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COLLEGE OF TECHNOLOGY AND ENGINEERING

RFID-based Smart Toll Collection System

An Embedded System Device with Manuscript

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A Final Course Requirements for
CT329 Embedded Systems

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Acknowledgement

Working on a group project is an exciting and challenging experience as it allows individuals with different skills and backgrounds to form together to achieve a common goal. We want to express our heartfelt gratitude to all who have contributed to the success of this innovation project entitled "RFID-based Smart Toll Collection System".

First and foremost, we want to express our profound gratitude to our project team members who have dedicated their time, knowledge, and creativity to bring this notion to reality. Their hard work, collaboration, and innovative thinking have been instrumental in the creation and execution of this project.

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Abstract

Automated Toll Collection System is a new technology for collecting toll in a faster and more efficient way. It is a great alternative to long waiting at manual toll plazas. In order to overcome the time-consuming process, reduce fuel consumption, and improve highway operations at the same time, we have come up with a concept of RFID-based automated toll collection system using Arduino. RFID stands for Radio Frequency Identification; RFID cards are unique identities provided to every vehicle. Whenever a vehicle with such Unique ID reaches the toll plaza and swipe unto the sensor, the RFID card reader attached on the toll plaza gate reads and registers the card and transfers the unique ID to the Arduino UNO R3, displays the message on the LCD, and activates the servo motor as the gate barrier. Accordingly, the processor works and deducts a fixed money from the prepaid card in the real world. If the card is valid, the processor will command the motor to start and open the gate, letting the vehicle to pass.

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Chapter I: INTRODUCTION

Project Context

As the growth of technology and the Internet of Things (IoT) increases, innovation in the transportation aspects has also been paralleled. Tolling as a method of financing the transportation system is becoming more common in other countries and some parts of the Philippines.

Toll roads are critical to the development of the economy. Such is the wisdom behind the pursuit of the Build, Build, and Build infrastructure program of the government. Toll roads significantly speed up travel and the flow of goods, and decongest traffic. Reduced travel time, in turn, raises economic productivity and serves as a major non-fiscal incentive to prospective investors. (Eñano, 2021)

In addition to that, according to Eñano, in the Philippines, toll roads are beginning to make an impact on the economy. Seamless travel through these toll roads will lead to economic development in areas outside of the capital region.

In fact, the economic condition of a nation has been closely related to efficient ways of transportation. Increasing number of vehicles on the road, result into number of problems such as congestion, accident rate, air pollution and many other.

All economic activities for different tasks use different methods of transportation. For this reason, increasing transportation is an immediate impact on

productivity of nation and the economy. Over time, tolling systems have become more efficient and adaptable. These solutions not only reduce the need for physical installations on the roads, but they also consider data as an asset, using it to make cashless tolls more efficient and secure.

Purpose and Description of the Project

This project, entitled, "RFID-based Smart Toll Collection System", is a project model of a stopping system (toll collection system) used at toll plaza centers. The idea for this project was inspired by the actual system, in which vehicles are stopped using a toll gate barrier that is completely automated and is activated when any vehicle passes in front of the sensor.

In this project, the developers use an RFID Reader to detect and read an RFID tag from a vehicle, a tiny servo motor to lift the barrier, and an LCD that displays the validity state of the RFID tag, which is the mechanism involved in this project.

This toll fee is an essential part of highway operations because the tolls collected help fund highway development and maintenance. It has also the ability to better understand traffic patterns and identify crash hot spots through the collection and analysis of toll data, leading to fewer incidents and safer roads.

Objectives of the Project

General Objectives

This study aims to develop an RFID-based Smart Toll Collection System.

Specifically, it aims to

1. design a device that collects toll fee from road vehicles
2. aids in the development of highway operations and transportation
3. integrates innovation and benefits of tolling system in the transportation industry
4. maintains safety and security of the vehicles
5. minimize traffic congestion, indirectly improve fuel economy, increase revenue and reduce pollution
6. understand traffic patterns and identify crash hot spots through the collection and analysis of toll data

Chapter II: TECHNICAL BACKGROUND

Technicality of the project

The technicalities of toll collection system with data analytics require developing and putting into use a complicated gadget that integrates RFID and an Arduino to generate an automated toll collection system.

The base idea on implementing RFID-based Toll Collection System is to automate the toll collection process and by reducing manual operation in toll booths and the long queues at toll booths using RFID tags installed on the vehicles. In addition to that, this project model can not only help the vehicle owners and system administrators from collecting toll fees but also to help eradicate road problems, increase highways operations, and integrates innovation and benefits of tolling system in the transportation industry. Here we are going to see some points regarding to purpose behind choosing this topic & what is the requirement of this type of the project in our day-to-day life.

With the design of the project, it only takes 1 minute to complete the toll collection process for one vehicle. As there is a reduction in time for completion of the process, thus, in actuality it will indirectly reduce traffic as such & as there is no traffic so no fuel wastage takes place & the purpose of designing the highways is achieved.

Details of the technologies to be used

The RFID-based Toll Collection System integrates and utilize various technologies to succeed in execution.

Fundamentally, the system involved the utilization of Arduino Uno R3, MFRC522 RFID Reader, servo motor, and 16×2 I2c LCD. Hence, the MFRC522 RFID Reader communicates with an RFID tag to complete its function. The RFID reader is one kind of wireless module used for transferring the data to identify and track tags which are connected to objects. The RFID tag mainly includes the stored information. Some of the RFID tags are run by electromagnetic induction from magnetic fields formed nearby the reader. RFID reader comprises an RF module that works as a transmitter as well as a receiver of RF (radio frequency) signals. Mifare RC522 is the high integrated RFID card reader which works on non-contact 13.56 MHz communication, is designed by NXP as low power consumption, low cost and compact size read and write chip, is the best choice in the development of smart meters and portable hand-held devices.

MF RC522 use the advanced modulation system, fully integrated at 13.56MHz with all kinds of positive non-contact communication protocols. The TX of the RF module is inbuilt with an oscillator to make the carrier frequency. A modulator to intrude commands upon this carrier signal and an amplifier to raise the signal sample to wake the tag. The RX (receiver) of the RFID module contains a demodulator to remove the returned information and also grips an amplifier for supporting the signal of processing. A microprocessor is used for forming the control unit, which uses an operating system, a memory of the module filter and also stores the data. On the other hand, a 16x2 Liquid Crystal Display is also used. The LCD will be connected to microcontroller. The job of LCD is to display all the system generated messages coming from the controller. LCD will provide interactive user interface. This unit requires +5VDC for it proper operation. This module is used for display the present status of the system. In addition to that, the servo motor is used with the system to open and close the toll gate, after the authentication of the vehicle.

How the project will work

This project gives the simplified system and procedure for users and vehicles to pay toll at toll booth by making them automated.

The RFID Reader mounted at toll booth will read the prepaid RFID tags from vehicles and automatically respective amount will be deducted from the card. Since every vehicle registration ID is linked to users account in the real world, toll can be deducted from the account bank directly and the toll gate opened automatically. The system consists of RFID tags that are attached to the vehicles, RFID readers that are installed at toll plazas, and an Arduino microcontroller that acts as a gateway between the RFID reader and servo motor (gate barrier). When a vehicle passes through the toll plaza, the RFID reader reads the RFID tag on the car and sends the data to the Arduino. The Arduino then uses the data to retrieve the necessary information from the central database, such as the toll fee and the vehicle owner's account balance (in actuality). Overall, the RFID-based toll collection system using RFID and Arduino is a fast and efficient way to collect toll taxes/fees without the need for manual intervention, leading to reduced traffic congestion and increased revenue for toll road operators.

Circuit diagram of the project

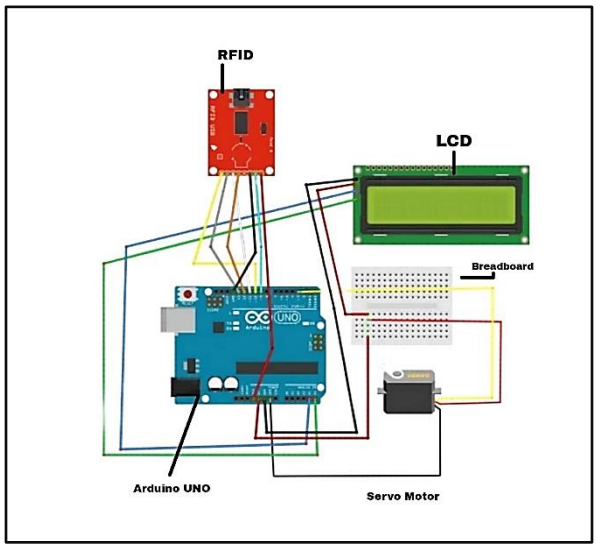


Figure 1. Shows the circuit diagram for the RFID-based Smart Toll Collection System.

The diagram shows the device's electrical components and connections, including the Arduino UNO, servo motor, Arduino breadboard, LCD I2C 16x2 and MFRC522 RFID reader.

A circuit diagram is an essential tool for ensuring proper operation. The RFID-based Smart Toll Collection System was precisely executed and built. It is also a flexible device for troubleshooting and maintenance resource, allowing quick repairs and updates.

Chapter III: METHODOLOGY

Data and Process Modeling

Data and process modeling are vital components in software development that aid in understanding the device and functionality of the system.

This system takes place concurrently with sensor activation, ensuring that the card ID number is properly scanned and process and collect data. Hence, can perform and scan the cards and will read its data and the traffic gate will automatically open if the card is registered or valid.

Every time a registered vehicle approaches the toll booth, the RFID reader activates whenever an RFID tag is trying for a scan. Data processing will begin as the LCD display the output including the status and UID of the card. Whether the card has a valid access or invalid.

In actuality, transaction will begin, depending upon the balance available toll will be deducted directly. The software further updates the details in the centralized database server (which is the Microcontroller integrated with the program within the system model). On the other hand, whenever any vehicle owner registers to the authority which prompts stolen vehicle to be easily identified as the ID assigned with it is unique. All the toll plazas will be connected to each other along with the centralized server in the form of LAN in the real world.

Context Diagram

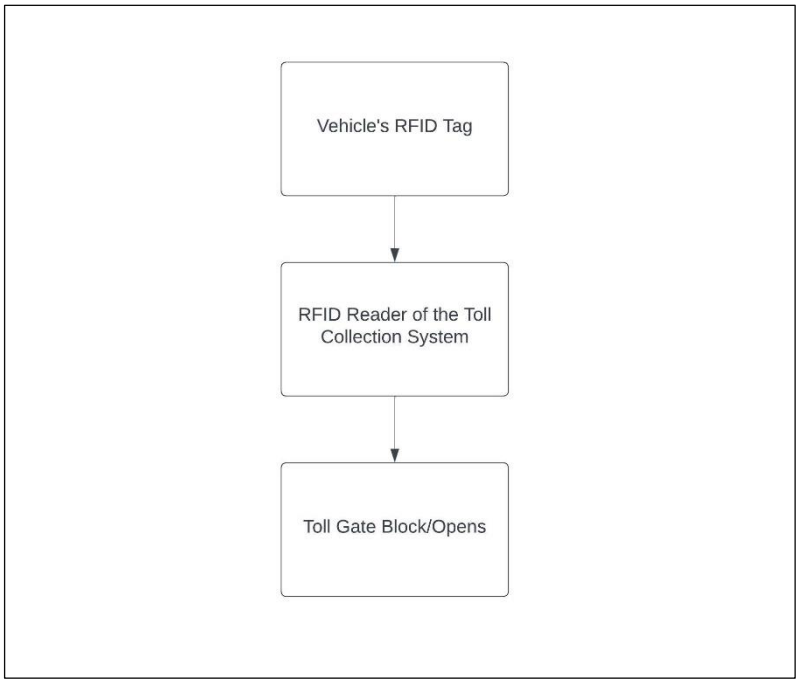


Figure 2. Context Diagram

This context diagram, outlines how external entities interact with an internal software system. The diagram was used to provide the overview of the system and its inputs and outputs. The RFID tag is the primary device to input data represented in the first box. The Arduino UNO R3, RFID module reader, and the toll gate which is integrated with the servo motor are shown as sub-device next to the primary device box since they are integral to the functioning of the overall system of the project.

Data Flow Diagram

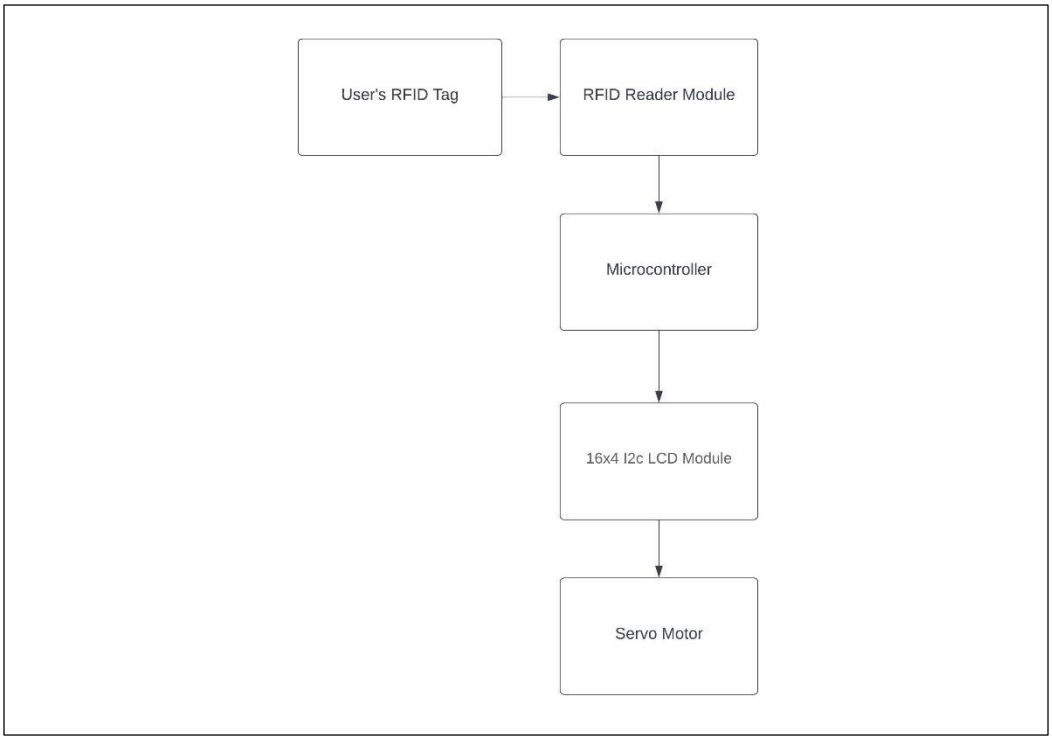


Figure 3. Data Flow Diagram (DFD)

The components in this Data Flow Diagram (DFD) the critical elements of the project, are the RFID tag, UNO R3, RFID module, Microcontroller (Arduino), 16×2 I2c LCD and servo motor. Arduino is the project's main microcontroller that's controlled all other components. The RFIS module receives data from the user’s RFID tag and sends output to the LCD which is executed by the servo motor.

System Flowchart

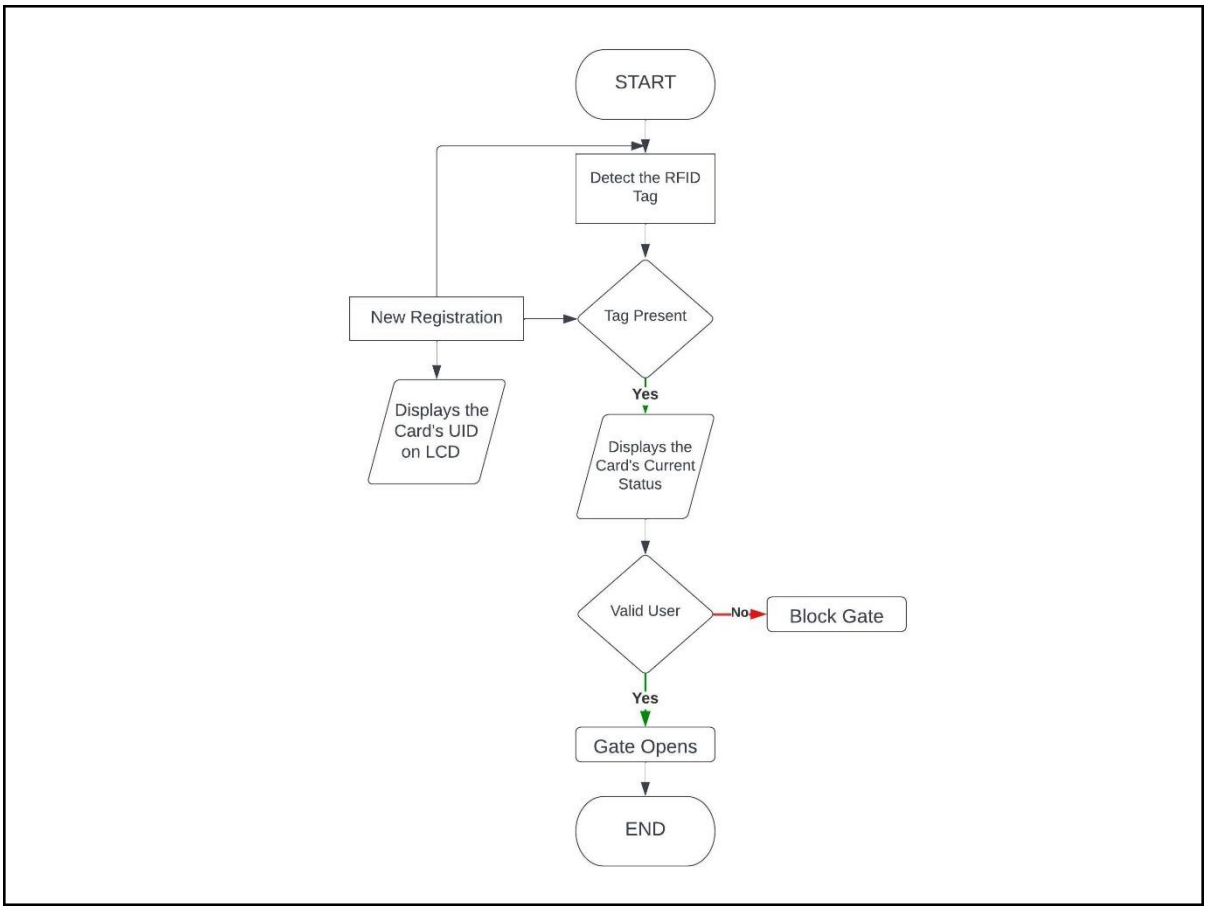


Figure 4. System Flowchart

The flowchart shows the flow of the RFID-based Smart Toll Collection System Using Arduino and an RFID module. The diagram shows the various steps involved in the device's operation. Transfer of data from the RFID tag to the RFID reader, which will receive by the Arduino. Arduino decodes this data, sending orders to the LCD and servo motor.

Program Flowchart

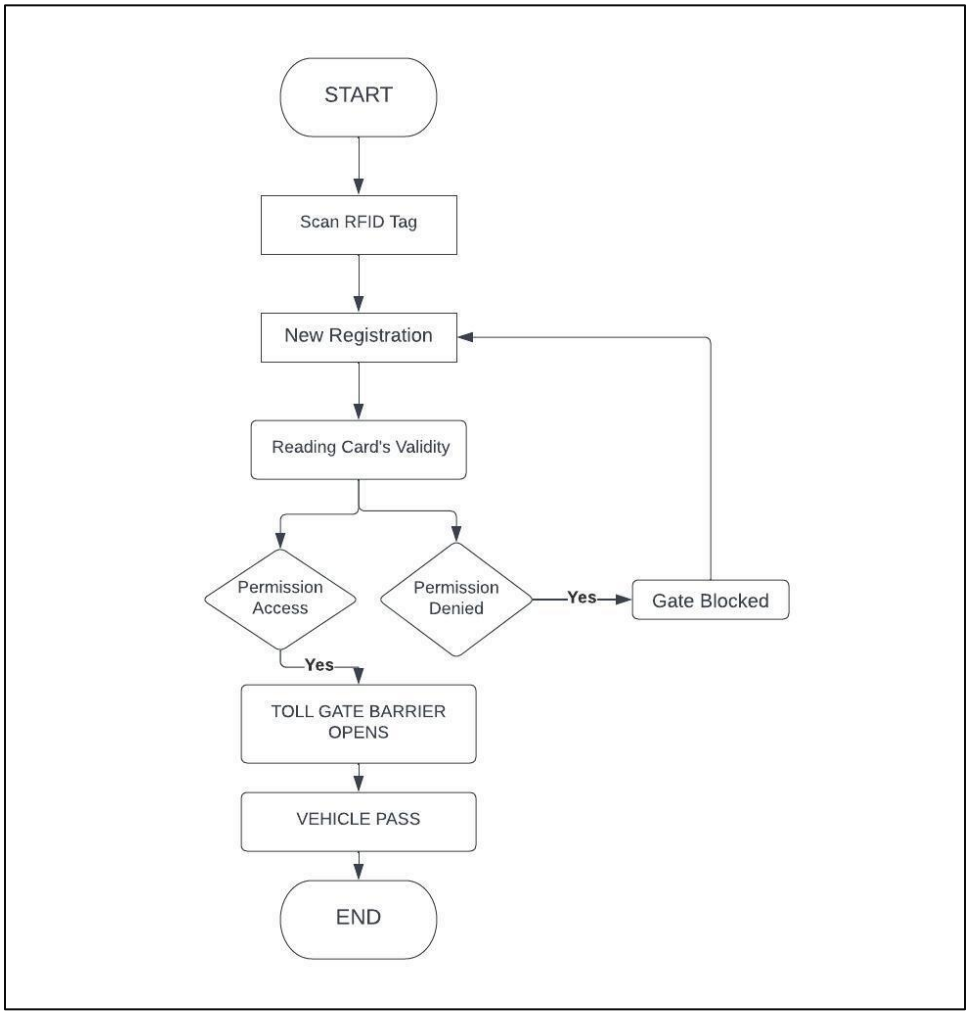


Figure 5. Program Flowchart

This program flowchart illustrates the logic of the smart toll collection system using Arduino and an RFID module.

System Architecture

Network Topology

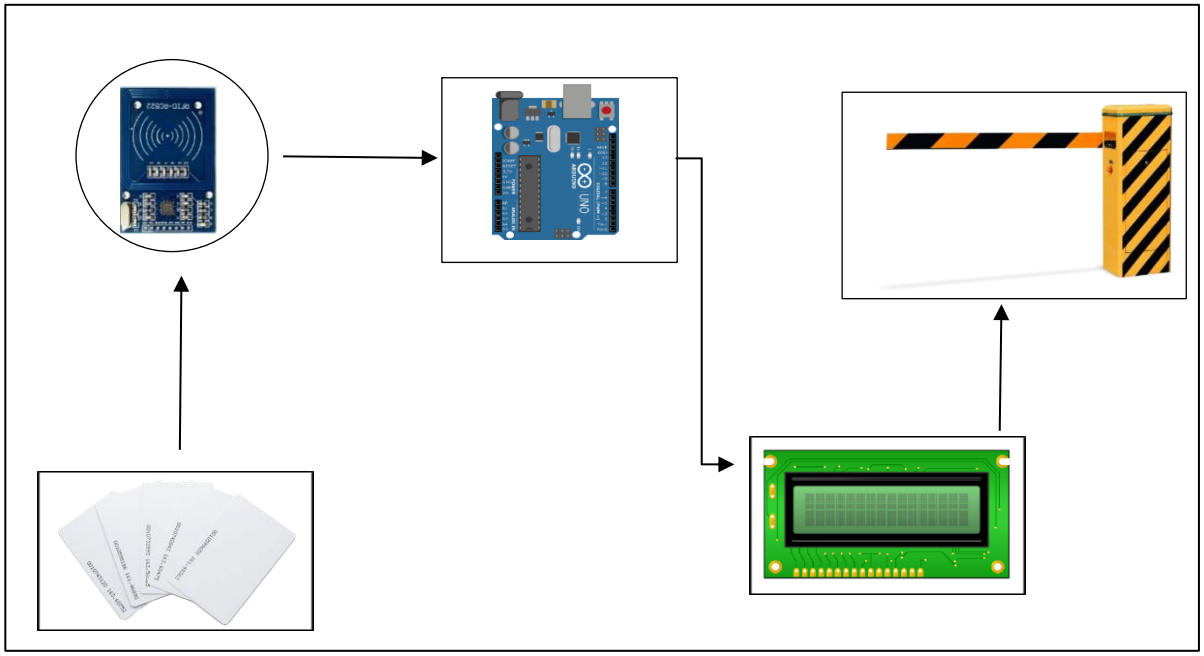


Figure 6. RFID-based Smart Toll Collection System

Figure 6, shows the network topology of the system. The network topology for the RFID-based smart toll collection system utilizing primarily an Arduino UNO R3 and an RFID module typically involves a point-to-point connection between the components. The Arduino serves as a coordinator or central hub in this setup. It is in charge of directing the toll gate's (servo motor's) functioning in accordance with the information input received from the RFID module.

Development

Parts and Equipment Needed:

Components	**Quantity**	**Description**
Arduino UNO R3 board	1	This is the heart of the project, and you can use boards like Arduino Uno, Arduino Nano, or Arduino Mega. It provides the processing power and GPIO pins necessary for the toll collection system to function.
RFID Reader Module	1	The RFID reader is one kind of wireless module used for transferring the data to identify and track tags which are connected to objects. The RFID tag mainly includes the stored information. Some of the RFID tags are run by electromagnetic induction from magnetic fields formed nearby the

		reader. RFID reader comprises an RF module that works as a transmitter as well as a receiver of RF (radio frequency) signals.
RFIG Tag	1	RFID stand for Radio frequency identification. The RFID tag is mainly divided into two type, active tag and passive tag. Active tag comes with internal power supply and passive tag required UID (unique identification) code to RFID reader when they are comes in contact with each other.
Servo Motor	1	It is a small device that has an output shaft. The shaft is positioned to a specific angular position by sending the servo a coded signal. As long as the coded signal exists on the input line, the servo will maintain the angular position of the shaft. If the coded signal changes, the

		angular position of the shaft changes.
Jumper Wire	11	These are used to establish connections between the Arduino, RFID module, LCD, breadboard and servo motor.
16×2 I2c LCD	1	It is called Liquid Crystal Display. In this project a 16x2 character LCD is being utilized. This will be connected to microcontroller. All of the system generated messages originating from the controller will be displayed on the LCD. For this device to function properly, it needs a +5VDC. This module is used to show the system's current state providing an interactive user interface.
USB cable for Arduino UNO	1	This cable is used to connect the Arduino UNO board to your

		computer for programming and power supply. It usually has a standard USB-A connector on one end and a USB-B connector on the other end.
Arduino Breadboard	*1*	A component utilized for a convenient wiring to further the connection of the wires between each component being used.

Table 1. List of Components

Software Specification:

For the development of the RFID-based Smart Toll Collection System, the following software tools and frameworks will be utilized:

1. Overview:

This project focuses on a toll collection system using

a Radio Frequency Identification (RFID) technology. The RFID system uses tags, through which information embedded on the tags are read by RFID readers, the proposed system eliminates the need for vehicles and toll authorities to manually perform ticket fees and toll fee collections in the real world, respectively. Thus, it is a more efficient toll collection by reducing traffic and eliminating possible human errors.

2. Integrated Development Environment (IDE): Arduino IDE

The Arduino IDE is a popular and user-friendly development environment specifically designed for Arduino boards. It provides a simple and intuitive interface for writing, compiling, and uploading code to the Arduino microcontroller.

3. Programming Language: C++

The Arduino IDE uses a simplified version of the C/C++ programming language. This language is well-suited for embedded systems development due to its efficiency, low-level control, and close integration with hardware.

4. MFRC522 RFID Module Library

The project integrates the use of MFRC522 RFID Module library compatible with the RFID reader. The library allows the Arduino to communicate with the RFID over serial communication, enabling to complete the necessary function of the system.

5. Version and Configuration

Depending on the release at the time of the project, the precise version of the Arduino IDE may change, although it is advised to use the most recent stable version available. The RFID library to be used will depend on the RFID module selected for the project. The specific version of the library should be selected based on compatibility with the module and its features. The Arduino IDE, along with the C/C++ programming language and the appropriate RFID library, provides a suitable development environment for the project. These software tools and frameworks facilitate the programming, compilation, and uploading of code to the Arduino board, enabling the project to fully function. They offer compatibility with Arduino boards and RFID module commonly used in such projects, ensuring seamless integration and functionality.

Installation Process

To install and set up the software development environment for the RFID-based Smart Toll Collection System using Arduino, below are the outlined step-by-step instructions:

1. Arduino IDE Software Installation:

1.1 Visit the official Arduino website at https://www.arduino.cc/en/Main/Software.

1.2 Download the Arduino IDE for your operating system (Windows, macOS, or Linux).

1.3 Run the downloaded installer and follow the on-screen instructions to complete the installation.

2. Connect Arduino Board:

2.1 Connect your Arduino board to your computer using a USB cable.

2.2 Ensure that the board is recognized by your operating system. You may need to install drivers for your specific

Arduino board if it's the first time you're connecting it. Refer to the manufacturer's documentation for driver installation instructions.

3. Configuration of Arduino IDE:

3.1 Launch the Arduino IDE.

3.2 Navigate to "Tools" in the menu bar and select the appropriate board from the "Board" submenu. Choose the Arduino board you are using for your project.

3.3 From the same "Tools" submenu, select the correct port under the "Port" option. It should be labeled with your Arduino board's name or COM port number. If the port is not visible, make sure your Arduino board is properly connected to the computer.

4. Install Required Libraries:

4.1 Click on "Sketch" in the menu bar, then select "Include Library" and then "Manage Libraries".

4.2 In the Library Manager window, search for the necessary libraries for your RFID-based project. For example, the RFID module, search for "MFRC522" and install the appropriate library.

4.3 Follow the prompts to install the selected libraries. Make sure to install all the required libraries for your project.

Building the Circuits

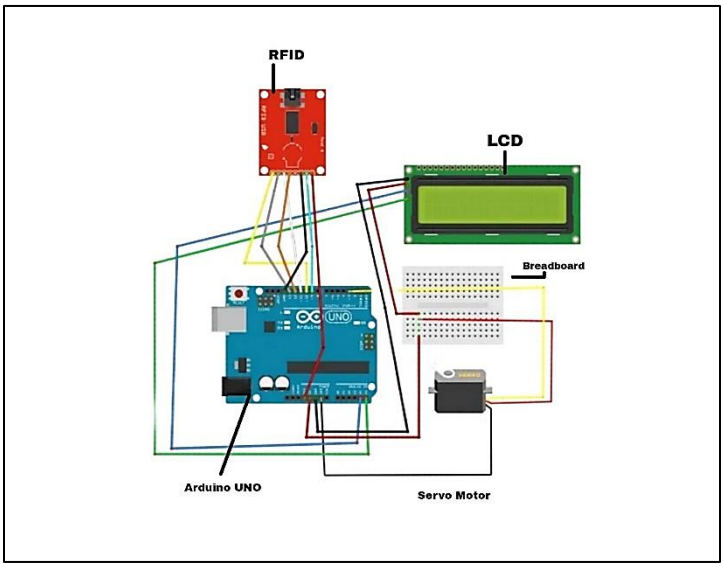


Figure 7. Circuit layout of the RFID-based Smart Toll Collection System

Designing the circuit for an RFID-based Smart Toll Collection System, involves connecting the Arduino UNO R3 board, RFID module, breadboard, servo motor, and LCD.

Program/Sketch:

RFID-based Smart Toll Collection System:

```
#include <SPI.h>
#include <MFRC522.h>
#include <Wire.h>
#include <LiquidCrystal_I2C.h>
#include <Servo.h>
LiquidCrystal_I2C lcd(0x27,16,2);
#define RST_PIN 9
#define SS_PIN 10
MFRC522 mfrc522(SS_PIN, RST_PIN);
Servo myServo;

int *aux;
int card1[4];
int flag = 0;
int lcd = 13;
int cnt =0;

void setup() {
     pinMode(lcd, OUTPUT);
     lcd.init();
     lcd.backlight();
     SPI.begin();
     mfrc522.PCD_Init();
     lcd.print("     SWIPE");
     lcd.setCursor(0,1);
     lcd.print("     HERE  ");
     myServo.attach(3);
     myServo.write(0);
     }
     void loop() {
         if ( ! mfrc522.PICC_IsNewCardPresent()) {
             return;
         }


         if ( ! mfrc522.PICC_ReadCardSerial()) {
             return;
         }
         for (byte i = 0; i < mfrc522.uid.size; i++) {
                 aux[i]= mfrc522.uid.uidByte[i];
         }
         if(flag == 0)
         {
         lcd.clear();
```

```
          lcd.print("Your card UID is: ");
          lcd.setCursor(0,1);
          for (byte i = 0; i < mfrc522.uid.size; i++) {
          card1[i] = aux[i];
          lcd.print( card1[i], DEC);
          lcd.print( " ");
          flag = 1;
                  }
          delay(3000);
          lcd.clear();
          lcd.print(" CAPAROS, IMPANG");
          lcd.setCursor(0,1);
          lcd.print("  LUCENO, CALAPUTOC   ");
}
             else{

              for (byte i = 0; i < mfrc522.uid.size; i++) {
              if(aux[i] == card1[i])
              cnt++;
                   }
                  if(cnt == mfrc522.uid.size-1)
                  {
                   lcd.clear();
                   lcd.print("   ACCESS     ");
                   lcd.setCursor(0,1);
                   lcd.print("   PERMITTED    ");
                   delay(400);

                  myServo.write(180);
                  delay(5000);
                  myServo.write(0);
                  }
                  else
                  {
                    lcd.clear();
                    lcd.print("    ACCESS     ");
                    lcd.setCursor(0,1);
                    lcd.print("    DENIED     ");
                    delay(2000);
                   }
                 }
                 lcd.clear();
                 lcd.print("    TOLL TAX ");
                 lcd.setCursor(0,1);
                 lcd.print("     SYSTEM   ");
        cnt=0;
      }
```

This sketch creates a Software Serial connection on the digital pins with the RFID reader module and other components involved. The setup() function initializes the pins and starts the serial communication. The loop() function continuously checks for incoming commands from the RFID module and calls the appropriate processes to operate the toll gate based on the received inputs from the RFID tags. Installation of the required library for the RFID module in the Arduino IDE is necessary before uploading the sketch to the Arduino board. Additionally, modification is possible to fit the particular setup, such as adjusting PINs or adding additional functionality.

User guide

Introduction:

The RFID-based Smart Toll Collection System is a project that enables a convenient collection of toll fees from the vehicles with less than a minute. The project utilizes the Arduino board as the central controller, which communicates with the RFID reader for the system to function.

Following the instructions in this user guide will teach you how to set up the hardware components, install the necessary software, and upload the code to Arduino IDE. Once the setup is complete, the device will be ready to use. This project offers a flexible and user-friendly interface which is easy to utilize.

System overview:

The RFID-based smart toll collection is a system that utilizes Arduino microcontroller board and an RFID module to enable an automatic toll collection at toll plazas. The system consists of hardware components, including the Arduino board, RFID module, servo motor, and the LCD, as well as the other additional software and hardware components involved.

Hardware set-up:

To set up the RFID-based Smart Collection System using Arduino and primarily an RFID, follow the procedures below:

1. Gather the required components:
   - Arduino UNO R3 board
   - MFRC522 RFID Reader Module
   - RFID Tag
   - Jumper wires
   - Breadboard (optional)
   - 16×2 I2c LCD
   - Servo Motor
2. Connect the RFID module to the Arduino:
   - Identify the pins on the RFID module: SDA, SCK, MOSI, MISO, GND, RST, 3.3v.
   - Connect the SDA pin of the RFID module to the D10 pin of the Arduino.
   - Connect the SCK pin of the RFID module to the D13 pin of the Arduino.
   - Connect the MOSI pin of the RFID module to the D11 pin of the Arduino.
   - Connect the MISO pin of the RFID module to the D12 pin of the Arduino.
   - Connect the GND pin of the RFID module to the Ground

pin of the Arduino.

- Connect the RST pin of the RFID module to the D9 pin of the Arduino.

- Connect the 3.3v pin of the RFID module to the 3.3v of the Arduino.

3. Connect the LCD (Liquid Crystal Display) to the Arduino: GND, VCC, SDA, and SCL.

- Connect the LCD’s VCC to the Arduino's 5V.

- Connect the LCD’s GND to the Arduino's Ground.

- Connect the LCD’s SDA to the Arduino's A4 pin.

- Connect the LCD’s SCL to the Arduino's A5 pin.

4. Power the Arduino:

- Connect the Arduino board to a power source using a suitable power supply.

- Ensure the power supply provides sufficient power for the Arduino and the LED strip.

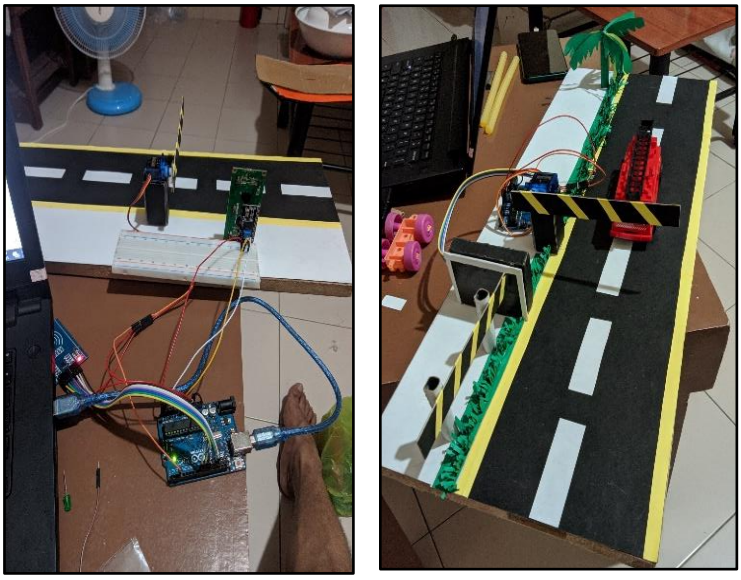
- Connect the power supply to the appropriate power input on the Arduino.

5. Using the breadboard:

- If there are additional wires to connect, thus, using a breadboard is optional.

6. Ensure all the connections are secure and well-insulated to avoid any short circuits or loose connections.

With the hardware setup complete, you can proceed to the software setup, which involves installing the Arduino IDE and necessary libraries and uploading the code to the Arduino.



Software Installation and Configuration:

You must perform software installation and configuration procedures to create an intelligent RFID-based smart toll collection system. Here is a step-by-step guide to help you through the process:

1. Install the Arduino 1.6.0:

- Download the version of the Arduino 1.6.0 (https://www.arduino.cc/en/software).

- Follow the installation instructions specific to your operating system.

2. Install the RFID library:

- Open the Arduino IDE.

- Go to "Sketch" > "Include Library" > "Manage Libraries."

- In the Library Manager, search for “MFRC522"

- Click on "Install" to install the library.

3. Write the code for the smart toll collection system:

- Start a new sketch in the Arduino IDE.

- Write the code to enable the system to function using the Arduino and RFID module. It will involve setting up digital or analog output pins.

4. Upload and test the code:

- Connect the Arduino board to your computer using the USB cable.

- Click the "Upload" button in the Arduino IDE to upload the code to the board.

- Once the code is uploaded, disconnect the Arduino from the computer and power it using an external power supply.

System Operation:

System Operation: RFID-based Smart Toll Collection System

Once the hardware and software components of smart toll collection system are set up and configured, follow the steps to operate the system:

1. Power Up the System:

a. Ensure that the power supply for the Arduino and relay module is connected and providing the required power.

2. Sending and Processing Commands:

a. The RFID module receives data from the RFID tag and transmits them to the Arduino.

b. The Arduino's programmed sketch receives the commands and processes them accordingly.

c. The Arduino activates the LCD and the servo motor based on the command received, either blocking or opening the toll gate barrier.

d. When the card is valid/registered, a message will display on the LCD and activates the servo motor, depending on the card’s validity.

System Maintenance:

To perform system maintenance on your RFID-based Smart Toll Collection System, you can follow these steps:

1. Check Hardware Connections: Ensure that all the hardware components, including the Arduino board, RFID module, and any additional components, such as LCD and servo motor, are correctly connected.
2. Update Firmware: If any firmware updates are available for the Arduino board, download them from the manufacturer's website and update the firmware accordingly.
3. Check Code and Debug: Review the Arduino code that reads the RFID tag and execute the received command. Look for any potential errors or bugs affecting the device's performance.

4. Inspect External Components: If you have any external components, such as LCD and RFID reader, check their functioning. Ensure that they are correctly connected and functioning as expected. Replace any faulty parts if necessary.

Conclusion:

This project gives the simplified procedure for users and vehicles to pay toll at toll booths by making them automated. It is low cost, high security, far communication distance and high efficiency. It does not only can improve technology level of charging fees in the actual world, but also improve passage ability of expressway. The toll collecting system is a useful tool for cutting administrative expenses and fees while also significantly reducing traffic and polluting emissions from toll stations. A single RFID tag is used for all of these tasks, eliminating the need to manually carry money and records. Additionally, this method of toll collection is environmentally benign and increases the capacity of toll lanes. Also, an anti-theft solution system module which prevents passing of any defaulter vehicle is implemented, thus assuring security on the roadways.

Through the integration of hardware components such as the Arduino board, RFID module, servo motor, and LCD, along with the software components including the Arduino sketch and Arduino IDE, the system provides a user-friendly interface for executing a toll collection system.

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