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WISE-Energy: Wireless Integrated Smart Energy Systems

Dody Ichwana Putra[1*], Randi Primasoza Putra[2], Shelvi Ekariani[3]
dody.ichwana@it.unand.ac.id, shelviekariani@sci.unand.ac.id
[1,2]Computer Engineering Department, Universitas Andalas
[3]Mathematics and Data Science Department, Universitas Andalas

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Abstract

This paper introduces WISE-Engergy, Wireless Integrated Smart Energi Systems. This system is designed to optimize indoor electricity usage by fostering user awareness of energy-saving practices. Users are reminded to turn off electrical devices when leaving the room through notifications on an Android smartphone application. The research aims to increase public awareness of the importance of energy conservation and to apply technology to achieve higher energy efficiency. The contribution of this research lies in the development of an innovative energy-saving system that can be implemented in various indoor environments to support sustainable energy-saving efforts. The test results show that this system successfully achieves its intended goals. The notifications sent to the last user in the room effectively encouraged them to turn off the lights upon leaving. The WSN communication test between room 1 and room 2 also demonstrated that the system could transmit power data from room 2 to room 1 via the XBee module. System evaluation and testing indicated that SENIOR successfully notified users to turn off electrical devices. This research makes a significant contribution to addressing energy-saving challenges and promoting an energy-saving culture in the community.

A. Introduction

Increasing awareness of the importance of saving electrical energy has become a significant concern in maintaining environmental balance and reducing energy costs. Inefficient and uncontrolled use of electrical energy indoors is one of the factors causing energy wastage that can be avoided. Therefore, developing a system that can automatically control electricity indoors is important in achieving higher energy efficiency.

One effort to save electrical energy is to turn off lights when the room is not in use or when no one is inside. People must remember to turn off electrical devices after using them, especially in office and academic environments. This issue is the leading cause of electrical energy wastage in these sectors due to inefficient energy management and user awareness in controlling electricity usage according to needs. For instance, the negligence of turning off electrical devices after use results in unnecessary electricity wastage. This phenomenon worsens energy usage efficiency and negatively impacts the environment.

The proposed solution to increase public awareness of turning off electrical devices after use is by utilizing technology. With the help of technology, we can develop a culture of energy-saving in the community. Research on building electricity usage control systems has been conducted previously [1] [2] [3] [4] [5] [6] [7]. However, these studies focused more on creating intelligent systems for electricity consumption without aiming to increase public awareness of saving electricity after using electrical devices. This paper introduces WISE-Energy, a Wireless Integrated Smart Energi System using a wireless sensors network (WSN). Our main goal is to design and implement an innovative system that can help save electrical energy indoors by utilizing Android platforms and WSN as the basis for development. With this system, the community is expected to be more aware and actively contribute to sustainable energy-saving efforts.

This paper is organized into several main sections. Section 2 will explain the research methodology used in this study. Section 3 presents the results and discusses this research. Section 4 will contain the concluding discussion. Finally, Section 5 will provide conclusions and recommendations.

B. Methodology

1. System Design

The WISE-Energy was designed with several functional requirements in mind. First, the system will detect the user's arrival and send a notification to log in to the system when the user's Android device is detected using the test room WiFi. The application will only connect if the user uses the service set identifier (SSID) in the test room. Next, the user is asked to log in to the system via the Android application, which is followed by a notification to turn on the lights, if necessary, when the user is detected as the first person to enter the room. This ensures that the lights are only turned on when someone is in the room, avoiding unnecessary energy consumption.

Second, the system provides a notification via the Android application to the last user who leaves the room to turn off the lights. The system will detect the last user to leave the room by counting the number of users connected to the test room's WiFi. Users can respond to notifications provided by the system to turn the lights on or off according to their needs from the Android application. If the last user does not respond to the notification sent by the system, the system will automatically turn off the power to the electrical device. This way, the lights can be turned off automatically when the room is not in use, providing efficiency in electricity use.

For multi-room implementation, WSN is used for node device communication through current sensors to the server in the first test room. The system acquires current sensor data from the test chamber and sends it to the server. This current sensor data is essential for monitoring electricity consumption in different rooms and providing information about actual energy consumption. With this data, users can evaluate and manage electricity usage efficiently. In this research, lights are used as indicators of electricity use, but various electrical devices can be monitored in their implementation. WISE-Energy plays a role in providing notifications to users to control the use of lights based on the presence or absence of users in the room. Figure 1 shows the use case of WISE-Energy.

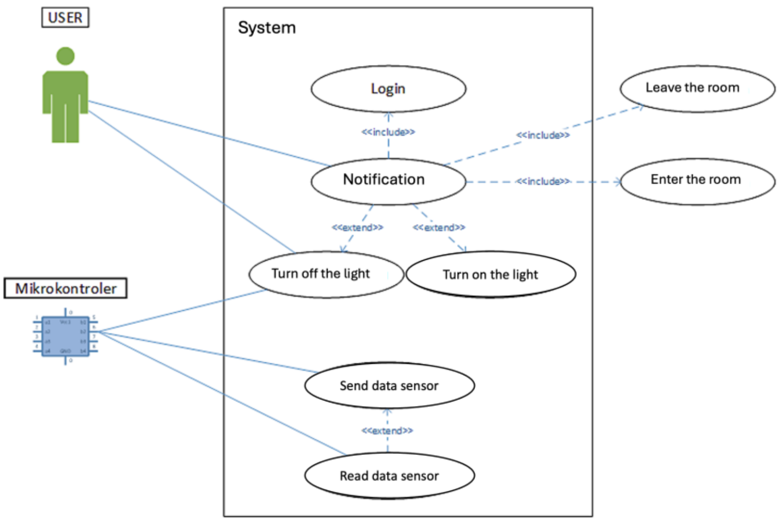


Figure 1. WISE-Energy's use case.

In this study, it is important to ensure the stability of the WiFi network in the room for smooth and real-time data transmission between devices. We use Received Signal Strength Indication (RSSI) measurement to determine if the user is in the test room. The RSSI is obtained by assessing the signal strength received by the receiver. As the distance between the receiver and transmitter increases, the RSSI value decreases. By understanding the relationship between distance and signal strength, we can estimate the distance between two devices based on the measured RSSI value. The system architecture in this research is depicted in Figure 2.

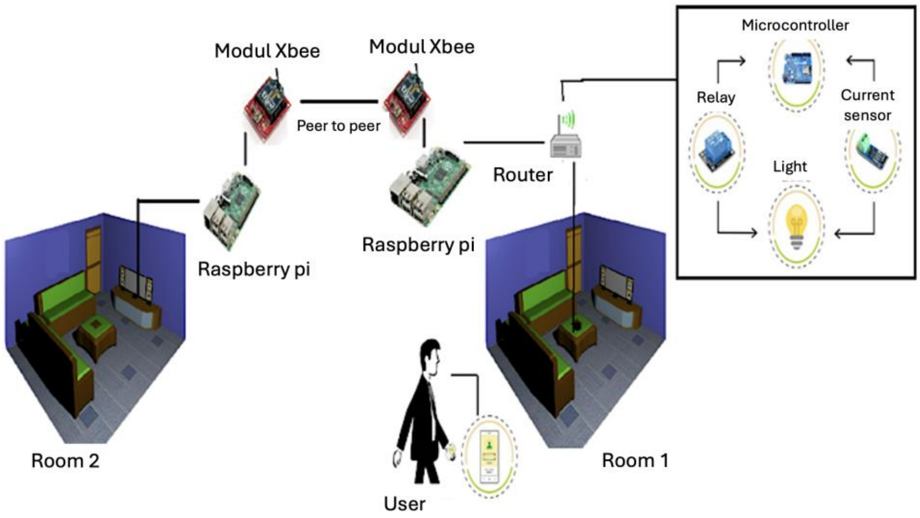


Figure 2. Architecture systems design.

This study explores a system that sends alerts to users to regulate light usage based on occupancy (refer to Figure 2). Additionally, the system enables data transfer between rooms using WSN communication. The sensor in test room two sends its current reading to test room one via the XBee module. This allows for centralized collection and management of power data from both rooms on the server. The implementation of this system aims to increase user awareness about the importance of conserving electrical energy and reduce unnecessary energy waste.

2. Hardware and Software Design

The WISE-Energy hardware block diagram is depicted in Figure 3. The system makes use of the following hardware components:

- Wemos D1: This microcontroller is based on ESP-8266 and enables direct WiFi communication with Android mobile applications.
- SCT-013 Current Sensor: This component measures electric current.
- Relay: This device controls the switching on and off of lights.
- Access Point (AP) Router: This functions as a Wi-Fi transmitter, providing network connectivity.
- Raspberry Pi: This acts as a server for managing and transmitting sensor data.
- XBee: This component facilitates data transmission between rooms.

- Smartphone: This provides an interface with both the microcontroller via WiFi and users.

This combination of hardware allows WISE-Energy to effectively monitor and control indoor electricity usage automatically.

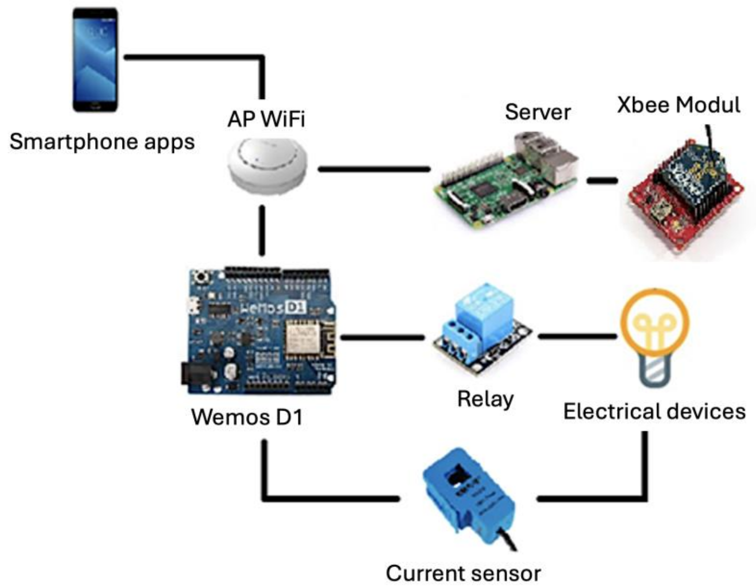


Figure 3. Hardware block diagram.

The WISE-Energy system is powered by Android mobile applications. In Figure 4, we can see the pseudo code for mobile apps process, starting with system initialization. The first step involves initializing the system, followed by connecting to the WiFi SSID and user login. User login verification ensures that only authorized users can access the system.

Upon successful verification, the system calculates the Received Signal Strength Indicator (RSSI) value on the user's smartphone. An RSSI value greater than -64 dBm indicates the user's presence in the room, while a value lower than -64 dBm suggests that the user has left or is not in the room. The -64 dBm threshold was determined through indoor smartphone signal strength measurements.

If the RSSI is lower than -64 dBm, the system checks the user database to determine if the user is the last person remaining. If so, a notification is sent to the smartphone app to turn off the lights. Users have the option to manually turn off the lights or do so through the Android application.

```
1. **System Initialization:**
    - Call InitializeSystem()

2. **Connect to WiFi:**
    - Prompt user for WiFi credentials (SSID and password)
    - Call ConnectToWiFi(SSID, password)

3. **User Login:**
    - Prompt user for username and password
    - Call VerifyUserLogin(username, password)
    - If login is invalid:
        - Print "Invalid login credentials. Please try again."
        - Go to step 2

4. **Calculate Smartphone RSSI:**
    - Call GetSmartphoneRSSI()

5. **Check User Presence:**
    - If RSSI > -64 dBm:
        - Print "User is in the room."
    - Else:
        - Call IsLastPersonInRoom(username)
        - If user is the last person:
            - Print "Sending notification to turn off lights."
            - Call SendNotificationToTurnOffLights()
        - Else:
            - Print "Other users are present in the room."
```

Figure 4. Apps mobile pseudo code.

On embedded devices, the microcontroller will connect to the available WiFi network. Then, the system on the microcontroller will check whether there is input from the server. If the system on the microcontroller receives a command from the server, the microcontroller will send the command to the relay to turn on or turn off the electrical device connected to the relay. Additionally, the existing sensors will continue to read the current in the electrical device in real time, and the reading data from the sensors will be sent to the server.

3. WSN Data Delivery Scheme

The power value data collected by the sensors in each room is sent to the server via an Xbee pair-to-pair connection to the first test room. The data is temporarily stored on the Raspberry Pi in each room before being transmitted to the server. Figure 5 illustrates a data transmission scheme using a Wireless Sensor Network (WSN).

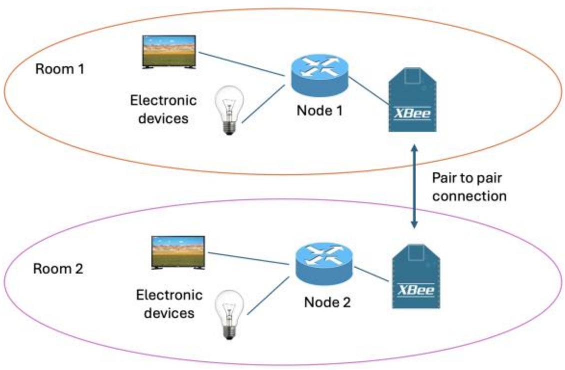


Figure 5. Data transmission scheme on WSN.

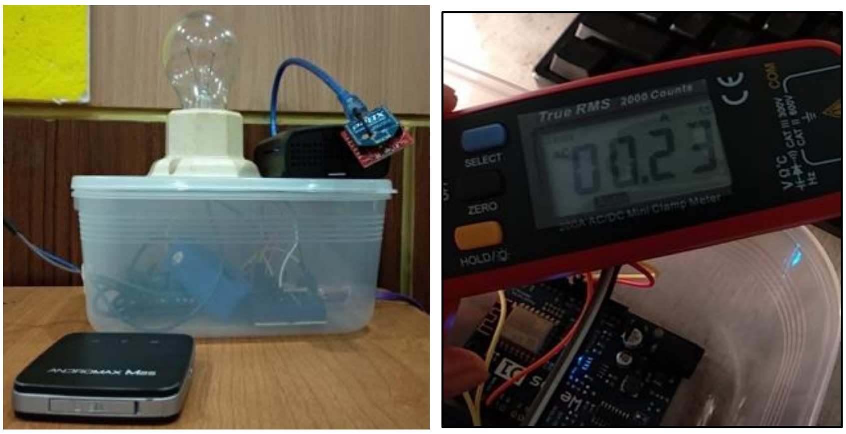
Once the sensor data is transmitted wirelessly to the server in the first test room, the server processes the data. The received data is then analyzed to gather information about electricity usage in the second test room. The server can analyze usage patterns, calculate energy consumption, and store historical data for monitoring and evaluation. This processed information can help optimize electricity use and identify potential energy savings. Additionally, the data can be integrated with a mobile application or dashboard to provide users with notifications and information regarding their room's electricity usage. This process increases energy efficiency and raises user awareness about electricity conservation.

The data is stored in the server database, which consists of 3 tables: "sensors" for sensor data, "power" for the data recorded by the sensors, and "users" for registered user data in the system. There is also a "temp" table that stores temporary values for the space in use.

C. Result and Discussion

A. Implementation System

The WISE-Energy system involves several hardware and software components that have been described previously. Figure 6(a) shows the hardware implemented in this system, while Figure 6(b) shows an ammeter to compare the SCT-03 current sensor readings. Next, Figure 6(c) shows the hardware implementation in the first and second test chambers. The SENIOR system can operate properly and produce accurate data by integrating these hardware components.

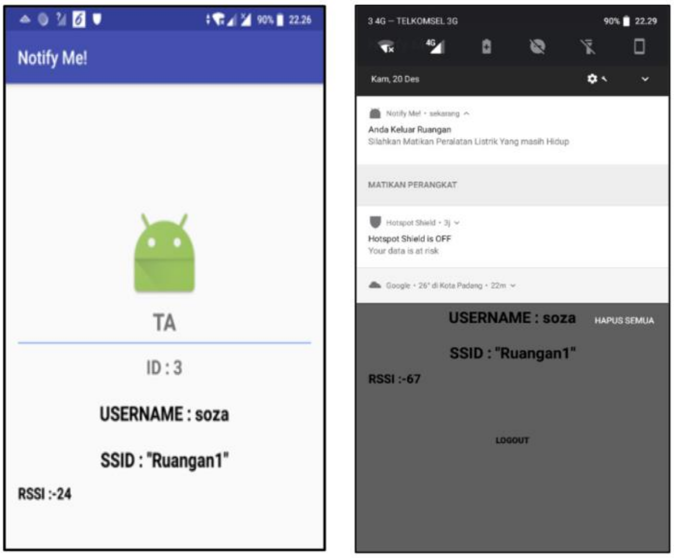


(a) (b)

(c)

Figure 6. (a) Hardware implementation, (b) Comparing SCT-03 sensor data with an ammeter, (c) Hardware implementation in test rooms 1 and 2.

The Android application's user interface implementation is shown in Figure 7. In Figure 7(a), the main page of the application displays the user's personal information and shows the strength of the WiFi signal connected to the smartphone. Additionally, the application provides a notification reminding the last user who left the room to turn off the lights. This notification is illustrated in Figure 7(b). With this feature, users can easily and efficiently control indoor light usage, ultimately saving energy.



(a) (b)

Figure 7. User interface in the Android application.

B. Testing Scenarios

Testing was conducted in two rooms with predefined scenarios. The focus of this test is a room lamp, which serves as an electrical device. Each test room has a specific entrance and exit. An Access Point (AP) is positioned in the middle of the room. The mobile application system will identify users who exit the room based on the strength of the WiFi signal emitted by the AP as they approach the exit. The room layout and the AP's location in the room being tested are illustrated in Figure 8.

In test room 1, Figure 8(a) shows the position of the access point, located in the middle of the room with the exit being parallel to the access point position. This room has an area of 16 m2 with a wall length of 4 m. In Figure 8(b), the access point in test room 2 is depicted with the exit slightly inclined to the right of the access point position, also in the middle of the room. This room has an area of 9 m2 with a wall length of 3 m.

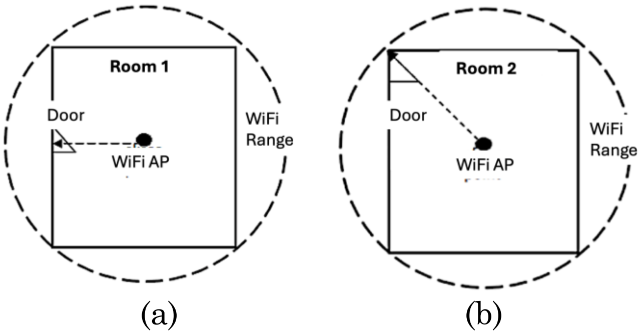


Figure 8. Schematic of test room, (a) test room 1, (b) test room 2.

To detect users leaving the room, the system utilizes the strength of the WiFi signal emitted by the access point. The mobile application reads the WiFi signal strength, which is pre-defined in the system. This enables the system to identify users who have left the room and trigger notifications to turn off the lights. The sensor labeled SCT-013 measures the power value in the room, and sends real-time sensor readings to the server.

C. Testing and Analysis

The first test was carried out on the SCT-013 sensor to read the electric current in the lamp. The Wemos microcontroller will read the SCT-013 sensor output in the form of analog data, which is then converted into digital data via ADC. The test continues by comparing the SCT-013 sensor data with current data obtained from the Ammeter. The purpose of this test is to compare reading errors by sensors. The graph in Figure 9 shows the current comparison between the SCT-013 sensor and the Ammeter. Errors occur during measurement due to inherent noise in the microcontroller ADC input. This affects calculations in the EmonLib library and results in incorrect values on the sensor. In testing, it was found that the average % error of the SCT-013 sensor was 18.76%, which means the success rate for measuring current by the SCT-013 sensor was 81.24%.

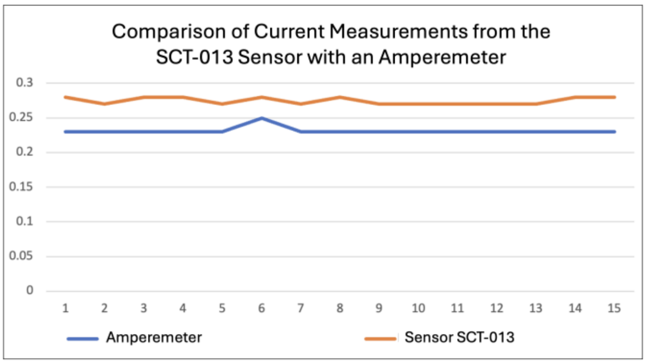


Figure 9. Comparison of current readings of the SCT-013 sensor with ampermeter

In the upcoming test, we will measure the RSSI strength that can be received by smartphones around the test room. After taking measurements, we found that the distance between the AP and the room exit was 2.1 meters. By comparing the distance of the AP to the exit door in rooms one and two, we can conduct WiFi signal strength testing. The test results for room 1 are depicted in Figure 10. The data shows that when testing the WiFi signal strength against the distance of the AP to the exit door of room one at a distance of 2 meters, the RSSI value or WiFi signal strength is higher, less than -64 dBm.

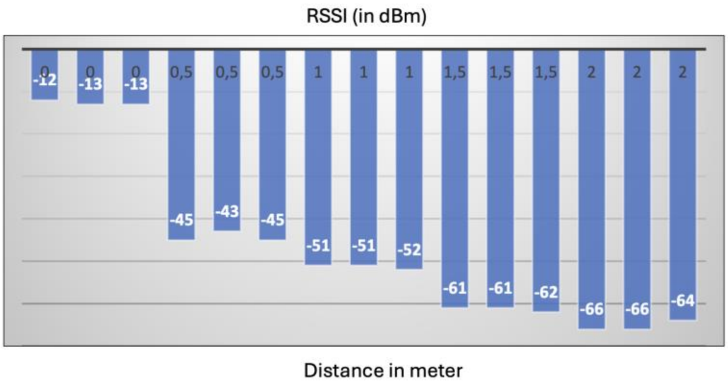
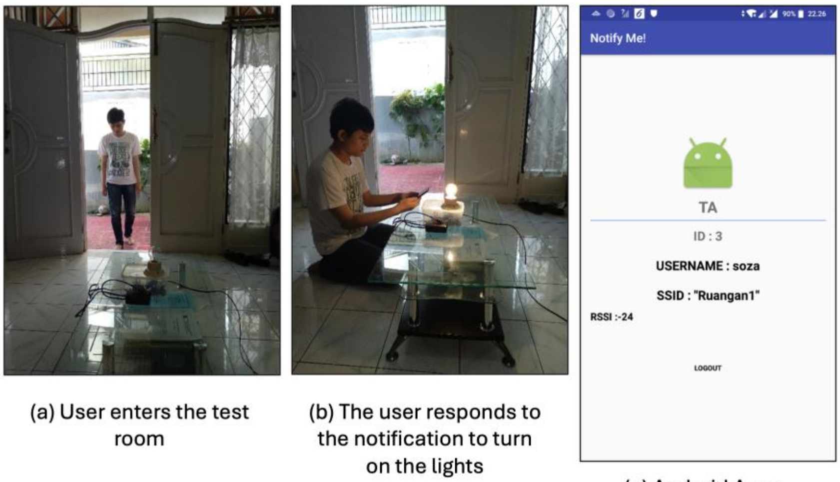


Figure 10. Measurement of RSSI values against distance in test room 1

- Scenario 1: testing when the user enters the room.

During the test, when the user enters the room, one of the users is asked to enter room 1 and room 2 with the initial condition that the room lights are off. After entering the room, the user will respond to the notification provided by the system to turn on the lights (as seen in Figures 11(a) and 11(b)). In Figure 11(c), the RSSI value or WiFi signal strength read in the mobile application is -24 dBm for room 1 and -38 dBm for room 2. These two RSSI values are still in the indoor room category, as indicated by the lights up in test room 1, as seen in Figure 11(b).



(a) User enters the test room

(b) The user responds to the notification to turn on the lights

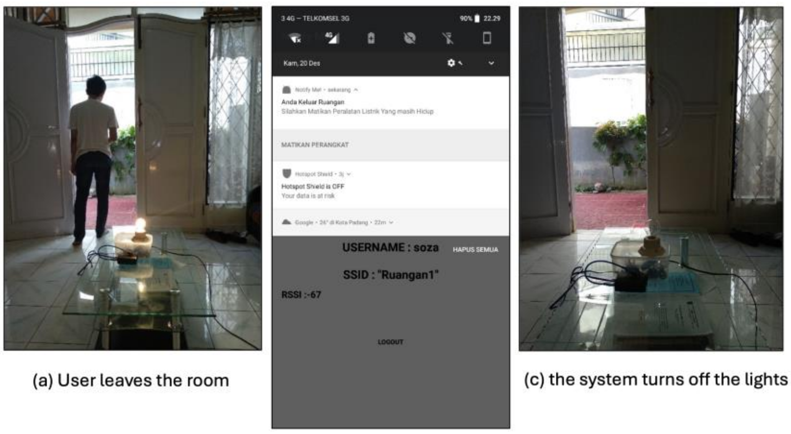
(c) Android Apps

Figure 11. Testing when a user enters test room 1.

- Scenario 2: testing when the user leaves the room

In Scenario 2, the testing involves instructing the only user in room 1 or room 2 to leave the room with the initial light on. The user has not responded to the notification provided. Figure 12(a) depicts the user leaving the room, while Figure 12(b) shows the notification display on the Android application when the system detects the user leaving.

In Figure 12(b), the mobile application reads the RSSI value or WiFi signal strength, which is -67 dBm for test room 1. Based on this RSSI value, the system categorizes users in room 1 as being outside the room. This is indicated by the system sending notifications to users who leave both room 1 and room 2. Figure 12(c) demonstrates that the lights in room 1 are automatically turned off by the system when the user who leaves does not respond to the notification in the application by turning off the lights.



(a) User leaves the room

(b) Notification on android apps

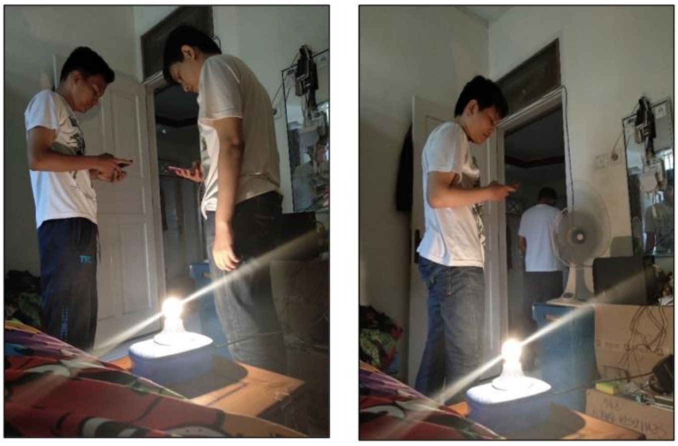
(c) the system turns off the lights

Figure 12. Testing when the user leaves test room 1.

- Scenario 3: testing when two users are in the room

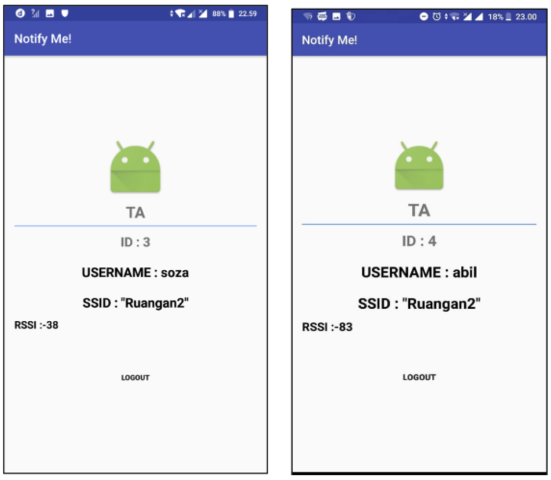
In a scenario where two users are in the room, one of the users from test room 2 was asked to leave the room with the lights on. Initially, Figure 13(a) shows two users in test room 2 with the light on. Then, in Figure 13(b), it can be seen that when one user leaves and there are still other users in the room, the system does not provide notifications to users who leave the room, as shown in Figure 13(c) and Figure 13(d). The sensor data from test room 2 is wirelessly sent via WSN to the server in test room 1 to create a centralized energy usage reporting system, with further information processing on the server. The WiFi signal strength read in the mobile application is -38 dBm for user 1 and -83 dBm for user 2, allowing the system to detect that user one is still in the room while user two has left room 1.

Based on the testing with two users in the room and one of the users leaving, it can be concluded that the system successfully identified the whereabouts of the user when one of the users left the room without giving a notification to turn off the lights, as there was still one user in the room.



(a) Two users in test room 2

(b) One of the users exits test room 2



(c) App interface on user 1

(d) App interface on user 2

Figure 13. Testing when two users are in test room 2.

D. Discussion

The WISE-Energy study focuses on promoting efficient electricity use by raising public awareness about the importance of turning off electrical devices when not in use. The system also aims to create a smart home that automatically turns off electrical devices when the user leaves the room and sends a notification to the user. It successfully achieves this by providing notifications to users based on their presence in the room using WiFi signal strength. If the user does not respond to notifications to turn off the lights, the system will automatically turn off the lights. Although the system has not been tested to measure its success in increasing the culture of saving electricity in society, it promises to be an effective solution for reducing indoor electrical energy waste and has the potential to be implemented in various environments as part of sustainable energy-saving efforts.

E. Conclusions

This paper presents the implementation of WISE-Energy, an indoor electricity usage saving system that utilizes Android and Wireless Sensor Network (WSN) technologies. Our testing confirmed that the system successfully met its objectives. The system effectively prompts the last user in a room to turn off the lights upon leaving, and the testing of WSN communication between room 1 and room 2 yielded positive results, demonstrating the system's ability to send power data from room 2 to room 1 via the XBee module. However, there are areas for potential improvement, including enhancing the notification mechanism for greater effectiveness and considering the use of WiFi sensing for automatic light settings. Additionally, integrating with Internet of Things (IoT) technology could enhance the efficiency of monitoring and remote-control systems.

F. References

[1] S. Khunchai, S. Apichat and R. Tama, "The Development of an Automatic Control System for Electrical Appliances with Object Detection Technology," in *18th International Conference on Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology (ECTI-CON)*, Chiang Mai, Thailand , 2021.

[2] M. Masnur, "Aplikasi Sistem Pengendali Energi Listrik Menggunakan Raspberrypi Pada Smart Building," *Sintaks Logika,* vol. 1, pp. 103-106, 2021.

[3] A. Parsa, T. Abbasian Najafabadi and F. Rajaei Salmasi, "Implementation of smart optimal and automatic control of electrical home appliances (IoT)," in *Smart Grid Conference (SGC)*, Tehran, Iran, 2017.

[4] A. A. A. Rahim, R. Boudville and S. Hussain, "Design of Fuzzy Logic Control for Automatic Switching OFF Electric Iron," in *9th IEEE International Conference on Control System, Computing and Engineering (ICCSCE)*, Penang, Malaysia , 2019.

[5] L. Susanti, D. Fatrias, D. Ichwana Putra, H. Kamil and M. Vivi, "A Configuration System for Real-Time Monitoring and Controlling Electricity Consumption Behavior," in *International Conference on Information Technology Systems and Innovation (ICITSI)*, Bandung, Indonesia, 2018.

[6] D. Xing and J. Li, "Circuit Switch Automatic Shutoff Technique for Electrical Equipment Based on Big Data Analysis," in *IEEE Conference on Telecommunications, Optics and Computer Science (TOCS)*, Shenyang, China , 2020

[7] S. Khunchai, S. Apichat and R. Tama, "The Development of an Automatic Control System for Electrical Appliances with Object Detection Technology," in *18th International Conference on Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology (ECTI-CON)*, Chiang Mai, Thailand , 2021