



## Implementation of a multiple mode, automated Prototype Radio Frequency Identification Attendance and Access Control System

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### ABSTRACT

This study is aimed at implementing a Radio Frequency Identification (RFID) user attendance log database, multiple access control and monitoring system for intended users in a facility. The research motivation is due to the need for a secure verification and flexible automated access control system using the RFID scheme. To achieve it, the methodology involves both hardware and software implementation. The hardware consists of a RFID module, a Real Time Clock (RTC) module, a motorized door and a display screen interfaced to a microcontroller. The software implementation involves programming the microcontroller using C++ based programs and developing a dedicated mobile application with a user database. The Mobile Application interfaces with the RFID system hardware as a flexible automated security tool with user classification, access limitation and emergency exit modes. The RFID system verification protocol allows users authentication based on its user classification mode. By implication, the system with its multiple mode access control structures namely; a user classification, access limitation and an emergence exit modes, can monitor category of users, provide flexible access control and generate user attendance log.

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### INTRODUCTION

The RFID is an evolving and rapidly growing technology in the sector of contemporary access control technologies. The technology offers superior performance over other automatic identification systems and can be used as a security tool in many areas like municipal transportation, animal identification, electronic immobilization, industrial automation, identification and access control of people (Abirami *et al.*, 2022; Israa, 2015).

Notably, security concerns are among paramount factors considered in any organizational settings. As a result, different safety techniques have been developed and used for the safety of lives and properties within such settings. To ensure safety, simple traditional locks or alarm systems are utilized as well as security personnel. However, these systems have their drawbacks when strict, effective and seamless control systems are needed in their areas of deployment. These drawbacks could be in form of loss of lock keys, alarm failure, slow response by operators etc. To eliminate these drawbacks, different systems were developed, namely; voice

identification door access, password access etc. with new demerits emerging. However with the development of RFID, a safe security system could be built to efficiently meet the security needs of organizations with little or negligible drawbacks. Accordingly, a blend of RFID systems enhanced with flexible access control features to achieve automated monitoring system using standard designed algorithm ensure that user data is protected (Arque, C.L., and Rendulich, J., 2020).

The RFID system is developed on radio frequency to interconnect with electronic devices and computers which are able to identify active and passive tags and transponders within a range of a few centimeters to some kilometers. It uses wireless electromagnetic fields to transfer data for the purposes of automatically identifying, authenticating and tracking tags or chips attached to objects. Tags contain electronically stored information; some tags are powered by electromagnetic induction from magnetic fields produced near a reader (Ibrahim *et al.* 2018; Luckyn, and Boma, 2020).

The basic RFID system can be thought of as having two parts: the frontend and the

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backend (code repository). In contrast to the back-end server architecture, the front-end comprises embedded IC tags (transponders) that can be accessed by reader devices (transceivers). In its most basic form, a tag replies to a reader's query with an identifier (ID), identifying the tagged object base on the data earlier captured and enrolled for object. RFID tags can be powered externally (passive) by the reader electromagnetic radiation while the reader can be powered by an internal or external power supply. Tag data and object information are two categories for tag-related information. Tag data includes information such as secret codes, special identifiers, etc. that supports tag operations. While, object information consists of information on the tagged object (such as its description, maker, or owner e.g. finger print, special codes etc.) or the supported actions and services (e.g. programmed physical access control, inventory management etc.).

This study focuses on implementing an attendance generation log and a automated multiple access control system based on RFID scheme interfaced with a mobile application for security and ease. Importantly, in the report chronology, a presentation of review of related work is done, followed by an overview of the RFID system in section 2. Section 3 highlights the methods in implementing the automated RFID system as well as the test carried out. Lastly, sections' 4 and 5 discuss the results obtained and conclusion respectively.

## LITERATURE REVIEW

Appraisals of RFID based attendance and access control systems within the last decade reveal a steady technologically advancing attendance and access control schemes with one or two levels of automations with blends of similar attendance and access control technologies. Consequently, a review of the work of Sai *et al.*, (2016) revealed that they implemented a monitoring and access control system based on RFID and Zigbee technology which could be used at Parliamentary Campus. Their research employed the RFID technology interfaced with Zigbee wireless module because of its extensive usage for access control system, its cheapness, waterproof and easy to use as well as its unique Electronic Product Code (EPC) feature. They noted that the system can also be used for industrial, commercial and security HVAC closures. In a similar work, Peter *et al.*, (2016)

proposed an RFID-based access control security system using GSM technology. The system utilized a 125KHz RFID system, a microcontroller configured to send control signals, a DC motor, relay, buzzer, LCD, and a GSM/GPRS modem.

In 2018, an automatic RFID-based access control system using Arduino was designed by Ibrahim, *et al* (2018) and, Orji, Oleka, and Nduanya, (2018). Their systems combined RFID technology and a microcontroller to accomplish their operations. The RFID reader which is fitted at entrance detects RFID tag, captures the user's User Unique Identifier (UID) and compares it with the stored UID for a match. If the user UID captured matches with any of the stored UID, access is granted; otherwise access is denied. Their results showed that the systems are cheap, effective, and a reliable means of granting or denying access in a secured environment.

After the outbreak of the Covid – 19 pandemic in 2020 and the ensuing Covid – 19 preventive protocols to curb the spread of the virus by WHO, attendance and access control systems design for public spaces steadily evolved from being mainly contact base (e.g. the use of finger print) to be noncontact base systems in which, users data collection were done via contactless transducers like facial scanners, temperature scanners etc. The shift in the system initialization to contactless modules was due to the ease of spread of the Covid virus via touch and very close contact.

Due to this development, researches were undertaken to fit into the Covid – 19 prevention protocols. Researchers designed and implemented RFID attendance systems using Microcontrollers and peripherals like GSM modules, Google Sheets, cameras etc. Their works demonstrated systems that comprise the application of RFID and wireless database record entries. The systems eliminate time wastage experienced in manual attendance and maintained record entries that are statistical built for proper allocation of suitable attendance and for other usage. In their works, the adaption of RFID in actualizing efficient and automatic students' attendance recording system and some level of access control achieved considerable degree of successes and acceptability of usage (Aditya and Muskan 2022; Aravindhan, Karuppasamy and Sangeetha 2022; Arque, C.L., and Rendulich, J.,

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2020; Choe *et al.*, 2023; Luckyn and Boma, 2020; Minh-Duy *et al.*, 2022; Vibin *et al.*, 2021).

More so, employing special parameters in RFID system automation, Muhammad and Izanoordina (2022) designed a RFID detection attendance system activated by a microcontroller operated body temperature scanner. According to Muhammad and Izanoordina (2022), the system works by scanning user's body temperature and then reading a user's RFID card depending on the body scan output. If the user's temperature is above 37 degree Celsius, a safety alarm goes on continuously. If the user's temperature is below 37 degree Celsius, the system scans their user's ID, marks the attendance corresponding to that code ID and saves the information in SD card. Similarly, Aaron *et al.* (2022) designed an automated RFID attendance system merged with identity cards deployed in a university premises. In the design, RFID tags are embedded in staff and students' identification cards to generate attendance from the given users at any time the university premises. Aaaron *et al.* stated that their attendance system was interfaced with a mobile application (BrasApp) developed using the javascript platform. The App has a module to track attendance of students at various spaces in the university and a virtual ticket generating module for cafeteria use.

A summary of the research works reviewed showed that some of the researchers restricted their works using only one automation protocol or none at all. Thus, the improvement in this research is that it employs a secure RFID card reader identification interfaced with a mobile security App that enables flexible automated access control and monitoring system using multiple mode procedures built upon three classes of users (e.g. staff, non – staff authorized user and visitors) as well as an access space limitation or restriction and an emergency exit modes. These modes architectures interfaced to a database management system regulate the type and number of classified users' access is granted into a facility. Thereby, controlling and monitoring users' entry and exit behaviors. Notably, the mobile security App. with its flexible user classification and access space architectures changes the entry and exit requirements to hall spaces and thus regulating the numbers and type of users who access can be granted.

### Theoretical Description

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### 1. The RFID System

RFID system is a wireless communication and electronic mechanism that consists of two main hardware components namely; a RFID tag (transponder) and reader (transceiver), and a database management framework or server. The RFID tag and reader are link to back-end application system of a database management framework or server (Arjuna, Zaliman, and Ali, 2009; Lauren, 2023). Figure 1 shows the basic RFID system.

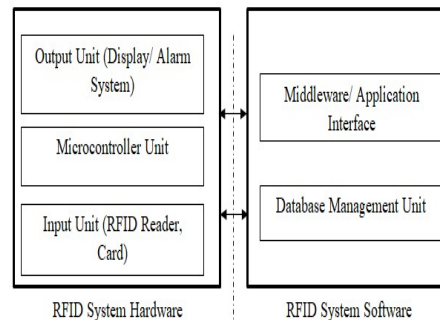


Figure 1: The basic RFID System

### 2. The RFID Tag

The tag consists of a coupling element and a low power Complementary metal – oxide semiconductor (CMOS) IC. The CMOS IC houses an analog Radio frequency (RF) interface, antenna turning capacitor, RF to DC rectifier module, Electrically Erasable Programmable Read – Only Memory (EEPROM), digital control and data modulation circuits. The tag functions as programmable microchip storage device. Tags can be classified as active tags, semi – active tags and passive tags based on their power source utility (Finkenzeller, 2010).

### 3. The RFID Reader MFRC522

The RFID reader contains RF transceiver module, signal processor, control unit and an antenna plus a serial data interface to a host system. The readers interrogates the tags and typically implements a radio interface to the tags and also a high level interface to a backend server with a database management system. The card reader module MFRC522 which supports ISO 14443A/MIFARE NTAG modes is a highly integrated reader for contactless communication at 13.56MHz. It is designed to create a 13.56MHz electromagnetic field and communicate with RFID

tags of ISO 14443A standard. The internal transmitter of the MFRC522 is capable to drive a reader/writer antenna designed to communicate with ISO/IEC 14443 A/MIFARE cards and transponders without the addition of active

circuitry. More so, the in-built digital module efficiently manages the ISO/IEC 14443A framing and error detection (parity and Cyclic Redundancy Check - CRC) functions of the MFRC522 (NXP Semiconductor, 2016 April).

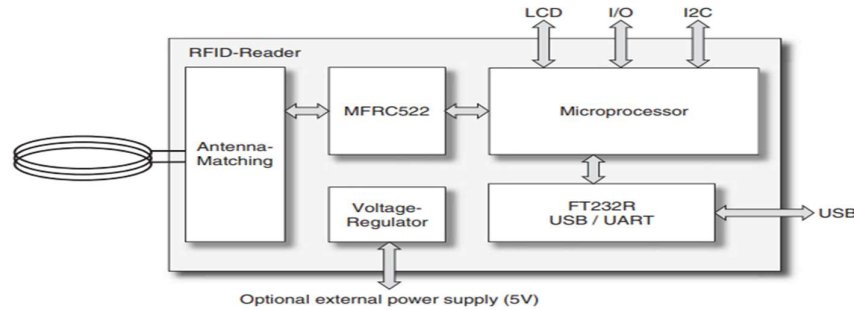


Figure 2: Block diagram of a complete RFID reader for 13.56 MHz (Finkenzeller, 2010).

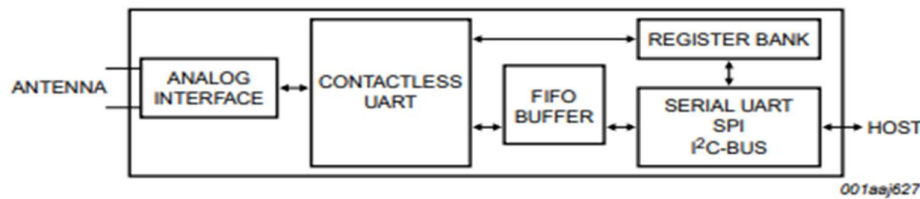


Figure 3: Simplified block diagram of the MFRC522 (NXP Semiconductor, 2016 April)

#### 4. The Database Management Framework

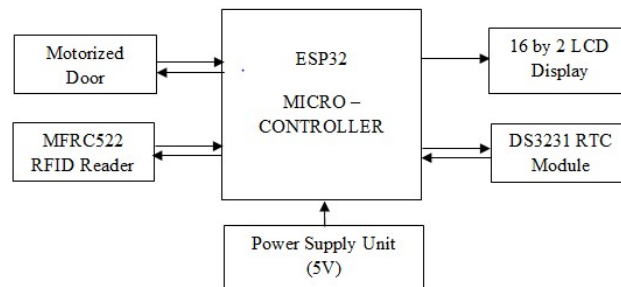
The database stores and manages data from the reader. Typically, it contains an asset's name or model number, information about user(s), the unique RFID serial number associated with users, and fields related to when and where the associated tags are interrogated. Generally, a computer or a microcontroller is needed that runs middleware between the reader and database management system to filter the data and then pass that information to the database (Finkenzeller, 2010; Lauren, 2023).

#### METHODOLOGY

The design approach employed to achieve the RFID system is basically in two phases namely;

1. The hardware design and implementation
2. The software development

The hardware design uses a comprehensive block diagram and circuit diagram to analyze the hardware components selection and interconnections. In addition, the software development evaluates the software sketch development and implementation for the system's components compatibility and functionality as well as data management.



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Figure 4 Block diagram of the system architectural design

### Hardware Implementation

The hardware design consist of the microcontroller, the electronic and the mechanical sections which involve the analysis, component specification and calculation, component lay – out and connections procedures and assembly of the circuit lay – out of components of the various segments. By the design scheme as shown in figure 4, the ESP32 microcontroller is connected to RTC module, I2C LCD display unit and Motorized door and they are powered by a 5V regulated DC power supply. They serve as the main controlling unit, real time monitoring unit; information display unit, and door opening and closing mechanism of the system respectively. The card reader is powered by the output power pin of the ESP32 Microcontroller. The ESP32-WROOM-32 with ESP32-D0WDQ6 chip was used as the microcontroller in this study. The embedded chip is designed to be scalable and adaptive. There are two CPU cores that can be individually controlled, and the CPU clock frequency is adjustable from 80 MHz to 240 MHz. The chip also has a low-power coprocessor that can be used instead of the CPU to save power while performing tasks that do not require much computing power.

During the connections of the various components, considerations were made to ensure that components' selections were within limit and in conformity of data sheet specifications of the components used. As schematically presented in figure 5, the card reader connection to the ESP32 was realized by interfacing the ESP32 pins D23, D19, D4 and D2 to the RC522 Card Reader pins 3 Master Out Slave In (MOSI), 4 Master In Slave Out (MISO), 2 Clock (SCK), 8 Serial Data Line

(SDA) and 7 Reset (RST) respectively. The RC522 input power pin was connected to ESP32 microcontroller to power it as well as its GND pin to the ESP32 GND pin.

In interfacing the ESP32 with the motor door mechanism, the RTC module and I2C LCD, as shown in figure 5, the ESP32, L293D motor Driver and motor interconnection was actualized by connecting pins D26 and D13 of the ESP32 to the motor driver pins IN1 and IN2 respectively. The ESP32 microcontroller and the Motor driver power input pin were connected to the 5volts DC power supply. Output pins 3 and 6 of the motor driver IC were connected to the DC motor to drive it in forward and reverse directions. Pins; Serial Clock (SCL) and SDA of the I2C LCD and the DS3231 were connected together as like pins and then connected to pins D22 and D21 of the microcontroller respectively.

### Principle of Operation of the Hardware

The architectural layout process starts when the RFID reader scans data from the RFID card and the data is transmitted to the ESP32 microcontroller. The microcontroller is Wi-Fi enabled. It analyzes the input data sent to it and communicates to the Display unit and the motorized door. The motorized door is driven by a motor drive IC (L293D) and a 5V DC motor. When the motorized door receives data from the microcontroller via IC motor driver, the driver automates the opening or closing of the door by controlling the DC motor to rotate clockwise or anticlockwise respectively. The microcontroller processed data (attendance log) are stored in the data management software in the controller and the instructional messages are displayed on the LCD display unit.

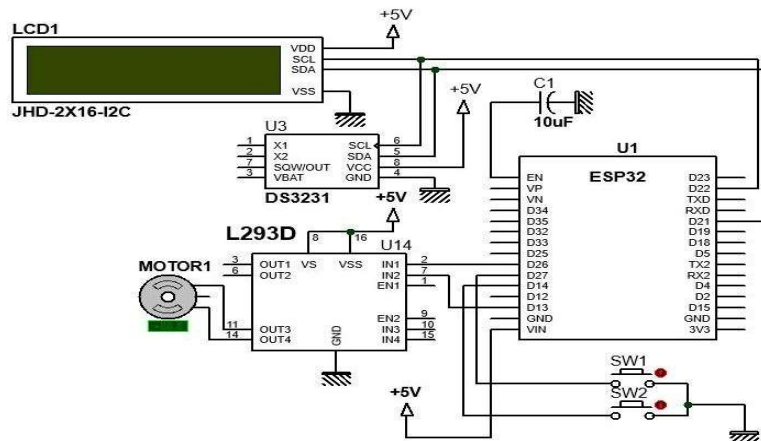


Figure 5 Connection of the ESP32 microcontroller to the RTC Module, I2C LCD and the L293D

### The Software Development

In the software development, the microcontrollers, RFID cards were programmed and interfaced with the database that manages basic information of the intended users, attendance log files, and authorization files. This was achieved using Arduino software 1.8.15 version and MIT App Inventor.

### The Arduino software application Development

The Arduino software application was used to develop the necessary firmware applications programs for seamless connectivity and communications between the different components used in the hardware and software implementation for the ESP32 WROOM, the

L293D motor IC, the RFID Reader, the I2C LCD display, the DS3231 and the software interfaces.

### MIT App Inventor Mobile Application Development

The MIT App Inventor was used to develop the mobile App. and browser used for remote automated access control and monitoring of the RFID system via a dedicated mobile application or web browser. The designed App. was uniquely developed for personnel in charge of security of the space in which the RFID system is deployed. Figure 6, block representation of how the MIT software interfaces to develop mobile Apps. Figure 7 is a pictorial presentation of the MIT design window.

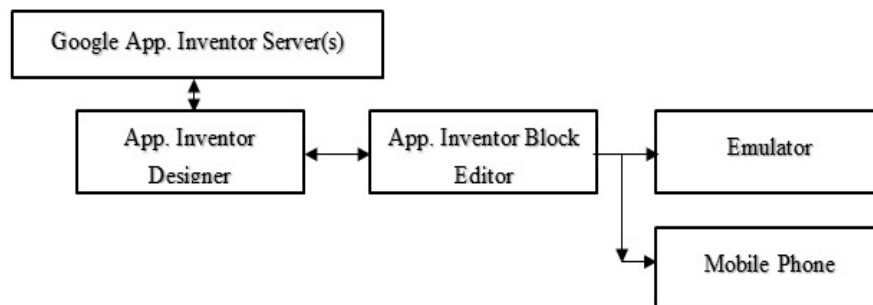


Figure 6 Diagram of the workings of the MIT App. Inventor for Mobile App. Development

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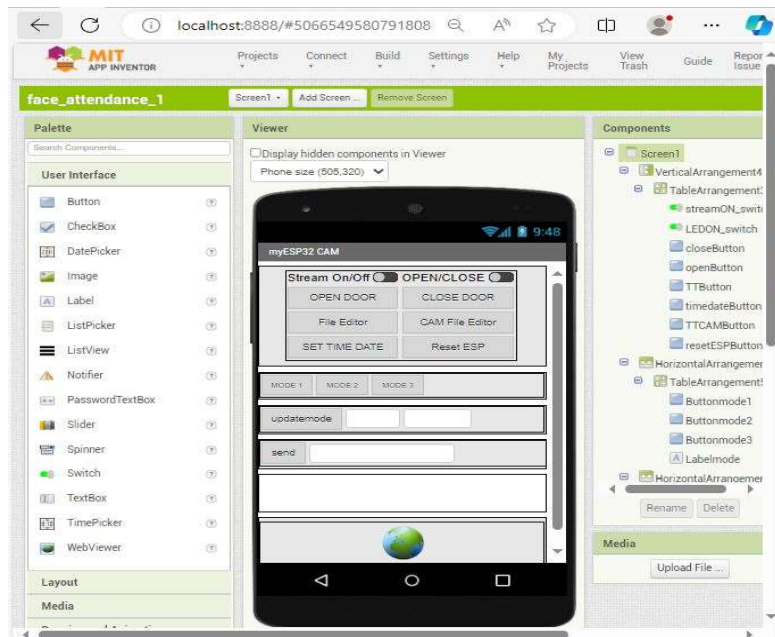


Figure 7 MIT App. Inventor design window for the Mobile Application

### Automated Operation modes and User Registration

#### 1. Automated Operation modes

Three operational modes are developed with the aid of MIT App. Inventor for multiple access control and automation flexibilities of the system. The modes are the User Classification Mode, the User Access Limitation mode and the Emergency Exits mode. Figure 8 and 9 illustrate the flowchart automated operations of the various modes.

#### 2. User Registration

The RFID cards are configured into three standard categories for user under the user classification mode. The categories are Mode 1, Mode 2 and Mode 3.

**Mode 1 Configuration** – This configuration is done exclusively for staff. Also, the mode allows its users access to the other modes. Here the RFID card unique number is obtained through the RFID reader. The IP address or edit file is

opened in a browser. The dt.txt is then opened on the display window to register the staff. The staff code (staff captured picture, name and unique ID number) is entered along with the card code and the mode number 1. The information is saved and the system is refreshed.

**Mode 2 Configuration** – This is structured to accommodate mode 1 and configured for non – staff authorized user. The procedure is the same as in mode 1. However, non – staff authorized users' codes are used for registration.

**Mode 3 Configuration** – The cards are registered without assigning user codes or details designated for visitors and other users. On the contrary, it assigns users' image to the card each time it is used. Figure 10 shows the registration platform for ten users.

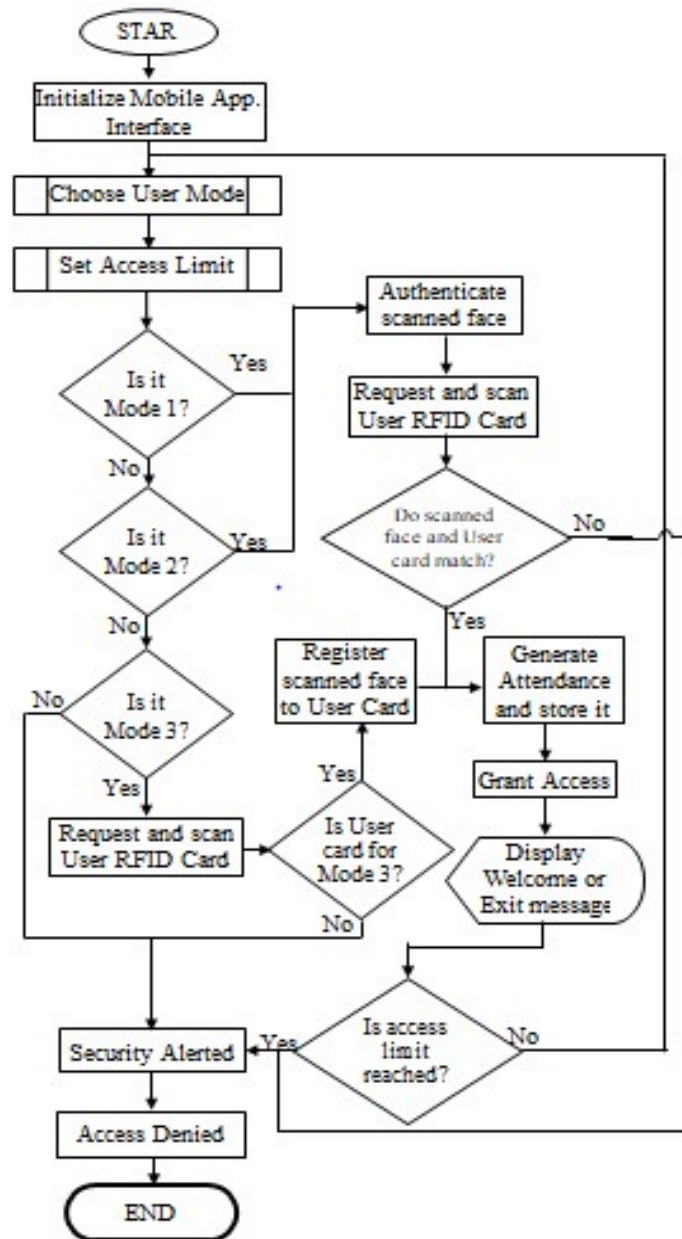


Figure 8: Flowchart of automated operation for the User classification and Access limitation modes



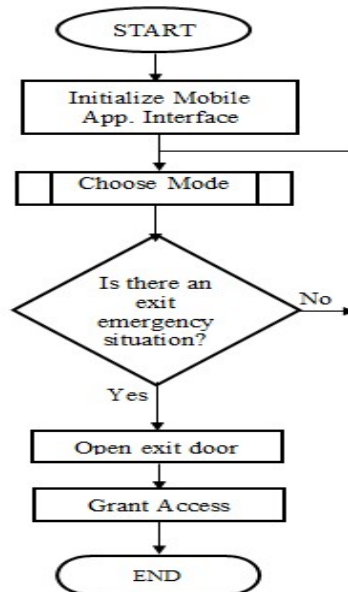


Figure 9: Flowchart of the automated emergency mode operation

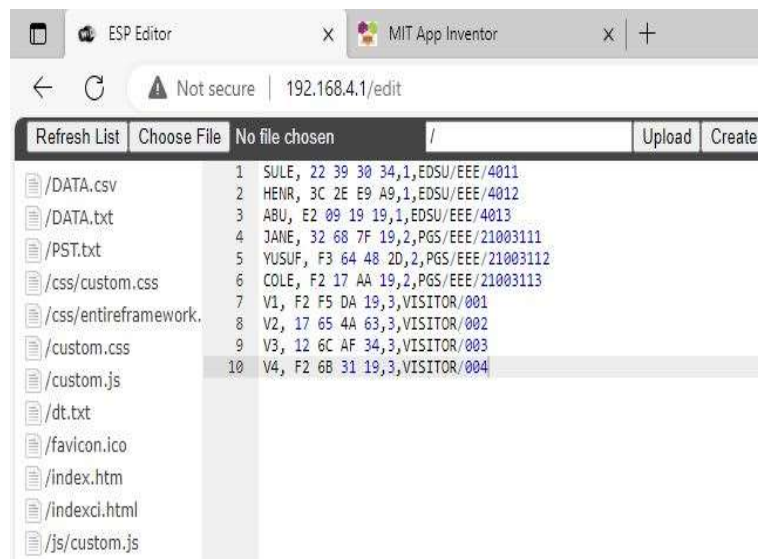


Figure 10: Users registration platform window

### Tests

The following tests were carried out on the designed system. These tests were done to generate results to evaluate the functionality and efficiency of the RFID system. The tests are;

1. User classification Mode test
2. User Access Limitation Mode Test

### 3. Emergency Exit Mode Test

Below were the tests carried out and their respectively results.

#### 1. User classification Mode test (Three Mode Test)

Test were carried out to validate the three mode or class of users namely Staff mode (Mode 1), staff and non – staff authorized user

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mode (Mode 2) and visitor and general user mode (Mode 3). By the design structure, priority is given to Mode 1 above the other modes. And by operation, Mode 1 only allows staff access, Mode 2 allows staff and non – staff authorized users access only and Mode 3 allows staff, non – staff authorized users and visitors access. The RFID system was switched to Mode 1 and the three categories of users were made to use the system to gain entry access. Thereafter, the system was switched to Mode 2 and then Mode 3 with the three categories of users querying to gain access to the facility respectively. The results of the different modes test are shown in Table 1; Results of the three modes test for user classification mode. Notably, as tests were ongoing attendance log is generated by the system for the various users.

#### 2. User Access Limitation Mode Test

The numbers of users allowed into a particular space was tested by carrying out the User limitation test. Tests were carried out for the three user class modes. Limits of persons were set at two, five and seven respectively for the three User Modes.

#### 3. Emergency Exit Mode Test

The emergency mode was tested by operating the system to operate without using the access control criteria to grant access to users to exit a given space. That is, opening the door in the event of an emergency.

### RESULTS AND DISCUSSION

The results of the various tests carried on the RFID system are noted under the test results sub – headings below.

#### User Classification Mode Test Results

Results from the user classification mode tests showed that priority is given to Mode 1 above the other modes. Namely; Mode 1 allowed only staff access, Mode 2 allowed staff and non – staff authorized user access only and Mode 3 allowed staff, non – staff authorized users and visitors access. Table 1 shows the user classification mode tests outcome while figure 11 shows LCD display of three modes and figure 12 shows the LCD Display when; A. Access is denied, B. Access is being processed, C. Access is granted to a user and D. the user exits respectively. Importantly, as the Three Mode Test were carried out, data log (attendance) on users' entry, exit and access denial were generated as shown in figure 13.

**Table 1:** Results of the three modes test for User Classification Mode

MODE TYPE \ USER CLASS	Mode 1	Mode 2	Mode 3
Staff Only	Access granted	Access granted	Access granted
Non – Staff Authorized User Only	Access denied	Access granted	Access granted
Visitors Only	Access denied	Access denied	Access granted



Figure 11; LCD Display of the three modes or User classification modes

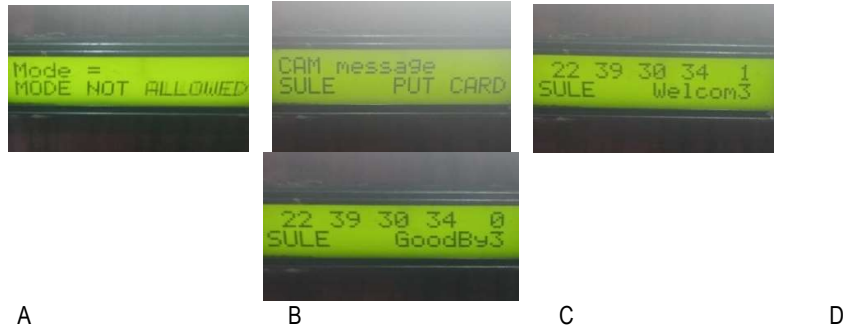


Figure 12; LCD Display message of; A. Access denial. B. Access processing for User (SULE) after scanned RFID is identified. C. Access granted of the user. D. Exit of the user.

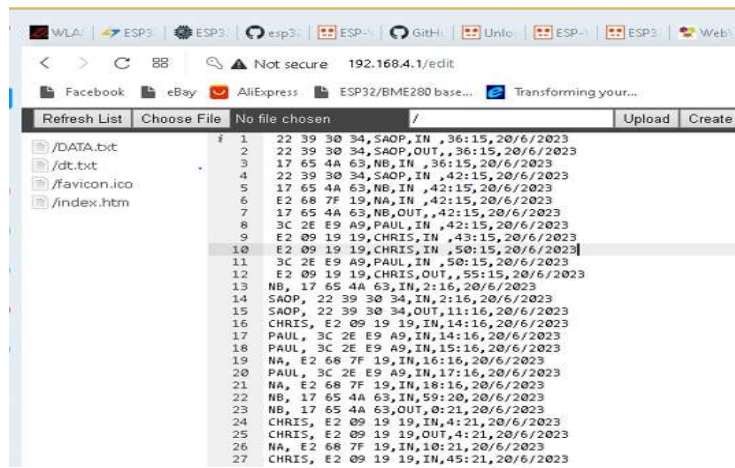


Figure 13 Data log generation

#### User Access Limitation Mode Test Result

The system is built to vary the numbers of users that can be granted access from one to a few thousands. This serves as a variable access limitation and population control (restrictions). Figure 14 shows the result of LCD Display when the maximum users (visitor) granted access by the system is set at two.



Figure 14; LCD Display of maximum allowable user.

#### Emergency Exit Mode Test Result

The results from the emergency test indicated that the closed space access door can be opened without passing through the security protocols by the mobile App. in an event of

emergency evacuation of individuals in the closed space.

#### CONCLUSION

This paper presented the analysis of the design and implementation of a multiple mode automated prototype RFID attendance and automated access control system for users in facilities based on secure and flexible access control protocols using ESP32 microcontroller, RFID MFRC522, I2C LCD Display and motorized door. The system's software operational architecture to classify its users, generate attendance log for them and regulate the numbers and categories of users who access is granted or denied into facilities met the drive of this study. That is, implementing a multiple mode, automated prototype RFID attendance and access control system as

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shown from the results analysis generated in the system tests carried out.

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