



## Development of an RFID-Based Control System for Residential Appliances with the Internet of Things

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### ABSTRACT

The Internet of things, or IoT, is a system of interrelated computing devices, mechanical and digital machines, objects, animals, or people that are provided with unique identifiers (UIDs) and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction. Many homeowners have difficulties monitoring their home electrical activity, which may cause electrical short-circuit, appliance overheating, or over-usage. These circumstances may lead to house fires, which can cause injuries or death to homeowners and dwellers and considerable damage to properties. The application of this research gives the idea to implement new studies towards the current developing form of technologies like the RFID and the Internet of Things. The compulsion of this paper is due to the continuous advancement of technology and to administer new tools effectively. The researchers chose only a feature of home automation: smart plug-in electrical outlets in residential areas controlled by a wireless RFID access and control switch. It uses an intelligent relay server that gathers data from a cloud database and gives the user easy access to the electrical appliances involved in the automation. Also, it helps monitor the status of every appliance involved in the study.

**Keywords:** *IoT, RFID, database, relay, software.*

### INTRODUCTION

Radio Frequency Identification (RFID) is a wireless technology that can be used to develop an access control system. The literature has revealed the use of this technology to automate various processes ranging from the industrial sector to home control (Li, Xu, & Li, 2008). It is suitable for many applications, such as automobile immobilizers, animal tracking, payment systems, automatic toll collection, and inventory management (Li et al., 2008).

Earlier, bar code was used to communicate, but now RFID has come into existence for better communication. RFID and bar code are similar in concept. Bar code utilizes optical signals to allocate context data from the label to the reader. In contrast, RFID uses Radio Frequency (RF) signals to transfer context data from the RFID device to the reader.



Ostojic, Stankovski, Lazarevic, and Jovanovic (2007) reported that using RFID devices in parking lots helps reduce chaotic effects and creates a hands-free parking system. Other works include using context-based RFID and sensor network suitable for the coming ubiquitous environment and situation information for the sensors and RFID identification tags (Hattori et al., 2003; Lee & Chung, 2004).

The Internet of Things (IoT) is a communication paradigm that envisions essential things in life will be integrated with microcontrollers, transceivers for digital communication, and appropriate protocol stacks that enable them to communicate with one another and with the users (Atzori, Iera, & Morabito, 2010). The IoT comprises three components: communication networks and computer systems (Stergiou & Psannis, 2017). In summary, it is also a concept that foresees the utilization of cyberspace, even for the simplest things in intelligent homes (Darianian & Michael, 2008; ITU, 2005).

Smart Home mainly consists of three modules: the server, the hardware interface module, and the software package. Smart homes are the residential extension of building automation and involve the control and automation of all its embedded technology (Domb, 2019).

Automation can be accomplished by using IoT and can give the inhabitants access to specific data in the house and control parameters remotely (Domb, 2019). One way to utilize the IoT is to use mobile cloud computing. Mobile cloud computing is a technology that refers to an infrastructure where both data storage and data processing operate outside of the mobile device, as mentioned in the study of (Stergiou et al., 2018). Cloud computing technology is changing how computer networks are used since services and features can be used on-demand according to the user's needs (Werner et al., 2019; Werner et al., 2017). This technology can provide processing power, software and storage services, or a distributed data infrastructure.

The study aims to design and run a system to provide power outlet automation for residential, commercial, and industrial applications and displays the outlet's status in a monitoring system. Also, the research aimed to gather and analyze data output from the system and perform the function test on the developed device and system. The application of this research gives the idea to implement new studies towards the current developing form of technologies like the RFID and the Internet of Things. The compulsion of this paper is due to the continuous advancement of technology and to administer new tools effectively.

The scope of this home automation system revolves around a smart relay control in electrical outlets and lights in residential areas. With this, it provides security and gives the user easy access to the electrical appliances involved in the automation. Also, it helps monitor the status of every appliance involved in the study.

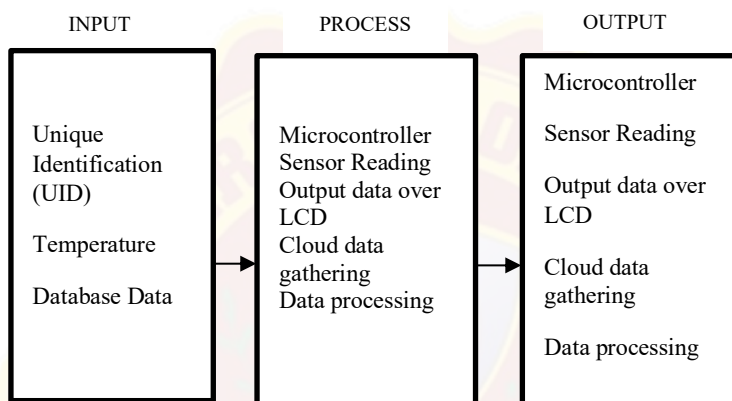
## METHOD

### *Research Design*

The study made use of the applied research approach. Before conducting the actual fabrication, a trade-off analysis between the two designs was made. The investigation was made to establish the best design based on the study's objectives.

### *Conceptual Framework*

Figure 1 shows the study's conceptual framework, having an input of UID, temperature, and database data. The microcontroller has its program for the processing stage of the system. Lastly, the gathered data is affected depending on its value in the output.



**Figure 1.** Conceptual Framework of the Study

### *System Block Diagram*

Figure 2 shows that the first phase of the monitoring system comprises getting input from a unique identification through the RC522 module from the wireless switching system and getting temperature data and electrical current connected directly to the central control and monitoring server. The UID is transmitted to a cloud database. After that, the Arduino receives the data through a Wi-Fi module and processes the data for the corresponding action. The last phase is the monitoring and control of outlets and lights.

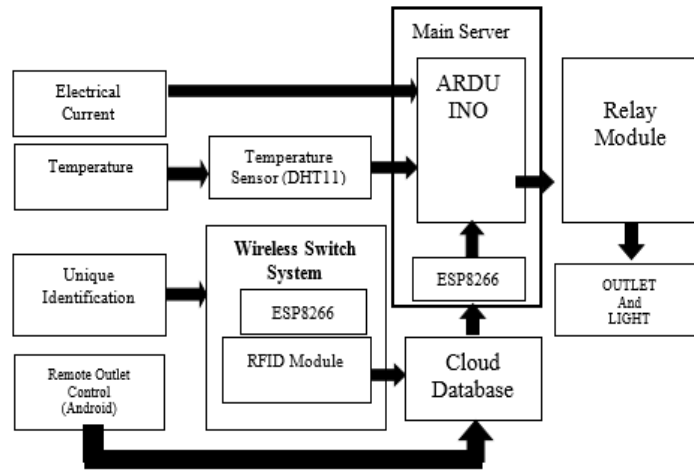


Figure 2. Functional Block Diagram

### System Design

The system is divided into four systems: Main Control Server, Wireless Switch System, Remote Access Control, and Cloud Firebase Database.

#### 1. Main Control Server

The central control server gathers data from a cloud database to turn the connected relays to control the outlet and lights of specific sectors. This server is connected to a firebase database where the data are stored on a cloud server. The data are retrieved from the database using an Esp8266 Wi-Fi module. The data gathered corresponds to specific commands, such as turning the relays on or off. Therefore, the server's primary function is to control the relays.

The home is divided into four areas: Living Room, Kitchen, Room1, and Room2. Each of the sectors has unique identification cards that can be used to control the outlet and lights. However, Room2 has only 6 UIDs to provide private room access to administrators only. LCD shows the output display of the line monitoring whether the outlets on each sector have a no-load status or an on-state status. Users can determine whether the outlet line is broken or s turned on. However, the outlet has an open connection or a non-functional outlet. Therefore, the LCD shows a no-load status. However, the LCD also indicates whether the outlet of the sector has no connected load.

#### 2. Wireless Switch System

This switching system is standalone from the server, which has a power supply unit. The system comprises an RC522 or RFID module, buzzer, and power supply. This wireless switch controls whether the lights of a particular sector are to be turned on or off using a context-based structure.



The switching system is an RFID-based switch that gathers a UID from a card key. The card key is verified from the database, whether the card key is a registered card or an unknown card. The system gathers the registered user's identity from the data if the card is registered. It transmits it again to the database with the time of access, sector of access, and access activity.

Buzzers represent the status of the switch. A long buzzer tone is outputted at the initial condition where the switch is first turned on. Also, it represents a successful connection from the database. If a registered card is presented to the sensor, the buzzer outputs a tone for two seconds. This means that the system recognizes the card, and specific command to the server is transmitted with the context of the UID. If an unregistered card is presented, the buzzer outputs three tones delayed by one second between tones. It represents that the system has detected an unregistered card. And transmits the context of the card together with the sector and time of access.

### *3. Remote Access Control*

The remote access control system is an android phone application built with an android studio, Java programming, firebase database, and Kotlin programming language. This system controls the relay through real-time database access using the Internet as the transmission medium. The application uses context-based access to determine whether the user is a registered access cardholder.

The application provides a login panel that a registered cardholder signs in with their credentials. After a successful login, the application provides a list of system activities. Also, the application provides a panel of controls to control the sector lights and outlets even if the user is not present in the sector. The android phone, which bears the application, should be connected to the Internet through Wi-Fi or mobile data.

Also, the application's primary function is registering cards with certain people. Guests and administrators use the app to register individual cards which control the sector lights and outlet. Each card registers a set of random-access numbers used as the PIN for the credential to use the app.

### *4. Firebase Database*

This separate system is a cloud database for storage and access node for the wireless switching system, central control server, and remote access control system. The database stores context data, such as the user's identity, time, location, and activity. The database comprises five parent nodes: Activities, Control, Credentials, Email, and Registered Card.

The data are collected by the Arduino processes from time to time since it is a monitoring and control system. The behavior of the microcontroller depends on the values gathered in the database. The gathered data is the basis for controlling the relays that connect the main supply line to the outlet and lights. On the other hand, the



Arduino is the one that makes the feedback of the system, i.e., when the data gathered corresponds to a registered user, the system controls the outlet and lights.

## RESULTS AND DISCUSSIONS

### A. Actual Design of the System

Figure 3 shows the fabricated hardware device of the central control server. The cut-out box enclosure houses the server's main components: the microcontroller, relay system, current sensor, and temperature sensor. It has an LCD that shows the temperature reading, connectivity status, and status of the sector, whether with a load or no load state.

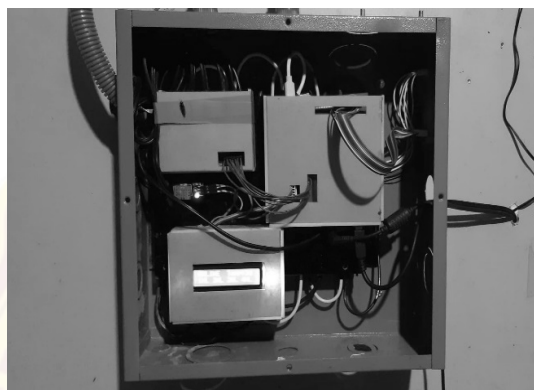


Figure 3. Main Controller of the System

The wireless switching system utilizes an RFID module, cards, and tags. The fabricated system could show the activity data log and display it in the android app, as shown in Figure 4.

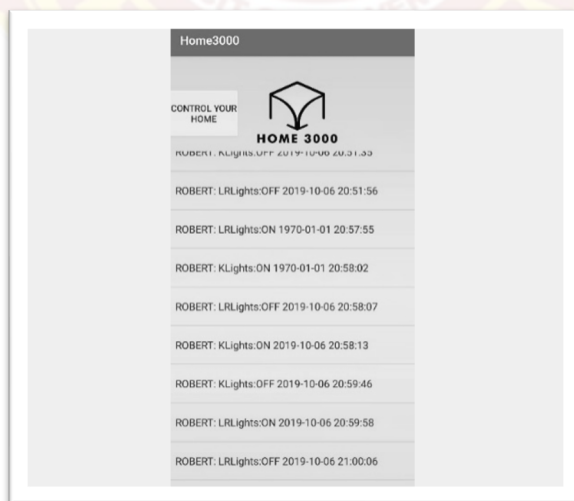


Figure 4. Sample Data Logger Output



## *B. Testing Result*

To operate the system, the user needs to register key cards using the “Home3000” android application designed by the proponents of this research. Once the card is registered to a specific user, the system automatically activates the critical card's control and access capabilities. Unlocking the system monitoring and control through the android application mentioned above or the wireless control console. The user logs in by scanning the key card on the wireless switching console of a specific house sector with a specific activity.

In the testing procedure, a 30-day monitoring and control system of the household was conducted using the system specified above. During the entire testing period, household members of the house are registered with key cards for control of the system. Within this period, we gathered a sample accuracy testing. The users are required to scan the card to control the whole system. The system is expected to respond with every switching access of the users. And also, the system is expected to operate stably to the complete 30-day control and monitoring stability testing.

The system operated in a controlled environment for 20 key card scans and 20 android application control for accuracy testing. The data gathered for the 20 key card scans on different sectors and activities resulted in 100 percent accuracy and a system response time of 3.06 seconds. For the android application accuracy testing, data gathering is done by controlling the system using the “Home3000” Android app. The system is controlled in Singapore to show the IoT capability of the system. For twenty attempts, the accuracy of the application is 100 percent with no absolute error and an average response time of 2.9 seconds.

## **CONCLUSION AND FUTURE WORKS**

Developing a control and monitoring system using current and context-based sensors through the Internet as a transmission medium greatly assists homeowners worldwide. The research proponents concluded that a stable and accurate control and monitoring system for electrical connections could provide adequate help for homeowners' automation reverie.

However, the developed system has two to three seconds of response time, which can be a delay—in future works. Making and establishing a more effective connectivity architecture is recommended. It is also important to reduce latency issues with the wireless switching console to reduce the delay in time response to ensure more effective and faster but still accurate control and monitoring system. In turn, this also adds satisfaction to the user.



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