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A Near Field Communication Authenticated Home Automation System

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Abstract: *This paper introduces an open source, affordable, easy to use and secure home automation system based on NFC* technology. *An Arduino Nano microcontroller is used as the main controller for the system. The system is limited to a home model for prototyping purposes. A web application works as the user interface while a standard wireless network is used as the medium for communication. A prototype of the system is presented as proof of concept.*

Keyworks: Automation, Smart Homes, IoT, NFC, Energy Efficiency

1.0 Introduction

In addition to the clamour to adopt clean energy in the face of the undeniable effects of global warming, many African urban and rural communities face growing energy demands with increasing energy costs. This makes the need for an improved energy efficiency at household level increasingly important.

Home automation refers to control of the home appliances by using computer technology. Computer Systems enables from remote control of lighting through to complex micro-controller or computer based networks with various degrees of intelligence and automation. Home automation provides security, energy efficiency and ease of use hence, it is adopted more.

By utilizing smart sensors, programmable controls and data-driven energy management systems, this work to develops an automated system that optimizes the use of lighting, heating, cooling and other appliances. The system is mobile based and uses NFC-enables smartphones or NFC cards/fobs to authenticate and activate the controlling system. The system can only be made active when the user's phone or the NFC and the NFC tag make contact. The NFC adds an extra layer of security. The overall goal is to create a responsive and sustainable system that reduces energy wastage while maintaining comfort and convenience for occupants. This is achieved by ensuring as needed and optimal operation of devices and appliances.

1.1 Benefits of Home Automation

The numerous benefits of home automation include:

- Adding safety through appliance and lighting control
- Improved security
- It saves money by reducing energy consumption.
- It is efficient as a time saving measure.

1.2 Challenges with Home Automation Systems

- Dependency on internet connection: Because most smart home technology requires an Internet connection to operate, when the Internet goes down a lot of the features needed for home automation becomes unavailable. This limits the functionality of the technology and its associated devices.
- Cost: Sometimes, implementing this technology does not come cheap. However, in cases when full automation is expensive, there is possibility of customization to take care of your peculiar needs.

1.3 Near Field Communication (NFC)

1.3.1 Types of NFC Tags

NFC communication can be of 2 modes which are the active mode and the passive mode [1].

In passive mode, one NFC device, the initiator, generates an RF field and the other NFC device, the target, uses the first device's RF field to send its stored data back to the first device via a process called load modulation. This is the most common mode of operation of near field communication because passive tags (which are less expensive and lack a battery) can be used. In active mode, the NFC tags depend on batteries to be able to generate electromagnetic signals.

1.3.2 Modes of Operation

Peer-to-peer mode: In peer to peer mode, two smartphones establish a bidirectional connection to exchange data as shown in figure 1. In this mode, smartphones can exchange any kind of data such as business cards, digital photos, or any data specific to an application provides a protocol stack illustration for peer to peer mode.

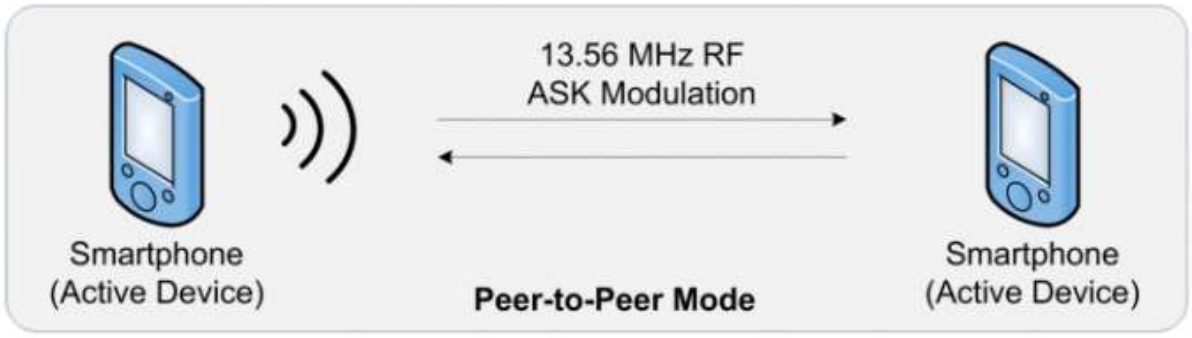


Figure 1. Peer to Peer Mode

Read/write mode: In reader/writer operating mode, a smartphone initiates the communication as an active device, and can both read from and write to an NFC tag as shown in figure 2. NFC tags are some form of passive RFID tags. It provides a protocol stack illustration for reader/writer mode.

Card emulation: In card emulation mode, as the user touches a smartphone to an NFC reader, the smartphone behaves like a standard smart card; thus, the NFC reader interacts with the Secure Element (SE) directly provides a protocol stack illustration for card emulation mode. The diagram is shown in figure 3.

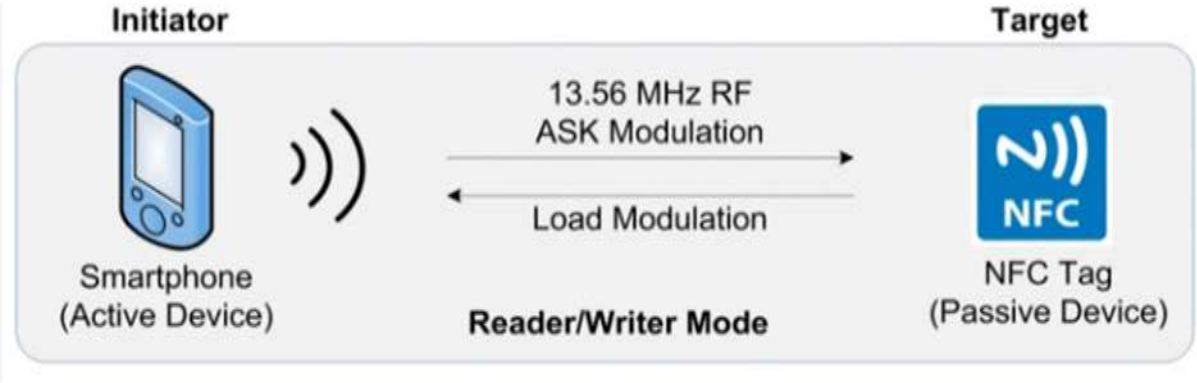


Figure 2: Reader/Writer Mode

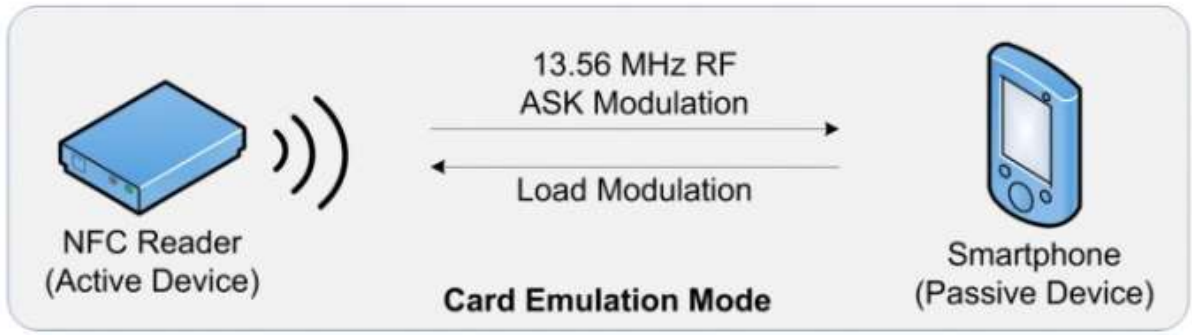


Figure 3: Card Emulation Mode

Some works have been done in this area. For instance, in [2], the authors presented a home automation system that employs the integration of multi-touch mobile devices, cloud networking, wireless communication, and power-line communication to provide the user with remote control of various lights and appliances within their home. This system uses a consolidation of a mobile phone application, handheld wireless remote, and PC based program to provide a means of user interface to the consumer. An android phone was used in home automation in [3]The prime objective of this paper is to assist handicapped/old aged people. It gives basic idea of how to control various home appliances and provide a security using Android phone/tab. The design consists of Android phone with home automation application, Arduino Mega ADK. User can interact with the android phone and send control signal to the Arduino ADK which in turn will control other embedded devices/sensors.

Home automation gives you access to control devices in your home from a mobile device anywhere in the world. The term may be used for isolated programmable devices, like thermostats and sprinkler systems, but home automation more accurately describes homes in which nearly everything (lights, appliances, electrical outlets, heating and cooling systems) are controlled as a unit.

2.0 Devices Used in this Project

- Arduino Nano: The Arduino Nano is a small, complete, and breadboard-friendly board based on the ATmega328 [4]. It can communicate with a computer, another Arduino, or other microcontrollers. See fig 4.

Fig 4. Arduino Nano

- Arduino Wi-Fi (ESP8266): A WiFi module with integrated TCP/IP protocol stack that can connect any microcontroller to a WiFi network [5]. See fig 5

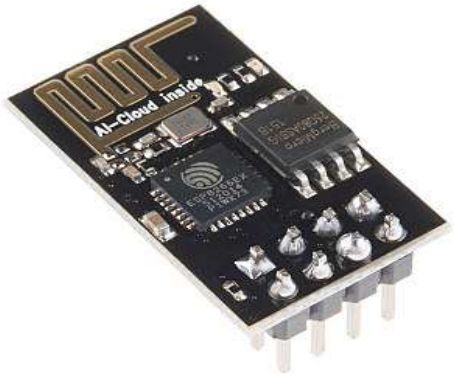


Fig 5. WiFi Module (ESP8266)

- Motor Driver
- Resistors
- RFID Reader Module (13.5MHZ) [6]. See figure 6.
- RFID Tag [7]

Fig 6. NFC Key Fob

- 5V DC Motor
- ON/OFF Switch
- 5mm LED (Yellow, Green and Red)
- 8 Volt DC Supply
- Mini Fan (for cooling simulation)

The software components of this work include: Arduino 8.5.0 (Arduino Software), Arduino Development Environment and Web Browser (e.g. Google chrome, Internet Explorer, Firefox)
The functions of the NFC tag in this work are as follows:

- Launch automation control platform
- Physically lock/unlock doors
- Phone activation

3.0 System Design and Implementation

The system schematic is shown in figure 7

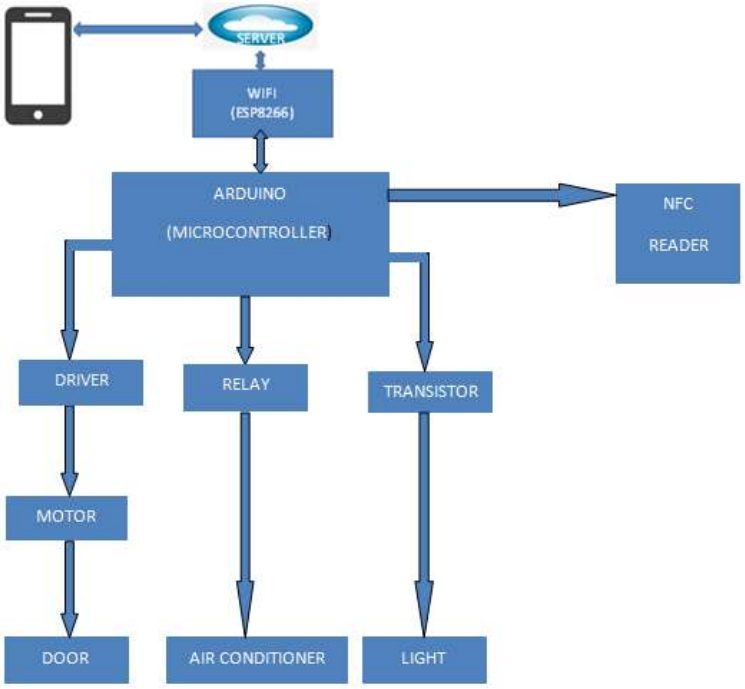


Fig. 7. Overall System Design

3.1 Design and Implementation

3.1.1 System Features:

- Access Control: A system to monito and prevent unauthorized entry.
- Temperature Control: This feature will maintain the temperature in the building to a set temperature. It can also totally switch off or turn on the cooling system as deemed necessary or as initiated by the user.

- Lighting control: This feature of this system controls the lighting system and the power outlets of the building.

The circuit diagram of this system is shown in figure 8.

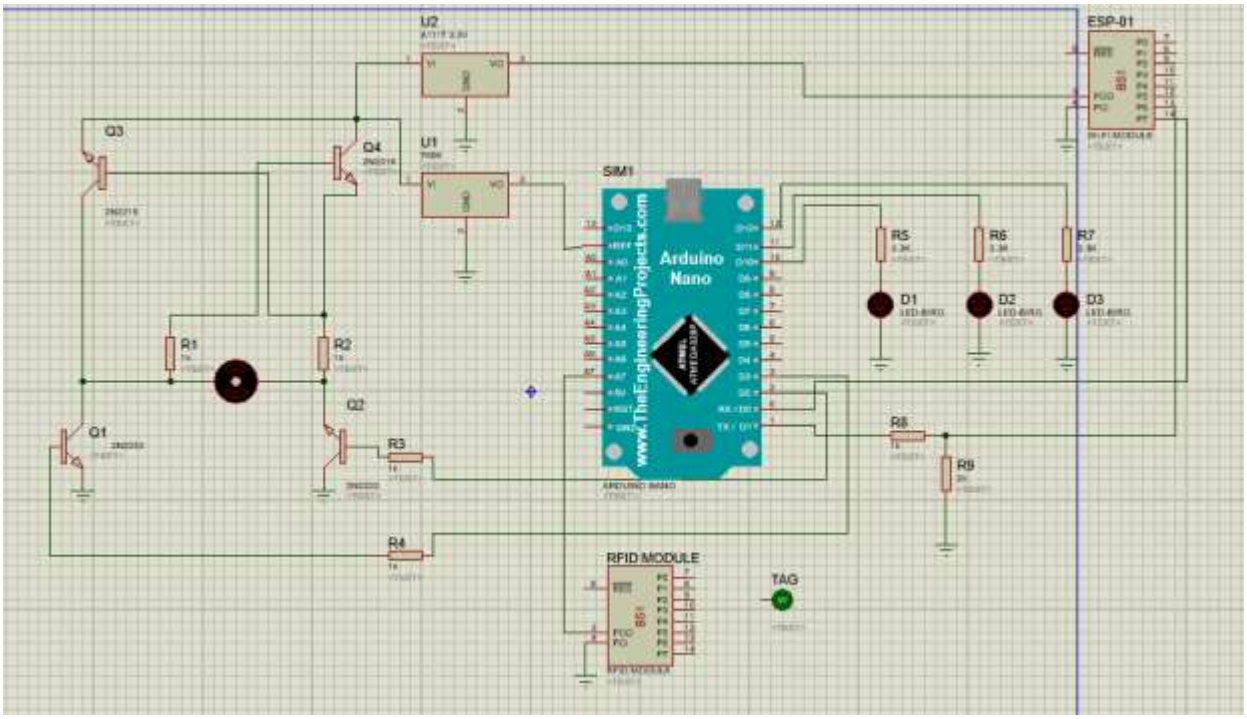


Fig. 8. System Circuit Diagram

3.1.2 System Programming

The programming for the system is shown below. The programming was done using Java programming. The choice of using Java was due to the faster runtime and ease of debugging. The lines of code are shown below. The code shows the implementation of user authentication feature, access control, etc.

- Writing Arduino and NFC code for authenticating users:

```
#include <ESP8266WiFi.h>
#include <WiFiClient.h>
#include <ESP8266WebServer.h>
/* Put your SSID & Password wifi credentials*/
const char *ssid = "Smart Home";
const char *password = "12345678";
ESP8266WebServer server(80);
bool LEDstatus;
bool DOORstatus;
String inputString = "";         // a String to hold incoming data
boolean stringComplete = false;  // whether the string is complete
void setup() {
  //
  Serial.begin(9600);
  // reserve 200 bytes for the inputString:
  inputString.reserve(200);
  server.handleClient();
  //
  if (LEDstatus) {
    // do something
  } else {
    // do something
  }
  //
  if (DOORstatus) {
    // do something
  } else {
    // do something
  }
  //
  if (stringComplete) {
    Serial.println(inputString);
    // clear the string:
    inputString = "";
    stringComplete = false;
  }
}
```

```
  //
  LEDstatus = false;
  DOORstatus = false;
  /* You can remove the password parameter if you
want the AP to be open. */
  WiFi.softAP(ssid, password);
  IPAddress myIP = WiFi.softAPIP();
  Serial.print("AP IP address: ");
  Serial.println(myIP);
server.on("/", handle_OnConnect);
  server.on("/ledon", handle_ledon);
  server.on("/ledoff", handle_ledoff);
  server.on("/dooropen", handle_dooropen);
  server.on("/doorclosed", handle_doorclosed);
  server.onNotFound(handle_NotFound);

  server.begin();

  Serial.println("HTTP server started");
}

void loop() {
  //
  DOORstatus = true;
  Serial.println("DOOROPEN");
  server.send(200, "text/html", SendHTML(LEDstatus,
DOORstatus));
}
void handle_doorclosed() {
  DOORstatus = false;
  Serial.println("DOORCLOSED");
  server.send(200, "text/html", SendHTML(LEDstatus,
DOORstatus));
}
void handle_NotFound() {
  server.send(404, "text/plain", "Not found");
}
String SendHTML(bool ledstat, bool doorstat) {
  String ptr = "<!DOCTYPE html> <html>\n";
  ptr += "<head><meta name=\"viewport\"
content=\"width=device-width, initial-scale=1.0, user-
scalable=no\">\n";
  ptr += "<title>Auto Control</title>\n";
  ptr += "<style>html { font-family: Helvetica; display:
inline-block; margin: 0px auto; text-align: center;}\n";
  ptr += "body{margin-top: 50px;} h3 {color:
#444444;margin-bottom: 50px auto 30px;}\n";
  ptr += ".button {display: block;width:
80px;background-color: #1abc9c;border: none;color:
white;padding: 13px 30px;text-decoration: none;font-
size: 25px;margin: 0px auto 35px;cursor:
pointer;border-radius: 40px;}\n";
  ptr += ".button-on {background-color: #1abc9c;}\n";
  ptr += ".button-on:active {background-color:
#16a085;}\n";
  ptr += ".button-off {background-color: #34495e;}\n";

void handle_OnConnect() {
  LEDstatus = LOW;
  DOORstatus = LOW;
  Serial.println("LED is OFF AND DOOR is CLOSE");
  server.send(200, "text/html", SendHTML(LEDstatus,
DOORstatus));
}

void handle_ledon() {
  LEDstatus = true;
  Serial.println("LEDON");
  server.send(200, "text/html", SendHTML(LEDstatus,
DOORstatus));
}

void handle_ledoff() {
  LEDstatus = false;
  Serial.println("LEDOFF");
  server.send(200, "text/html", SendHTML(LEDstatus,
DOORstatus));
}

void handle_dooropen() {
    ptr += "<body>\n";
  ptr += "<h3>Web Control Of</h3>\n";
  ptr += "<h3>NFC Based Home Automation</h3>\n";
  ptr += "<br>\n";

  if (ledstat) {
    ptr += "<p>Light is ON</p><a class=\"button
button-off\" href=\"/ledoff\">OFF</a>\n";
  } else {
    ptr += "<p>Light is OFF</p><a class=\"button
button-on\" href=\"/ledon\">ON</a>\n";
  }

  if (doorstat) {
    ptr += "<p>Door is Open</p><a class=\"button
button-off\" href=\"/doorclosed\">LOCK</a>\n";
  } else {
    ptr += "<p>Door is Closed</p><a class=\"button
button-on\" href=\"/dooropen\">UNLOCK</a>\n";
  }

  ptr += "</body>\n";
  ptr += "</html>\n";
  return ptr;
}
//
void serialEvent() {
  while (Serial.available()) {
    // get the new byte:
    char inChar = (char)Serial.read();
    // add it to the inputString:
    inputString += inChar;
```

```
  ptr += ".button-off:active {background-color: #2c3e50;}\n";
  ptr += "p {font-size: 15px;color: #888;margin-bottom: 10px;}\n";
  ptr += "</style>\n";
ptr += "</head>\n";
```

```
    // if the incoming character is a newline, set a flag so the main loop can
    // do something about it:
    if (inChar == '\n') {
      stringComplete = true;
    }
  }
}
```

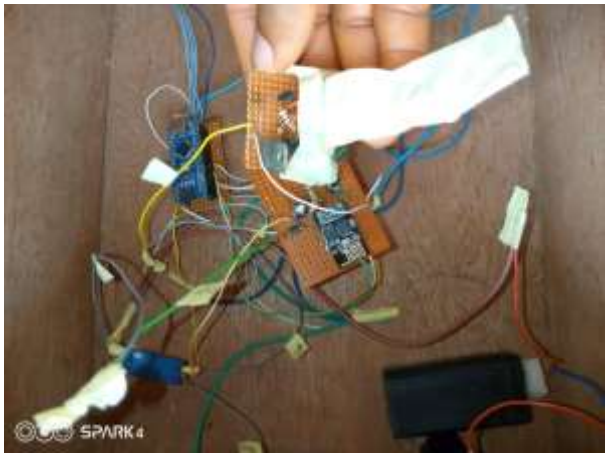
The authentication and control pages are shown in figure 9a and 9b respectively.

Figure 9a: Authentication page

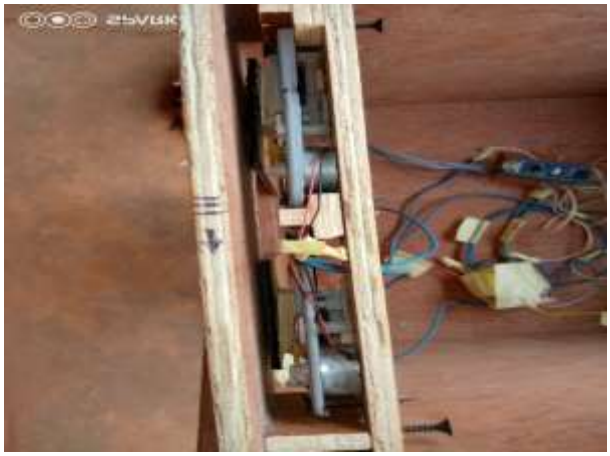
Figure 9b: Control page

4.0 Prototype Development

The system prototype was developed using plywood as the external structure. The components of the system were coupled and placed inside the structure for the sake of simplicity. Figure 10 illustrate the system setup.



a.



b.

c. d.

Fig. 10. System Prototype Development: a. Circuit Connections b. Door Mechanism c. Door Opening d. Front View of Prototype

5.0 Conclusion

The NFC based home automation system design was successfully implemented. Using a web browser on NFC- Smartphone, connection was made to Arduino through wireless network, allowing for control of the appliances in the home model. To further enhance the system, motion detectors which can automatically switch on lights if occupants enter a room, and switch off the lights after occupants have left can be added to the system.

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