of Things (IoT)-based room access management in academic environments.

b. Room Access Scanning Speed

This testing was conducted to measure the system's response time in granting room access after the E-KTP card is scanned by the user.

Table 2. RFID Access Time Testing Results

E-KTP	Check-in Time (s)	Check-out Time (s)	Result
1	0.742	1.065	Pass
2	0.548	0.441	Pass
3	0.964	1.277	Pass
4	0.861	0.855	Pass
5	0.815	0.652	Pass
6	0.545	0.561	Pass
7	0.911	0.753	Pass
8	0.441	0.342	Pass
9	0.435	1.055	Pass
10	1.019	0.752	Pass

Based on the testing results of ten registered E-KTP records with scheduled usage, all check-in and check-out processes were successfully completed without any failures. These results indicate that the system is able to accurately recognize and process each user's data. The E-KTP scanning response time during the check-in process ranged from 0.435 to 1.019 seconds, with an average of 0.728 seconds, while during the check-out process it ranged from 0.342 to 1.277 seconds, with an average of 0.775 seconds. Although variations in response time were observed, all processes operated stably without exhibiting any anomalies or significant delays. The differences in response time were influenced by network conditions and the communication process between the IoT device and the server.

c. Scanning Distance

This testing aims to evaluate the ability of the RFID module to read E-KTP cards at various distances and to determine the effective reading distance that can be optimally applied in the system implementation.

Table 3. RFID Scanning Distance Test Results

No.	Distance (cm)	Result
1	0	Pass
2	0.5	Pass
3	1	Pass
4	1.5	Fail

Based on the testing results, the system successfully read the RFID card at distances of 0 cm, 0.5 cm, and 1 cm, with all trials showing successful status. These results indicate that the RFID reader module is capable of optimally capturing the card signal at very close distances. Although the testing was conducted over a limited distance range, the results demonstrate that the system has good reading sensitivity when the RFID card is placed on or very close to the reader, which is consistent with the characteristics of room access system usage.

3.3.2 Black Box Testing

Black box testing was conducted to evaluate the system's functionality based on the conformity between input and the resulting output, without considering the internal structure of the system.

a. Room Access Using E-KTP

This testing focused on the room access process using E-KTP, schedule validation, two-RFID-card authentication, lecturer roles, and time-based automatic control mechanisms. The detailed testing scenarios and the obtained results are presented in Table X.

Table 4. Room Access Control System Testing Results

No.	Test Scenario	Expected Result	Result
1	Scan unregistered E-KTP	LCD displays "Invalid card".	Pass
2	Scan registered E-KTP without active schedule	LCD displays "Access denied".	Pass
3	Scan first valid E-KTP with active schedule	LCD displays "Scan again".	Pass
4	No second scan within 10 seconds	LCD displays "Timeout".	Pass
5	Scan the same E-KTP twice	LCD displays "Invalid access".	Pass
6	Scan two different E-KTPs not in the same schedule	LCD displays "Access denied".	Pass
7	Scan two different E-KTPs outside the registered schedule	LCD displays "Access denied".	Pass
8	Scan two different E-KTPs registered in the same schedule	LCD displays "Access granted", relay ON, solenoid unlocked, power ON.	Pass
9	During active session, scan two valid E-KTPs again	Relay OFF, solenoid locked, power OFF	Pass
10	Lecturer does not scan E-KTP/card within 15 minutes (regular/course schedule)	Schedule invalidated, system shuts down automatically	Pass
11	Lecturer scans E-KTP/card within 15 minutes (regular/course schedule)	LCD displays "Activated", schedule remains valid	Pass
12	Lecturer does not scan E-KTP/card within 15 minutes (non-course request)	Schedule remains valid until finished	Pass
13	Remaining time is 5 minutes	Buzzer sounds warning alarm	Pass
14	Remaining time is 1 minute	Buzzer sounds warning alarm	Pass
15	Schedule duration ends	Relay OFF, solenoid locked, power OFF automatically	Pass

Based on the black box testing results presented in Table X, all testing scenarios produced outputs that were consistent with the system's expected behavior. The system was able to handle various access conditions, such as unregistered cards, schedule mismatches, two-user authentication, and lecturer attendance validation. The automatic device control mechanisms also operated properly, including access locking, power disconnection, and warning notifications via the buzzer based on the remaining schedule time. These results indicate that the system has fulfilled the functional requirements and can operate reliably in supporting IoT-based room access management.

b. Emergency Button

Emergency button testing was conducted to ensure that the system is able to provide safe exit access under certain conditions, particularly when the room usage duration has ended. This testing aims to evaluate the system's response to manual input as well as the performance of the actuators in supporting user safety.

Table 5. Emergency Button Testing Result

No.	Test Scenario	Expected Result	Result
1	Press the emergency button from inside the room to open the door after the room usage time has ended.	Power is restored and the door is unlocked within a specified time limit.	Pass

Based on the testing results presented in Table X, the system successfully responded to the emergency button activation by enabling the relay module, restoring the power supply, and unlocking the solenoid door lock within the specified time limit. These results indicate that the emergency button function operates as designed and is capable of providing controlled exit access. Therefore, the system has met the functional requirements related to safety and operational reliability.

c. Admin Mode Access

Admin Mode testing was conducted to evaluate the user data management function through the administrator card mechanism. This testing aims to ensure that the system is able to distinguish between administrator and regular user access rights, as well as to properly handle the E-KTP registration process and data validation.

Table 6. Admin Mode Testing Results

No.	Test Scenario	Expected Result	Result
1	Scan Admin card	Admin mode is active	Pass
2	Scan unregistered E-KTP	UID is automatically displayed in the form	Pass
3	Scan registered E-KTP	System shows a notification that the card is already registered	Pass
4	Scan registered E-KTP again	Duplicate registration notification is displayed	Pass
5	Scan Admin card again	Admin mode is locked	Pass

Based on the Admin Mode testing results presented in Table X, all testing scenarios were successfully executed in accordance with the system's expected behavior. The system was able to activate and deactivate Admin Mode using the administrator card, as well as display appropriate responses when scanning both unregistered and previously registered E-KTP cards. In addition, the notification mechanism functioned properly by providing feedback to the administrator in the event of data duplication. These results indicate that the Admin Mode feature operates accurately and effectively supports the user data management process.

d. Authentication

Authentication testing was conducted to ensure that the web-based system access mechanism operates in accordance with the access rights of registered users. This testing focuses on validating user credentials in the form of email and password.

Table 7. Authentication Testing Results

No.	Test Scenario	Expected Result	Result
1	Enter valid email and password	System redirects to dashboard	Pass
2	Enter invalid email or password	Login request is rejected	Pass

Based on the authentication testing results presented in Table X, the system was able to process login requests properly. When users entered a valid email and password, the system successfully authenticated them and redirected them to the dashboard page. Conversely, when incorrect credentials were provided, the system rejected the login request and prompted the user to enter the correct information. These results indicate that the authentication function operates in accordance with the system's security and functional requirements.

e. Data Management

Data management testing was conducted to verify the functionality of the web-based system in managing operational data. The testing focuses on general data manipulation functions as well as specific features related to period management and course scheduling.

Table 8. Data Management Testing Results

No.	Test Scenario	Expected Result	Result
1	Add new master data	Data is successfully stored	Pass
2	Update existing master data	Data changes are saved correctly	Pass
3	Delete master data	Data is removed from the system	Pass
4	Activate/deactivate period data	Only one period is active at a time	Pass
5	Schedule validation based on active period	Schedule follows the active period	Pass

Based on the testing results shown in Table X, all data management functions operated as expected. The system successfully handled general data manipulation processes, including adding, updating, and deleting data. In addition, specific functions such as period activation control and student assignment to course schedules worked correctly. These results indicate that the data management module reliably supports the operational requirements of the system.

CONCLUSION

This study successfully designed and implemented an Internet of Things (IoT)-based classroom access and electrical usage management system by integrating an ESP32 device, an MFRC522 RFID module, and a web-based application developed using Laravel. The system utilizes the E-KTP as the user authentication medium to automatically control door access and electrical power usage in accordance with predefined schedules.

The testing results indicate that the system was able to read and process all tested E-KTP cards with a 100% success rate, achieving an average scanning response time of 0.682 seconds during the registration process, as well as 0.728 seconds and 0.775 seconds during the check-in and check-out processes, respectively. Scanning distance testing showed that RFID reading operated optimally at distances of up to 1 cm. The integration between the IoT devices and the web application functioned properly through a client–server communication mechanism, enabling access data and schedules to be managed and monitored in real time via an admin dashboard.

Overall, the developed system effectively supports automated classroom access management, improves facility usage efficiency, and contributes to the reduction of electrical energy waste in higher education environments.

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