A PROJECT REPORT ON

DESIGN AND CONSTRUCTION OF AN INTELLIGENT TOLL PAYMENT SYSTEM USING GSM PHONE NUMBER AIRTIME AND DATA

By

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CERTIFICATION

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DEDICATION

This report is dedicated foremost to Almighty GOD for his favor, grace and recurring help upon my life especially during the period of my stay on campus and during the period of the Project.

I am also dedicating this report to my Parents “Engr. and Pastor (Mrs.) J.O Adeuyi”, my Brothers “Pastor Gbenga Adeuyi, Mrs. Pelumi Adeuyi, Mr. Olanrewaju Adeuyi and Mr. Tholuwalase Adeuyi” and also to everyone who contributed to the success of my project for their indelible support and love.

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I want to express my sincere appreciation to the brethren: RCF Unilag, RCCG House of Grace Assembly Youth Church, PSF World-wide, "My Christian brothers and sisters" whose prayer cease not to be made for me, especially in a time like this. God bless you all.

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ABSTRACT

Considering the rate at which vehicles have to halt for toll fee payment has sadly resulted to traffic congestion at Toll plazas which often is the reason for a huge economical loss in terms of fuel wastage and in the cause of pollution. The main theme of this paper is to design an intelligent toll payment system with the use of a GSM Phone credit and data which serve as a means of payment to help lessen the over congestion at toll plazas which has fast become a norm in most of our mega cities and likewise this help to avoid human existence at toll plaza.

Toll gate at first instance are been put in place to curb traffic congestion. An intelligent toll payment is a system that has been designed both for convenience and for financial derivation or benefits, it can be furthered be used for expansion, operational and maintenance purposes.

In this paper, hardware and software designs were involved for developing an intelligent toll payment system with the use of a GSM Phone credit and data which serve as the means in which vehicle owner can make payment or recharge the system. The design is made up of a PIC16F876A, microcontroller, a radio frequency identification module (RFID) which comprises of a RFID Reader fixed at the toll gate frame so as to read data from incoming vehicles through a RFID Tag mounted on the vehicle windshield. If the vehicle belongs to an authorized or registered user then a toll deduction is done on the user account which in this case the user registered mobile number, a message is sent to the registered mobile number and the toll gate will be automatically opened. When the credit on the mobile number is exhausted, a phone credit will be used to make a top up through the mobile number to the card. Major status and updates of all progress on the toll payment system will be visualized on the LCD screen display through the aid of the microprocessor design.

This design provides transparency to the whole system of toll payment which will definitely help in drastically reducing issues such as corruption at toll gates, vehicle theft cases and tax evasion. The system also helps to keep records of vehicle owner data’s and transaction in this system is flexible and cashless.

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ABBREVIATION AND INDICES

ACK --- ACKNOWLEDGMENT

ANPR --- AUTOMATIC NUMBER PLATE READER

AVC --- AUTOMATIC VEHICLES CLASSIFICATION

AVI --- AUTOMATIC VEHICLES IDENTIFICATION

BLE --- BLUETOOTH LOW ENERGY

DSRC --- DEDICATED SHORT-RANGE COMMUNICATION

ETC --- ELECTRONIC TOLL COLLECTION

GSM --- GLOBAL SYSTEM FOR MOBILE COMMUNICATION

GPS --- GLOBAL POSITIONING SYSTEM

HOT --- HIGH OCCUPANCY TOLL

IR --- INFRARED

IVU --- AN IN-VEHICLE UNIT

LCD --- LIQUID CRYSTAL DISPLAY

NFC --- NEAR FIELD COMMUNICATION

OBU --- ON BOARD UNIT

PLC --- PROGRAMMMABLE LOGIC CIRCUIT

RF --- RADIO FREQUENCY

RFID --- RADIO FREQUENCY IDENTIFICATION

WSN --- WIRELESS SENSOR NETWORK

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND OF STUDY

According to a survey carried out on the e-toll collection which was implemented using RF communicator [1]. A MSP430 Launch pad was used for its implementation, various other research was carried out in order to avoid traffic congestion at toll booths where RFID was used for unique identification of vehicles and its transactions was recorded on a detailed monthly bill which will be sent to the customer at the end of the month [2].

Earlier, pollution monitoring research was carried out using the M2 M wireless sensor network using the Zigbee protocol [3]. For the sake of an efficient toll fare regard to distance travelled a proposed system has been developed. The intelligent traffic scheme with automatic toll collection is a fresh method used on vehicles once they enter the toll plaza, the RFID [4] tag attached to the vehicle windshield is used to read each vehicle with the help of RFID reader. The reader otherwise known as an interrogator receives this signal and send it to the microcontroller (SST). It is presumed that each vehicle has a unique identification number. When the RFID tags makes connection with the RFID reader, the vehicle information is gathered and validated to be accurate under certain circumstances such as valid customer, have balance in prepaid account and if the user is valid and have balance in the account the gate opens. When the RFID reader reads it, it sends the signal to the microcontroller, the microcontroller validates the information of the vehicle, the toll gate is already equipped with a stepper motor, and the stepper motor moves in an anti-clockwise direction and the toll gate opens and after a few seconds when the car passes the toll booth the stepper motor rotates in the direction of the clock and the toll gate closes. If the prepaid account of the vehicle owner has an insufficient balance then the toll gate remains closed, the driver can decide to recharge his account via GSM Phone credit and receive the receipt as a

text message. The vehicle owner is given a toll application when the toll system checks for the valid vehicle and the toll gate opens, the owner should press the start button then the GPS system saves the current location and keeps on tracking the vehicle with updating the latitude and longitude values and at the end of the journey the owner clicks the end button and same way the current location is been saved it compared with the previous values as the distance is measured and the fare is calculated and deducted from the predefined account, a study was carried out to obtain a fare based on the load of vehicle [5]. Due to an increasing number of vehicles [6] emitting toxic oxides earlier a research is been carried out using WSN [7] where smoke-emitting vehicles are observed and its information transmitted to a smartphone. Large amounts of atmospheric carbon dioxide lead to air pollution [8] where it is hazardous to living organisms. To prevent pollution, the owner of the vehicles should not disregard the emission rule that we have a suggested system where the vehicle is registered with a complaint for breach of emission regulations. When the vehicle enter the toll plaza the smoke sensor installed in the vehicle senses the smoke emitted and the RF transmitter installed into the vehicle send the vehicle information / data along with the smoke value and then the RF receiver at the toll plaza receives the information and send the signal to microcontroller, the controller compares with the limit value that the owner was warned about performing the emission test and if the driver ignores still, queries for infringement are addressed to law enforcement unit to report any of such driver for violating the emission law.

Additionally, Due to the lack of a processor or user interface for RFID tags, vehicle operators cannot easily determine account balance and have no warning of restricted or exhausted credit. This generates confusion as well as potential safety risks as riders pass with little warning to standard toll collection routes. Another purpose of the scheme is to provide toll collection mechanisms that decrease administrative burdens, enable users and toll officials to generate transaction reports, and maintain users ' privacy. Another purpose of the scheme is to provide customs collection facilities that are reliable and resistant to fraud or customs evasion efforts and that are easily incorporated into current customs management systems. [9]

1.2 PROBLEM STATEMENT

There has always been a need to identify what a problem is before proffering a solution to it. The design for an intelligent Toll payment system has different setbacks. Considering the fact that the RFID Reader only detect tags that are within the range of its radio frequency, depending on the **Tag S.O.A.P** which are the Tag SIZE, Tag ORIENTATION, Tag ANGLE and Tag PLACEMENT on the vehicle, depending on all of this factors and more the signals between the RFID reader and tag on vehicles can result into interference when if the range of the RFID Reader signal extends to two or more vehicles at the same time which in turns causes an inaccurate tag reading on the RFID Reader.

Cases could occur when there are Undetected incorrect Reads -this refers to the incorrect read of a tag or when the RFID reader is not functional at that moment. Such scenario result either to a “free ride” for the driver, or an undeserved fine for failure to pay – in which most times usually is the case.

Job loss, most of the staff are liable to lose their job if the electronic toll collection system be fully implemented in the Toll Plaza.

Over the years there has been records of collection errors in toll money not properly paid due to corruption in previous toll payment systems, such systems were alongside very slow and usually create traffic jam as each vehicle has to stop for manual cash transaction.

Many at times, both the existing and proposed electronic toll collection (ETC) system makes their toll Gate closing decision based on just Timing as the determining parameter by setting a specific amount of time assumed for the vehicle to have passed the toll gate, rather most times this method turns out not to be a safe practice, In this paper a better method is adopted which is the use of an IR Transmitter and Receiver sensor, IR sensor is a more effective way to determine if truly the vehicle has passed the toll gate or not, thereafter the Toll Gate mechanism can be activated to make the toll gate closed.

1.3 AIM

The goal of this project is to design and implement an intelligent toll payment system with the use of a GSM Phone credit and data that will serve as an easy means of payment for the user and maintain transparency of the toll collection system.

1.4 OBJECTIVE

The intelligent toll payment system is designed and implemented to meet the following objectives;

- To design a system that is able to access toll payment.
- To design a system that will make toll payment faster.
- To design a toll system that has data access from both the Tollgate service end and the User mobile number account.
- To design a system that has multiple ways of Toll payment.
- To design a system that can intelligently interact with user via GSM Phone.
- To design a system that can analyses and statically store data of its users.

1.5 SIGNIFICANCE OF THE PROJECT

This project will be a drastic improvement to the existing electronic toll collection (ETC) systems. One way it would help to improve most existing and proposed intelligent toll payment system is by the toll payment not making decision of closing the toll gate after the vehicle tags has been validated with a “Timer parameter decision making” alone but by implementing the use of a proper feedback signal gotten through an IR Transmitter and Receiver sensors to truly detect movement of the vehicle so as to prevent accident as in most case.

This project also intends to solve the problem of security, hit-and-run or theft of vehicles; by making a provision for the vehicle owner to report such case to the police unit after which, the unique identification number of such stolen vehicle will be stored in the

database for future reference for tracking and recovery whenever the vehicle is drove close the toll plaza where RFID Readers are active.

This project design scope can also be implemented to improve existing car parks and many other known places.

1.6 SCOPE OF STUDY

The scope of this project is about building a budget friendly and yet an intelligent toll payment system which involves the system collecting toll payments and getting credited using GSM mobile number. The system gets controlled and interacted by inputs gotten on the PIC16F876A microcontroller through the update signals gotten from the GSM module connected, IR transmitter/Receiver and the RFID reader and vehicle tags.

1.7 HOW THIS THESIS IS ARRANGED

Chapter One which comprises of the introduction of the project, its objective and the statement problem that is to be solved. Chapter Two is the literature review which is the background study of related works that has been done, their drawbacks and then the areas uncover in existing models alongside what my addition will be to the existing toll payment system. Chapter Three include the methodology of the project, a complete breakdown or description of the project components into different sections such as hardware and software components, all this is basically so as to discuss the designed work along a detailed analysis of the project done.

CHAPTER TWO

LITERATURE REVIEW

2.1 RELATED WORKS

Research has been carried out on papers with a similar focus to the proposed topic. The aim of this research and literature review is to gain more insight on design considerations and workflow processes in the design and constructing of the project. This literature review contains summaries of the reference papers with considerations from each research paper and how they relate or help in the understanding and design of the proposed project.

Electronic toll collection was first implemented in 1986. After that many electronic toll collection systems are implemented with different techniques. Some of them are as follows:

System proposed in [10] uses Wi-Fi for communication with the Smartphone of user. This phone contains all necessary data related to the user registration. User is registered at toll booth automatically as he passes through. But the scheme may not operate efficiently in nations with less smartphone penetration.

The suggested system in [11] Use the overhead camera to identify the plate number and use it as the user's account number. In the main server, the database is stored. But numeral plate deterioration or duplicate numbers can create false positives in the scheme.

System proposed in [12] uses NFC chips for car identification detection. NFC chips are intended to operate in the reader's immediate vicinity. If there is more than a critical limit to the distance between reader and chip, the system will not detect the car.

R. M. Hushangabade, S.V. Dhopte [13] proposed that the system is a great asset in the transport industry. It reduces the common problems in accounting for the transportation of goods from point to point, the built RFID Automatic tollgate scheme can automatically detect car identities and bill according to each vehicle's identity as pre-registered in the database. The system can tell vehicle owners automatically. These were the major achievements met in the paper, among other objectives also achieved which include tracking of the vehicles and remote database connection.

S. Nandhini1, P. Premkumar [14] proposed that the automatic toll tax payment scheme and the quantity of transaction data are sent by GSM modem technology to motorists ' cell phones. It is an innovative technology for automatic toll collection solution for the expressway network. In this paper, the system frame composition and operating flow is outlined and data information is also readily exchanged between motorists and toll officials, allowing for more effective toll collection by decreasing traffic and eliminating potential human errors.

Khalid Al-Khateeb, Jaiz A. Y. Johari has suggested that RFID traffic control avoids issues that generally occur with conventional traffic control schemes, particularly those associated to image processing and beam interruption methods. Rshreffler [15] proposed that ETC is a scheme aimed at eliminating the delay on toll roads by electronically collecting tolls. Automated classification of vehicles is strongly linked to automated detection of vehicles. For distinct kinds of cars, most toll facilities charge distinct prices, making it necessary to differentiate the cars that pass through the toll facilities.

In developing countries likes Bangladesh the amount of vehicle is increasing rapidly. According to 3rd-ESTForum Bangladesh Country Paper, annual growth of vehicle is more than 10% and most of them are motor vehicle [16]. So, the manual toll system has become a real concern in Bangladesh. Being one of the leading developing countries, Bangladesh is not able to implement automated toll system due to its vast Large-scale car quantity and high execution costs.

Currently, the government of Bangladesh has taken measures to digitalize the license plate amount of all cars. Countries with digitized license plate numbers can therefore use this project to introduce the automated toll scheme at a negligible price. There are several nations, such as China's RFID-based toll scheme [17]. Research on the development of image processing-based toll systems such as Shoaib Rehman's Automatic Toll Tax Collection Vehicle Number Recognition System [18] but the image processing scheme is computer-dependent.

From the literature, the use of Dedicated Short-Range Communication (DSRC), which includes bar-code and Radio Frequency Identification (RFID), has proved to be effective; but it is usually affected by signal interference. In the case of a barcode-based ETC, a sticker with an imprinted barcode will be placed under the vehicle's wind shield and will be read as the vehicle passes by the laser barcode reader on the toll place. This technique has been documented widely in the literature [19]–[29]. However, under poor weather conditions, the method is less accurate (particularly when it is foggy). Also, it is not reliable because the user data can be read off by any barcode reader. The technique is also renowned for its absence of flexibility and the restricted storage data that barcode technology provides. [30]. The RFID-based ETC includes the installation on the windshield of an in-vehicle unit (IVU). To read the RFID-tagged IVU, an RFID reader is installed on the toll plaza. The IVU involved in this technique enables more information to be stored than the barcode technology. It also offers quicker data transfer rates, and a moderate degree of security and reliability. The main drawbacks of the RFID implementation of ETC are that: (i) It has a restricted variety of interaction; and (ii) It's not inexpensive.

Automatic Number Plate Reader (ANPR) technology utilizes a stationary camera to record and recognize the vehicle number plate that passes through the toll site [31]. This operates under a very powerful premise: that all cars have number plates that are linked to the toll account of the car owner. The number plate recognized is checked with the number plate in the main database and the toll charge is deducted from the account of the car owner. If the recorded number is not correctly read or discovered in the documents, the authorities will be alerted by issuing an enforcement infringement alarm.

In this manner, it achieves two goals concurrently: automatic car identification to deduct toll taxes, and alerts for issuing / recording violations. If highly secure number plates are adopted which are very hard to falsify, this scheme can also handle the issue of vehicle theft and fake number plate generation. On the other side, ANPR is costly and its precision depends on the circumstances of the environment. [32].

WSNs promote efficient surveillance and control of devices and have been widely adopted for various intelligent apps [33]. A WSN is a network of machines (referred to as nodes) that senses the environment and communicates the information collected via wireless connections [34]. This information is transferred to a sink via various hops, also known as a controller or monitor that can use it locally, or is transferred via the Internet to other distant systems. The sensor network consists of a big amount of sensor nodes that are either densely deployed within or very near to the entity. These sensor nodes conduct various functionalities, from remote sensing and processing of information to communication. An automated system can leverage big node groups ' cooperative effort to enhance system efficiency. Furthermore, there are several technologies for implementing WSNs but they have significant disadvantages, including, but not restricted to, complexity, large-scale dissipation of energy, brief range, and small-scale networking. With its low energy dissipation and low velocity, So therefore, a fresh wireless network technology known as ZigBee is becoming increasingly popular [35].

2.1.1 GAP LEFT UNCOVERED

The above-mentioned references in the associated subjects discussed the elements of the project's in various branches, which is an electronic toll collection (ETC) system.

The former scheme is seen to have limitations from some of the articles reviewed in which the RFIDs stand out with many benefits. RFID tags do not need a battery because they can operate perfectly with the RFID reader energy radiated. Unlike physical wear and tear on the number plate, there is no damage. Reader to tag distance is no problem as high-power radio waves can detect the tag up to enough range. Unlike Wi-Fi no authentication is required quicker than the system suggested in [10].

2.1.2 MY ADDITION TO THE EXISTING SYSTEM

My project will be a drastic improvement to the existing electronic toll collection (ETC) systems. One way it would help to improve most existing and proposed intelligent toll payment system is by the toll payment not making decision of closing the toll gate after the vehicle tags has been validated with a “Timer parameter decision making” alone but by implementing the use of a proper feedback signal gotten through an IR Transmitter and Receiver sensors to truly detect movement of the vehicle so as to prevent accident as in most case.

Secondly, In cases whereby the driver does not have sufficient balance on his or her Vehicle RFID tag, Taking advantage of most new mobile devices having the new feature of been able to read passive high-frequency (HF) RFID based on the Near Field Communication (NFC) Protocol, The registered driver mobile phone and number will then be used in place of the RFID tags in this project design so that once the vehicle approaches the toll plaza with insufficient balance on the vehicle tag, provided there is sufficient credit on the registered phone and number estimated to the cost fee for per toll gate transaction, the RFID reader detect and process its transaction from the driver mobile phone, this way we ensure the need for human or manual transaction is eliminated and uninterrupted transportation movement achieved at the Toll plaza. Research and Findings, have it that this hasn’t been implemented anywhere in the whole yet.

2.2 THEORETICAL FRAMEWORK

2.2.1 WHAT IS AN ELECTRONIC TOLL COLLECTION (ETC):

Electronic Toll Collection (ETC) is used in urban areas, over bridges, in tunnels, in High Occupancy Toll (HOT) lanes, on toll roads, or through turnpikes. A toll collection system can be either be open or closed. The closed system needs either manual tollbooths or an ETC system for all entrances and exits. Nearly all manual toll systems will get converted to an ETC system in the future.

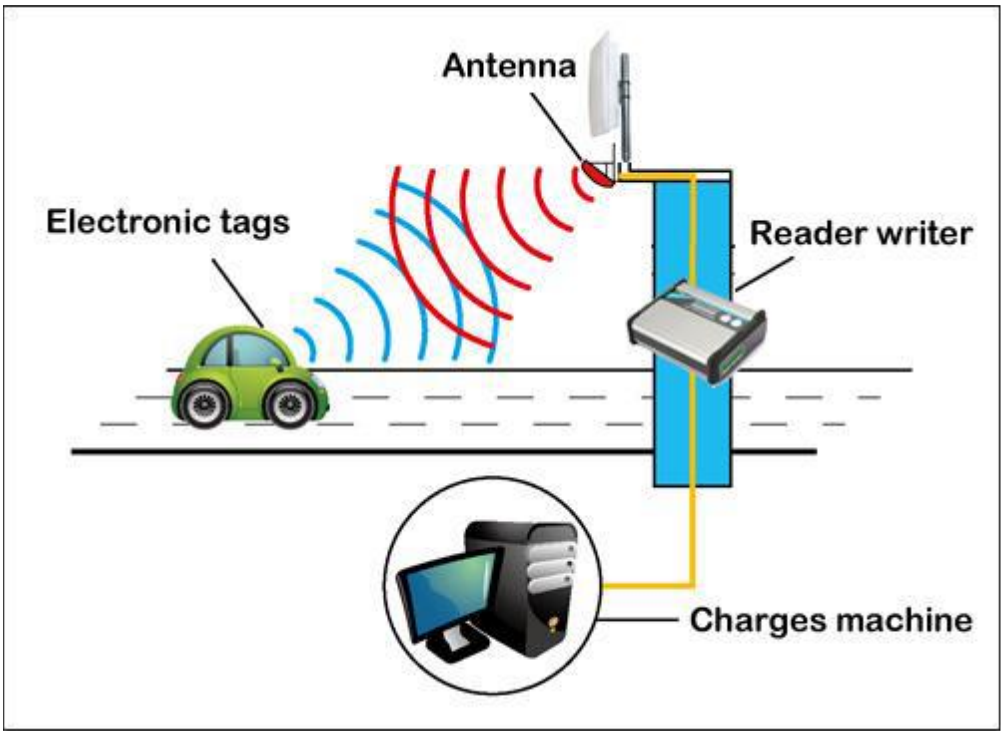

Figure 1: An ETC collection system.

An ETC system typically includes two main components:

- **Automatic Vehicle Identification (AVI)**

AVI involves the use of the car electronic radio frequency tags. In order to recognize car ownership, the tags either passively or actively interact with roadside readers. The toll costs can be deducted from the respective account once ownership is determined.

- **Automatic Vehicle Classification (AVC)**

By its physical characteristics, AVC techniques mounted on the highway can determine the class of a vehicle. Transaction processing is the method of debiting the accounts of clients and responding to client requests. Several techniques are used for enforcement of violations, including automatic number plate recognition (ANPR) technology. Usually, highway patrol officers are posted through unmanned toll booths, acting as a visible and efficient deterrent breach.

The four parts are somewhat autonomous and have been contracted individually by multiple toll organizations. This division of tasks has led to problems in some instances.

2.2.2 Advantages of Electronic toll collection system:

Electronic toll collection system is a digital system of collection toll from vehicles without stopping them. Electronic Toll Collection lanes enhance traffic flow speed and effectiveness and save driver time. An electronic toll collection system can pay a toll on a customer account created electronically. The scheme can determine if a passing vehicle is registered, automatically charge those cars, and alert customers who are not registered to the local highway patrol. The technique of collecting electronic tolls enables cars to pass through a toll facility without any intervention or stoppage being required.

- **Increased Capacity:**

The Electronic Toll Collection System will increase transportation capacity as we split the road by four lanes when passing the toll plaza. In addition, our system is automated to boost transportation ability when passing the toll booth.

- **Fuel saving:**

The complete elimination of deceleration, acceleration and idling. This results in the use of the Electronic Toll Collection System to save gas for the customers. Eliminating acceleration and deceleration leads to a decrease in vehicle operating costs.

- **Operating cost saving:**

The price of toll collection will be decreased over a period of time. The man-hour labor needed for the toll transaction is reduced as the scheme does not require any human interaction.

Time-saving customers of ETC do not stop paying toll, so travel time saves considerably. As the travel time can be estimated reasonably correctly, the reliability of the travel time is improved.

2.2.3 Different Types of Electronic Toll Collection System:

➢ Barcode-based Electronic Toll Collection System:

Electronic Toll Collection System based on barcode is a sub-category in the DSRC. In this, a bar-coded sticker is connected to the car and when passing through the toll plaza, a laser scanner reads it shows the functioning of a typical electronic tolling DSRC scheme. It's both the easiest and the oldest technology. It is used in multiple apps such as libraries to manage book records, shopping places to take sales and purchases into consideration, food business to store food information, and much more. Despite all these, it also has many disadvantages to be used for toll collection systems such as absence of reliability, less precision in poor weather, absence of flexibility, slow data read rate, less information about storage and simple to be theft.

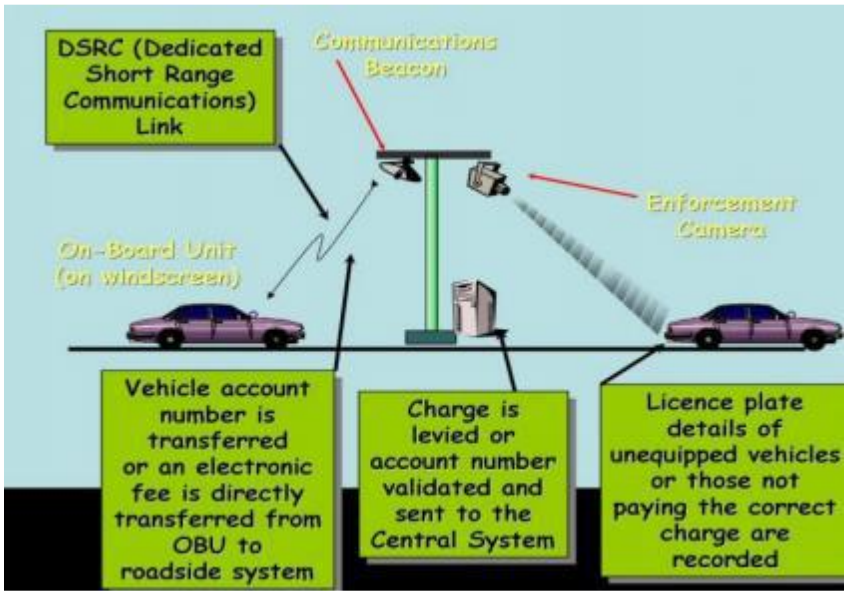

Figure 2: DSRC system for electronic tolling.

➢ ANPR (Automatic Number Plate Reader):

Another important technology is ANPR. It uses a stationary camera to record and recognize the vehicle number plate that passes through toll plaza. The permit numbers recognized are matched in the database and deducted from the tax. If the recorded number is not read properly or not found in the records, it issues an enforcement

violation alarm to the alert the authorities. In this way. At the same time, it sets two goals: to identify the car for tax deduction and to record the alert for implementation of violations. The Indian government has begun to issue high-security plates. Thus, this technology also helps with fake number plates to identify stolen vehicles and cars. It also has high price limitations and decreased precision under stormy circumstances.

Figure 3: IVU (In-vehicle unit).

- **Calm active infrared:**

Calm active infrared is a relatively new technology. It is similar to RFID system; the only difference is that it is equipped with an active infrared unit that contains all the information. When we compare with RFID It has a quicker information read rate, reliability, precision, effectiveness and operates well under all circumstances in the setting. It's also about the interference issue. The roadblocks in the use of this technology are lack of interoperability, supplier support and high price.

- **VPS-technique (Vehicle Positioning System):**

Another one is VPS-technique consists of worldwide satellite navigation system incorporation with a communication mechanism. It operates with the assistance of a global positioning system (GPS) device mounted on a car connected to an on-board unit (OBU) that stores the vehicle's coordinates and sends transaction data via GSM to

the toll authorities. This system is extremely reliable, precise and effective. Environmental circumstances do not affect the effectiveness of this system. It offers only the distance traveled with a payment choice and is extremely flexible in producing the respective payment information. Police patrol can also use it for highway surveillance and automotive theft prevention. The related deficiencies for this scheme are its excessively high cost of installation, operation and maintenance, cautious handling, additional energy requirement and other accessories. Present research made it very clear that among the above-mentioned techniques there are no clear trade-offs. The associated shortcomings for this system are its excessively high installation, operation and maintenance costs, cautious handling, extra energy requirements and other accessories. The current research made it very clear that there are no clear trade-offs between them above-mentioned methods. It also de-motivate the policy-maker to adopt newer advanced technologies as a single wrong decision can bring up loads of problems for coming generations with huge wastage of money and time. Therefore, it becomes essential to predict the best solution in terms of best alternative for such problems using a highly subjective decision-making technique.

- **RFID-based Electronic Toll Collection System:**

The best and easy technology is RFID-based Electronic Toll Collection System, Has an IVU (In-vehicle unit) mounted on the vehicle's front windshield. This IVU includes a cash card for road tax payment. The RFID frequency reader or antenna reads this at the toll place. The RFID-based Electronic Toll Collection System can be either prepaid or postpaid, with a door or without a door. Compared to barcode, it includes more data, has quicker reading rates, hard to be fraudulent and also relatively more reliable. As the number of features rises, the price, simplicity and ease of use must be compromised. It is also noted that it sometimes demonstrates the issue of device intrusion (mobile phones, other IVUs, walkie-talkies, FM radio or other electronic gadgets) near the toll plaza or passing cars. Installation and alignment angles play a major role in ensuring reliability and high precision of these systems gives a short concept of how RFID-based ETC technology works.

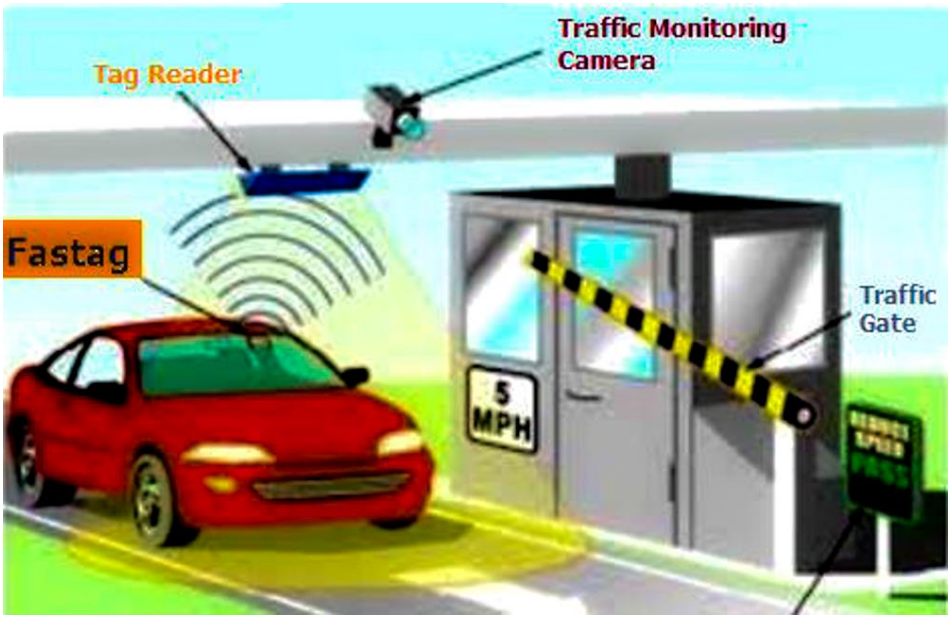

Figure 4: RFID technology for Electronic Toll Collection.

2.3 Radio Frequency (RF) Basic Technologies

Radio Frequency signals are actually Electromagnetic wave composed of the same light, ultraviolet and air radiation. Radio frequency waves / signals have both an electrical and a magnetic wave element and radiate outward from an antenna. The frequency operated by a RFID scheme is called a "carrier wave" or "carrier frequency." RFID devices work at frequencies that are distinct. Some popular RFID frequencies are as follows:

1) 30KHz to 500KHz. Also known as Low Frequency (LF)
2) 900KHz to 1500kHz. Also known as Mid Frequency (MF)
3) 2.4GHz to 2.5GHz. Also known as High Frequency (HF)

There is also another radio band assigned to RFID – 5.8 GHz. SHF (Super High Frequency); also known as Microwave. At the moment, this band is not being used due to lack of standards and some inherent limitations.

Antennas are tuned to resonate only to a small range of carrier frequencies focused on the specified frequency of the RFID scheme. This means that a system with a carrier

wave of 915 MHz (Center of 902 ~ 928 MHz) will not read a tag at 13.56 MHz, 125 kHz frequencies.

For all hardware requirements and laws, RFID systems use the decibel (dB) to define antenna gain, cable losses and energy output. In separate nations there are distinct regulations for distinct frequencies that need to be taken into account when designing, installing and using an RFID system.

- **Why RFID Why Not Infrared or Bluetooth "BLE or NFC"**

If one decides to use infrared for data transmission, he will find that line of sight is a big problem in IR. If any obstacle comes in between the infrared transmitter and receiver the signal will drop and the data will get corrupted but will even fail to reach the receiver. To avoid this from happening there has to be a better alternative. If RFID is used instead of IR the problem of line of sight will get solved. Line of sight creates the same problem at lower frequency but we can increase the RFID's frequency easily. Apart from this the RFID is more secure, in-that it only receives those frequencies which are registered with it, the other frequencies are out of range for it and It works just like the bar code reader reads the bars. [36]

Main Advantages of RFID Technology

- RFID does not require a direct line of sight
- RFID tags can be extremely durable against environmental factors or impact
- RFID tags can be re-written and re-used.
- RFID readers can read hundreds of tags within seconds
- RFID tags can hold more data than other types of tags or labels.
- RFID can be integrated with other internal processes.
- RFID tags can be printed with data such as orders, barcodes or company name.
- RFID tags can be encrypted and can be locked for extra security.

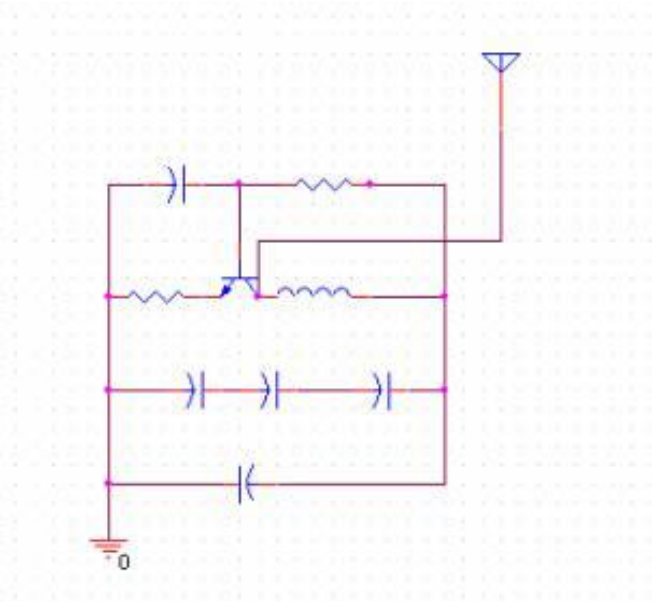

Figure 5: RFID internal circuitry.

- **Common Problem with RFID**

Reader collision and tag collision are some prevalent issues with RFID. Reader collision happens when two or more readers 'signals overlap. Simultaneous queries cannot be answered by the tag. In order to prevent this issue, systems need to be thoroughly set up. Tag collision happens when there are many tags in a tiny region; but since the reading time is very quick, to guarantee that tags react one at a moment, it is simpler for suppliers to create systems.

2.4 Basic Types of RFID Tags

2.4.1 Passive Tags

Passive tags are the most employed in the world due to many reasons, many of which are shown below.

They are small, inexpensive and have a long life (some over 20 years). They do not have their own power source therefore they require no maintenance to replace a worn-

out battery. They obtain power from the RF waves emitted by a reader. Therefore, they can only communicate when in the read-zone of a reader. Tag read range is anywhere from a few centimeters/inches to about 9 meters or 30 feet. We have successfully been able to obtain an excellent read rate but with only a few tags per second at about 40 feet. This was accomplished using very low loss cables and a high gain circular polarized antenna. You cannot obtain this read range in Europe due to power and bandwidth limitations.

The disadvantage of passive tags is the shortest read range.

Passive tags do not have batteries and depend on the reader's electromagnetic wave to create up sufficient energy in the integrated circuit of the tag to return the Unique ID to the reader.

By connecting the transmitter to the receiver, passive RFID tags and readers interact:

- **Load Modulation**

It is used in LF, HF and some UHF in the near field (close range).

- **Back Scatter (Load Matching)**

It is used for UHF and Microwave in the far sector (longer range).

The tag communicates with the reader through electromagnetic inductance in close-field communication. The tag and reader's coiled antennas form a transformer. The reader utilizes the wave of the carrier and changes the amplitude, stage or frequency (displacement / size). The tag detects and reacts properly as a shift in modulation.

Backscatter communication is used in the far field. Backscatter is a radio frequency wave's reflection when it strikes a conductive surface. The quantity of reflected energy relies on how well the surface resonates with the wave frequency.

Resonance is a system's tendency to oscillate at a certain frequency at peak amplitude. Like when you strike a guitar string, the guitar string and sound box resonate – it’s not just the string that is making the sound the whole system resonates!

The tag antenna is intended to resonate with the assigned system's particular carrier frequency. Therefore, even though the frequencies are very close, 125 kHz tags cannot be read by 134.2 kHz readers.

UHF tags can be specifically tuned to resonate in far-field communication based on the type of material to which they are connected. That's why you can now have Pallet tags – for timber or plastic, metal tags for metal bins, computer hardware metal tags.
The UHF tag can be adjusted to give you maximum resonance when you attach it to the fabric! Therefore, checking the reading rate and distance of a tag without mounting the tag to the material will not provide the right data.
Passive backscatter is used for transmitting information between the reader and tag in the UHF tags. Part of the electromagnetic wave is used to power the IC in the tag and the reflected part (backscatter) is used to communicate with the reader. [37]

2.4.2 Semi Passive Tags

1. Semi passive tags have batteries to power the IC.
2. Semi passive tags relies on the radio wave received from the reader in sending back its data back to the RFID reader.
3. Tag read range can be up to 30 meters or about 100 feet.
4. Tag can be coupled to sensors for measuring many different conditions.
5. Tag requires lower reader signal to activate.
6. Tag can have sleep mode to conserve battery life.
7. Disadvantage is higher cost, larger and heavier tag and battery maintenance is required.

2.4.3 Active Tags

1. Active tags have a battery or other power source. Some active tags can be attached to larger power sources such as 9 Volt, 12 Volt or AC power supplies.
2. Active tags have a radio transmitter of their own.
3. Tag has a longer variety of readings – up to or above 750 feet.
4. Tag can have up to 64 Kilo bytes of bigger memory.
5. Tags can be set to alarm when cable cutting is shifted, manipulated, or attached.

6. Tags can comprise motion, temperature, pressure, density change of magnetic flux sensors and more with tolerance limits for activation.
7. Tags can be set to continuously beacon or send out their identification, put into sleep mode until activated by a reader, or activate only when an environmental condition is met.
8. Histories of activities or events sensed by the tag can be stored in the tag's memory for retrieval at a later date.
9. Disadvantages of active tags are cost, size and weight.

2.5 Different frequencies of RFID

2.5.1 125 and 134.2 kHz. LF (Low Frequency)

- **Pros**

1. Minimum regulations from governments.
2. Small amounts of data stored 128 bits to 2 Kilobit.
3. Excellent for reading at slow speed and minimum distance.
4. Penetrates most materials such as water, tissue, and wood.
5. Can have high security using encryption and adjustable frequency.

- **Cons**

1. Minimum penetration around metals.
2. Slower read rates.
3. Minimum range.
4. Largest antenna requirement due to wavelength of 2,400 meters or 7,860 feet.

2.5.2 13.56 MHz HF (High Frequency)

- **Pros**

1. Penetrates water and tissue well.
2. Longer read and write range than LF.

3. Simpler antenna owing to 22 meters or 73 feet of wavelength.
4. The data rate is higher than the LF.
5. Smaller form factor.
6. Ideal for reading / writing smart cards.

- **Cons**

1. Maximum read range of 1.5 Meters or 4.8 feet under ideal conditions.
2. Does not penetrate or transmit well around metals - low read distance or about 20 cm or 8 inches.
3. Requires specific antenna configurations to obtain good read rates.

2.5.3 860 ~ 960 MHz UHF (Ultra High Frequency)

- **Pros**

1. Best frequency for read distances of over 1 meter or 3 feet.
2. Range of up to about 9 Meters or 30 feet under ideal conditions. (Europe 7 meters or 22 feet)
3. High Data transfer rate
4. Smaller antenna as wavelength is .33 Meters or 1.1 feet.
5. Controlled read zones using antenna directional capabilities.
6. One tag can be used to identify a product in one continent and read by a reader on another continent using a different frequency. 860 MHz ~ 928 MHz provides global interoperability.
7. Tags can be tuned to operate better when attached to a specific material.

- **Cons**

1. Difficult to penetrate water and tissue (though there are now tags for bottled liquids)
2. Numerous regulatory issues for frequency, power, channels, duty cycles, bands, etc.
3. To operate globally an IC must be capable of operating at 0.5 W to 4.0 W with varying duty cycles and output power.
4. Readers are more expensive than HF.

CHAPTER THREE

METHODOLOGY

3.1 PROBLEM FORMATION

This project looks at the various ways which Toll collection system can be improved. With recent progress in science and technology, it has become essential and necessary to incorporate automation to every circle of life and this system is been designed to eliminate this setback associated in the making of a stress free and yet reliable toll payment at toll plaza automatically “i.e. without the involvement of humans”. In order to improve the reliability, functionality and its effectiveness then the entire automating process will be incorporated with RFID modules, GSM module, PIC microcontroller, LCD display, IR sensor unit that enables the system automatically process vehicles and its transaction after validation whenever the RFID reader senses a RFID tag on the windshield of a vehicle in its range. Using the GSM technology, the system is able to display updates on the LCD Display and simultaneously send messages concerning its status to the user. This gives the user the feedbacks, acknowledgment and provide a transparent system void of fraudulent acts as in the case of manual transaction.

3.2 DESIGN CONSIDERATION

- **Power supply to individual unit or components.**

The power supply unit used in the design is such that the voltage and current requirement of each component are well taken note of and for component with less voltage requirement a voltage regulator is used to supply a constant power at a given rating.

➢ Implemented the UART Communication Protocol

Universal Asynchronous Receiver/Transmitter (UART) is not a communication protocol but a physical circuitry that converts parallel data into serial data. In UART communication, two UARTS communicate directly with each other. The transmitter UART converts data from a controlling device like a CPU into serial form, transits it in serial to the receiving UART, which then converts the serial data back into parallel data for the receiving device.

GSM / GPS modules like SIM900/800 uses UART communication for accepting AT commands that are used to control them and gather the replies. Example: In regions where Wi-Fi is not available we had to interface Bolt with a GSM unit for global monitoring and control.

Error Rate: This is calculated based on the Baud rate agreed upon and Baud rate that the microcontroller or peripheral can actually be set at due to internal hardware limitations. The formula for the same is (calculated in percentage)

Error% = ((Actual_baud/Baud_desired) — 1) * 100%

Example: If we want a baud rate of 2400 but the microcontroller practically can only give an accurate baud rate of 2396, we get.

Error% = ((2396 / 2400) — 1) * 100%

Error% = -0.16%

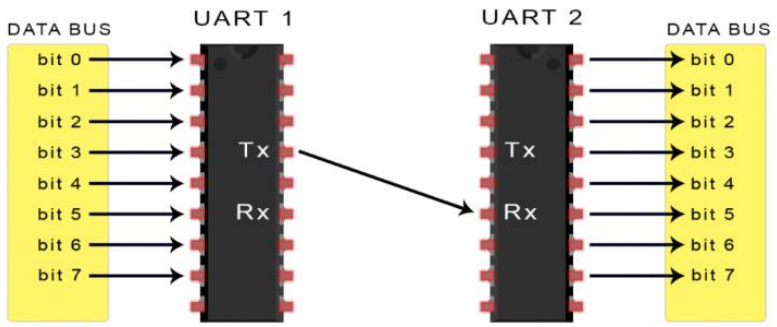

Figure 6: UART Communication Protocol connection

➢ Maximum Range.

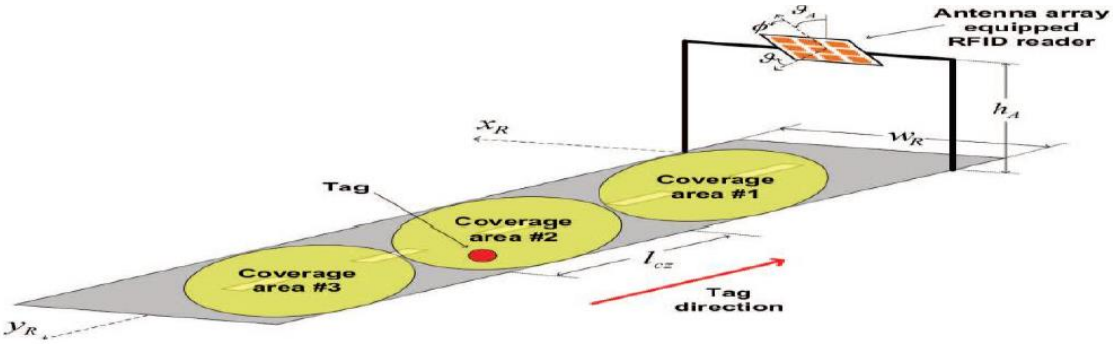

Figure 7: Electronic Toll Collection (ETC) System

Let us first consider the signal attenuation through a loss transmission path, described by the well-known Friis attenuation

Example with Ncz = 3. Formula (quantities expressed in dB)

$Pr = Pt + Gt + Gr + PL$ (1)

Where Pr and Pt are the received and transmitted power, respectively, Gt and Gr are the transmitter and the receiver antenna gain, respectively, while PL represents the path loss. RFID standards limit, in real applications, the sum of the transmitted power and the transmission gain, called effective isotropic radiated power (PEIRP) Furthermore, in an ideal case of a line-of-sight (LOS) propagation channel, PL = 20log10 ($\lambda = 4\pi$), where λ is the wavelength, and r is the distance from the transmitter to the receiver. Thus, since the received power should be larger than a threshold value Pth,

It can be rewritten as $r \leq \lambda\ 4\pi\ 10-P\text{th}-P\text{EIRP}-Gr20$

It should be observed that the receiver antenna gain is generally in the order of few dB, so the maximum system range is predominantly restricted by the maximum EIRP as well as the working frequency. In addition, maximizing the transmitter antenna gain to decrease power consumption may be of concern.

➢ Working Frequency.

The rules for frequency band evaluation solve the feasible working frequency and the maximum PEIRP so the selection is restricted to the suggested values. The frequency influences two design parameters in specific: maximum range and beam width of the antenna array. To fulfill the project demands, a trade-off must be established.

➢ Antenna array beam width

The significance of having a tiny beam width reader, which implies having high frequency in the practical situation of a size restricted antenna array. In reality, the half-power beam width (HPBW) can be approximated for a wide-side steered linear equally spaced array of N components with interelement range as.

HPBW ≈ 0.886 $bf\lambda\ L$ [rad]

where $L = Nd$ is the approximated dimension, while bf is the so-called broadening factor Taking into account the effect of a specific synthesis scheme, i.e. the choice of excitations for antenna amplitude.

➢ The Crucial Issues of Radio Frequency Power Selection.

The Decibel is a proportion of two signals and a 10th of a Bel. These calculations are "logarithmic measurements of the scale," so they use the logarithm of a physical quantity instead of the amount itself!

Bel = log (P2/P1)

Also, dB is a logarithmic metric and provides easy figures for large signal strength differences. This is very helpful because by adding and subtracting whole numbers you can readily calculate the profit and losses of the RFID system.

dB=10*log (P2/P1)

The dB system enables for the handling with simple math of large differences in signal strengths / levels.

The POWER LEVEL radio frequency is displayed either in watts or in dBm. DBm relates to a single milliwatt (1mW) energy in decibel. The formula gives the relationship between dBm and watts:

P(dBm) = 10 x Log (P/1mW)

P (dBi; references an isotropic radiator) = 1 - log (Pr/Pi), where Pi is power received from an isotropic antenna.

P (dBd; references a dipole antenna) = 10 Log (Pr/Pd), where Pd is power received from a dipole antenna. [37]

3.2 BLOCK DIAGRAM

The design of this project can be divided into various functional blocks which work together to perform the automated toll payment function.

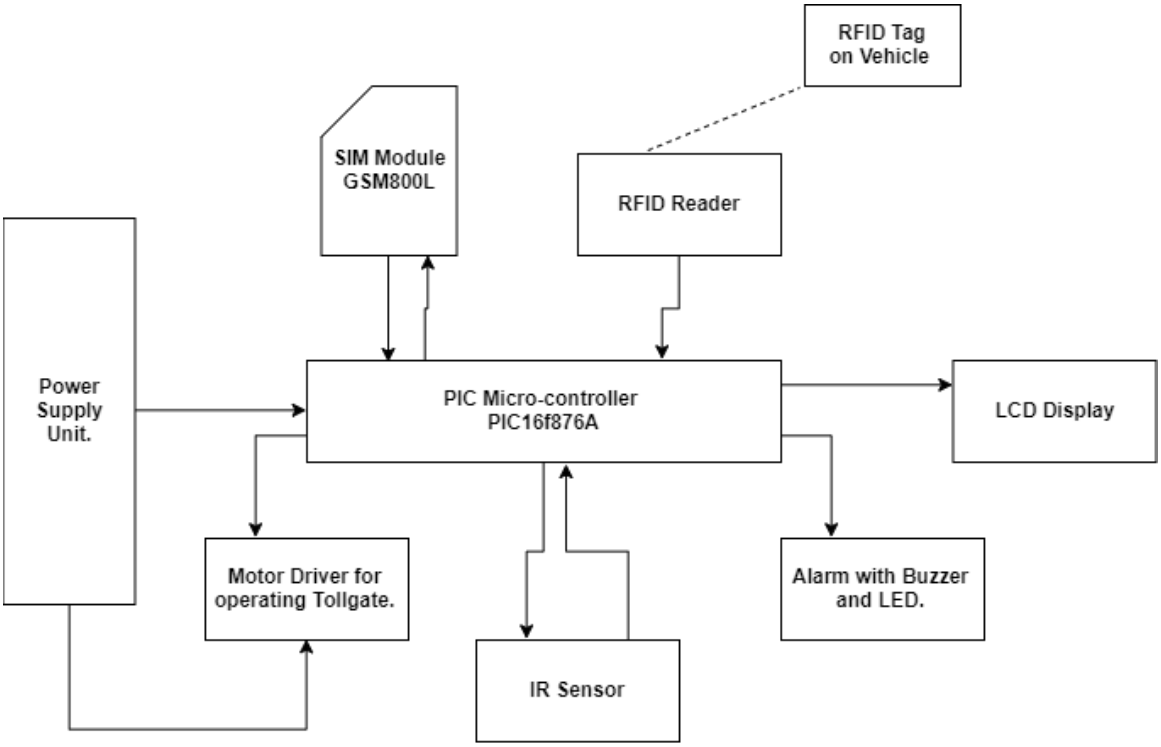

Figure 8: Detailed block diagram of an intelligent toll payment system.

3.3 HARDWARE EQUIPMENT

The system is made up of two parts, which are the software and the hardware. It is always important to have proper knowledge about all the hardware and software components of a project. A lot of components have been used to make this project work. In this project the most important part is PIC16F876A microcontroller, it contains all the software data in it. While a GSM module and SIM900A kit sends notification and serve as the means of payment to the system by the vehicle owner through his / her registered mobile number.

The hardware requirement consists of the following;

- Microcontroller
- RF-ID module and tags
- Resistors
- Capacitors
- GSM module
- DC Motor driver L293D
- DC Motor
- Voltage regulator
- Power supply
- LCD
- Crystal
- IR Transmitter and Receiver

3.3.1 Microcontroller

In this circuit, I will be making use of the pic microcontroller series precisely The Pic16f876a. this ic comes with 28 pins while some are configured by default for one function or another. Some are not configured; they need the interference of the program which will be embedded into it. The microcontroller supports wide range of programming language like assembly language, basic and c-language.

The microcontroller has embedded different features it has an EEPROM data memory of 256 bytes, 2 comparators, 5 channels of 10-bit Analog-to-digital (A/D) converter, 2 capture / compare / PWM functions, Universal Asynchronous Receiver Transmitter (USART) and other features.

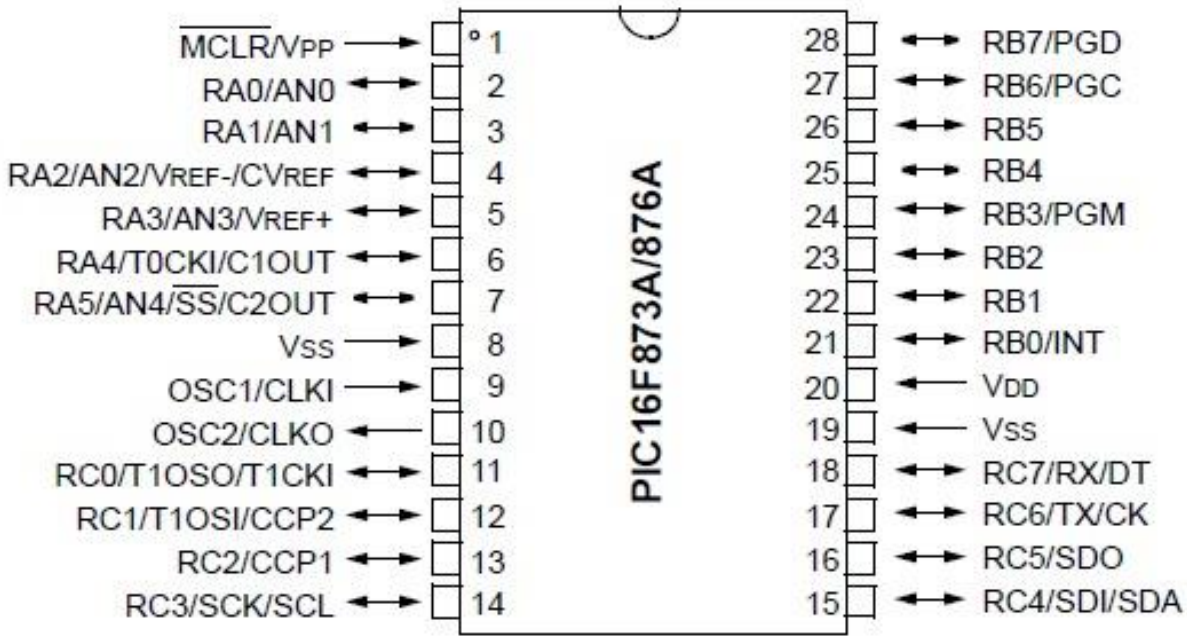

Figure 9 A schematic diagram of a PIC16f876a microcontroller.

We have stored the following data of the vehicle on the microcontroller PIC:

- Name:
- License Number:
- Car Number:
- Registered Mobile Number

3.3.2 RFID MODULE AND TAG

The RFID module (Reader) is a device which takes advantage of the characteristics of the radio wave to read and capture information stored on a tag. Radio

waves are used for the transferring of data to the reader from the tag. The RFID module has embedded on it a decoder that decodes the frequency disturbance between the reader and the tag. **RFID tags** can't generate or store power they are powered by the radio frequency energy which is transmitted from **RFID** readers/antennas. To power the tag and reflect the energy back to the reader, the signal sent by the reader and antenna is used.

Figure 10: RFID Tag and module

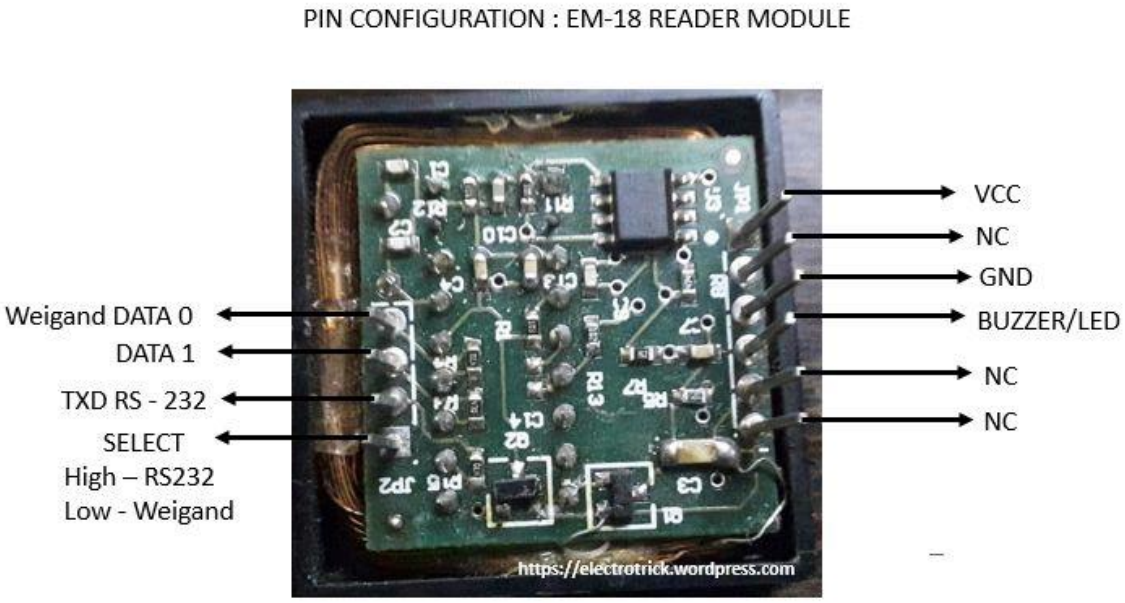

Figure 11: RFID Module Pin Configuration

3.3.3 GSM MODULE

The GSM module is a device that has the capability of sending and receiving information. The sim module which can be called a GSM module is a very complete dual-band communication solution. The GSM module provides GSM 900/1800MHZ with low power consumption for voice, SMS, data. The GSM Module [38] sends status as SMS to the driver registered mobile number as regarding deduction of balance of Toll fee, during a theft case SMS can be sent to a pre-registered nearby police station mobile contact for real time interrogation. It is interfaced directly with the microcontroller with the aid of an external power supply.

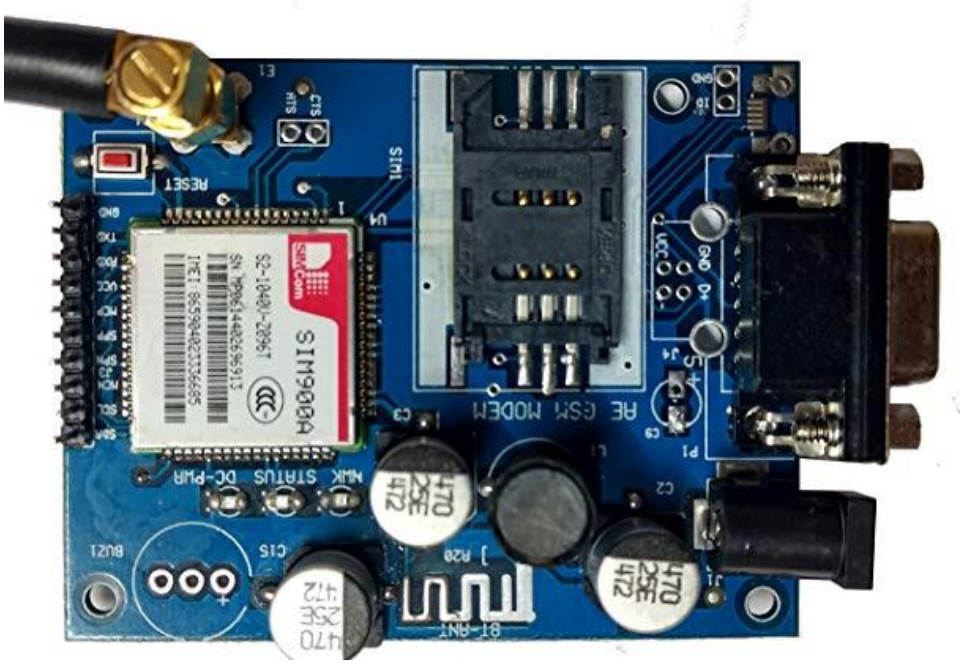

Figure 12: GSM Module SIM900A

3.3.4 DC MOTOR DRIVER L293D

The L293D Motor driver can be used in driving two DC motors simultaneously. The L293D IC is a dual H-bridge driver IC. A single H-bridge can drive a dc motor in both directions. L293D IC is a current amplifier IC as the output from the sensor is not sufficient to drive the DC motor directly, Therefore the L293D IC is used for this purpose. L293D has 16pins, having two enables pins and this pin should always be high to enable the bridge.

Features of L293D DC Motor Driver:

- Wide supply-voltage range: 4.50v to 3.60v.
- High-Noise-Immunity inputs.
- L293 and L293D variants.
- Separate supply of input logic.
- Protection of internal ESD.
- Thermal shutdown.

Input 1	Input 2	Motor Direction
1	**0**	Clockwise
0	**1**	Anti-clockwise
0	**0**	Idle
1	**1**	Idle

Table 1 : L293D Motor Driver Logic Table

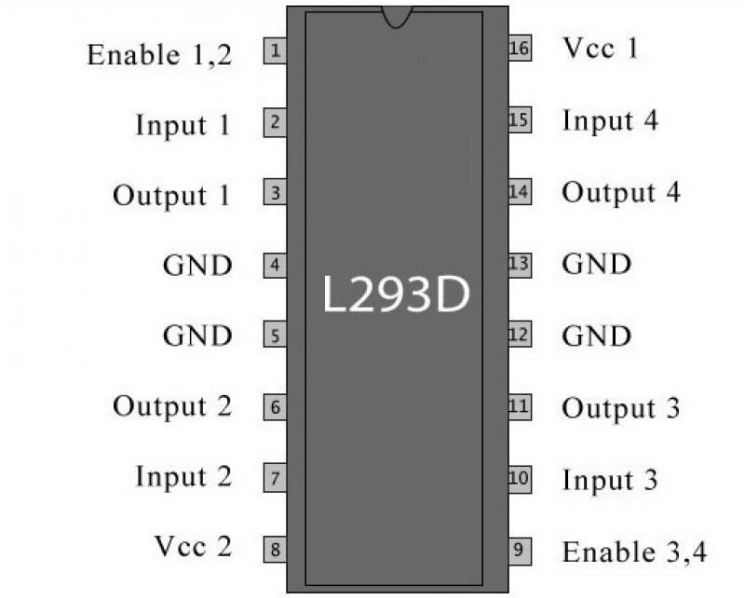

Figure 13: L293D pin Diagram.

i

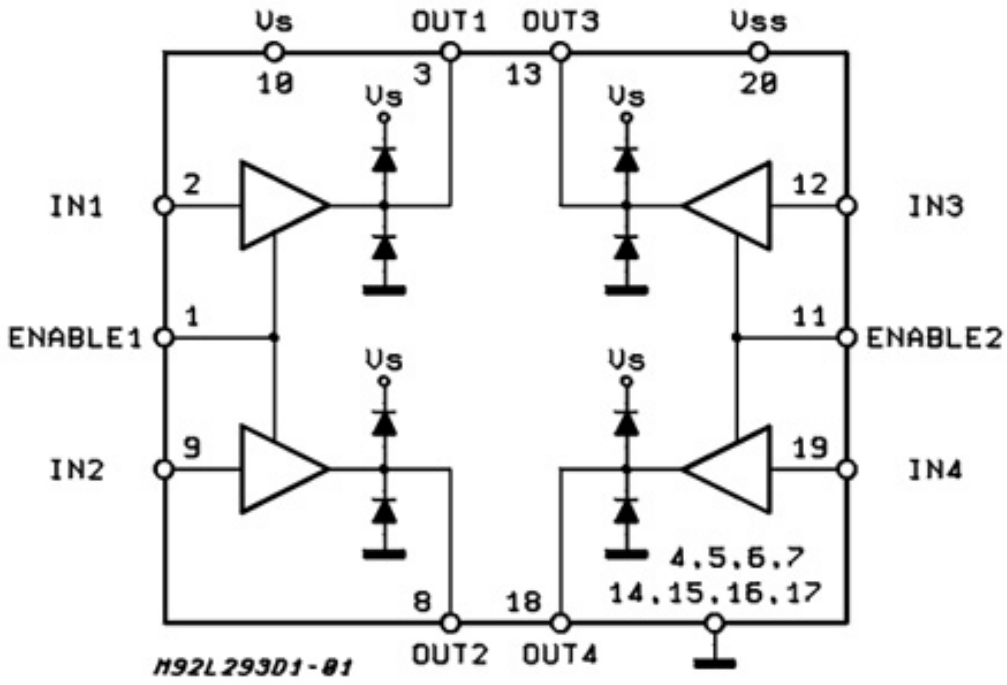

Figure 14: Circuit diagram of a L293D motor driver.

3.3.5 DC MOTOR

An electric motor is an electromechanical device converting electrical energy into a mechanical movement. A DC motor operates on the basis that the conductor experiences a mechanical force when the conductor is a current carrying conductor is positioned in the magnetic field. DC motors are mostly used in cases where almost constant speed is required and very high starting torque is not required as lathe, machine tools, centrifugal pumps etc. On the other side, series motors are used in instances where a strong high starting torque is needed such as electric traction, trolley car, crane, etc. cumulative compound motors are suitable for applications where the load fluctuates such as a rolling mill, printing press, reciprocating type compressors, crusher units, etc. Differential compound motors are rarely used because of its poor torque characteristics.

Figure 15: DC Servo Motor.

3.3.6 VOLTAGE REGULATOR

The voltage regulator LM7805 gives a constant power to the microcontroller. A diode is connected with LM7805 so that the circuit work only forward biased settings. LM7805 has three legs out of which, one gets the input voltage, one acts as ground and the other gives the constant voltage.

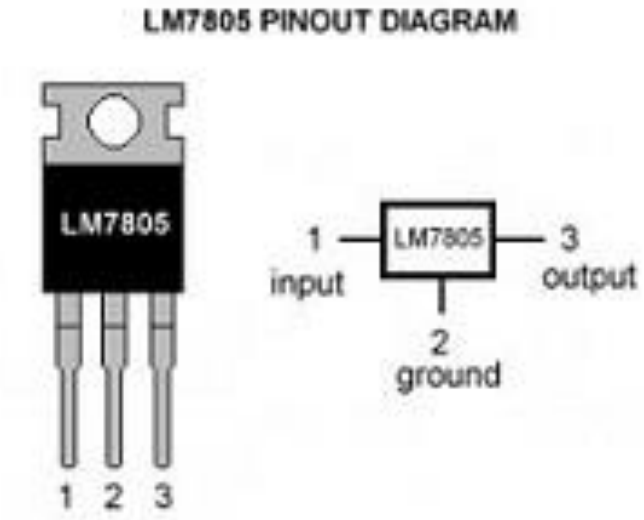

Figure 16: Voltage Regulator LM7805

3.3.7 POWER SUPPLY

The DC power supply is very vital component in any modern electronic devices because they require a broad variety of DC voltages to operate. A power supply is intended to provide the necessary quantity of energy from the primary source indicated voltage.

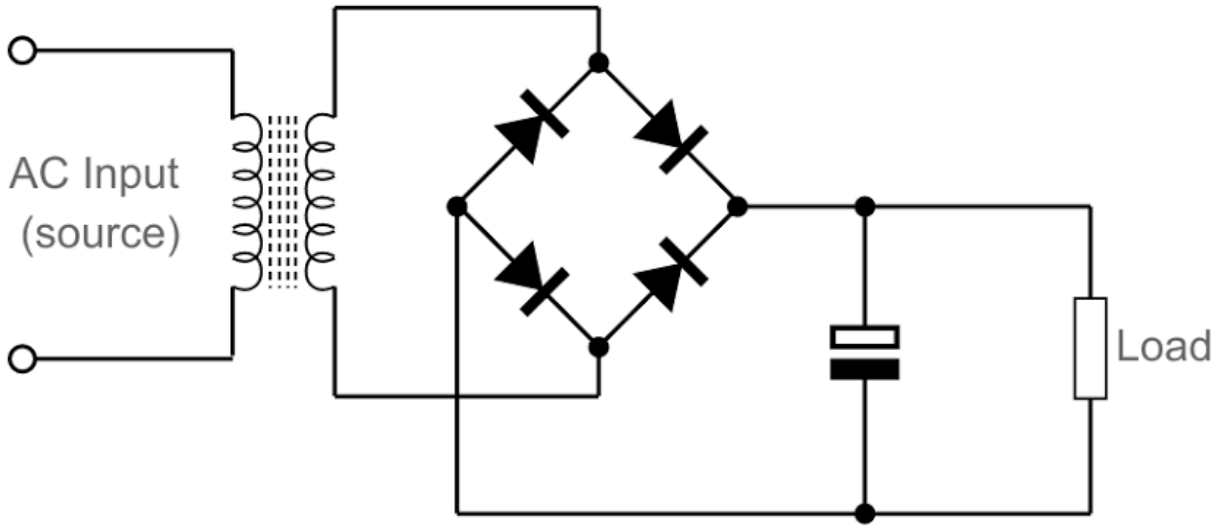

Figure 17: A DC Power Supply Rectifier.

At 230V; the average DC voltage of the secondary side of transformer is governed by the equation

$$Vdc = \frac{2Vmax}{\pi} = 0.637Vmax = 0.90 \times Vrms = 0.90 \times 12$$

$$= 10.8V$$

A pulsating DC power is delivered by the bridge rectifier

$$\boldsymbol{Ripple\ factor} = \sqrt{\left(\frac{\boldsymbol{Vrms}}{\boldsymbol{Vdc}}\right)^{\mathbf{2}} - \mathbf{1}} \qquad (3.4)$$

$$= \sqrt{\left(\frac{12}{10.8}\right)^{2} - 1}$$

$$= 0.48$$

Thus, indicating that the value of the ripple contents in the output are 48% of the DC component. This is much lesser than the ripple contents for a half wave rectifier.

$$Efficiency = \frac{Pdc}{Prms} \times 100\% \qquad (3.5)$$

$$= \frac{10.8}{12} \times 100\%$$

$$= 90\%$$

This is the maximum theoretical efficiency for the bridge rectifier

➢ Ripple Capacitor.

The filter capacitor is needed to filter out the value of the voltage ripples and undesirable frequencies. In this circuit, the required value of the minimum capacitor can be computed using the equation.

$$\boldsymbol{C} = \frac{\boldsymbol{I}}{\boldsymbol{2 \times f \times Vpp}} \qquad (3.6)$$

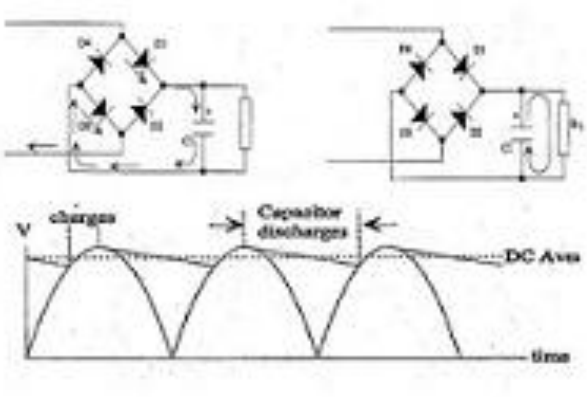

Figure 18: A filter capacitor for smoothing ripples

Where,

- *The peak to peak voltage is **Vpp***
- *The circuit current is **I***
- *The supply frequency from the line is **f***
- *Capacitance **C***

The secondary voltage of the transformer = $12V$

The value of the Voltage ripple $= \ 10\% \ of \ 12V \ = 1.2V$

The two voltage drop of the bridge rectifier = $2 \ \times \ 0.7 = 1.4V$

After rectification, the expected value of voltage = $12 + 1.2 + 1.4 = 14.6V$

The voltage is 15V approximately (peak to peak maximum output voltage of bridge rectifier)

For a LM7805 voltage regulator, the maximum value of the output current is $Imax = Iout = 1Ampere$.

$$\boldsymbol{C} = \frac{\mathbf{1}}{\mathbf{2 \times 50 \times 15}} \equiv \mathbf{1000}\boldsymbol{\mu f}$$

3.3.8 LCD

A 16x4 Liquid Crystal Display “LCD” means that it can display 16 characters per line and there are 4 such lines. That is, in this LCD each character is displayed in a 5x7 pixel matrix.

This LCD has two "Command and Data" registers, which store the command instructions given to the LCD by the command register. A command is an instruction given to the LCD to perform a predefined task such as initializing, clearing the screen, setting the position of the cursor, controlling display, etc. The data register will store the information that will be displayed on the LCD. The information is the character's ASCII value to display on the LCD.

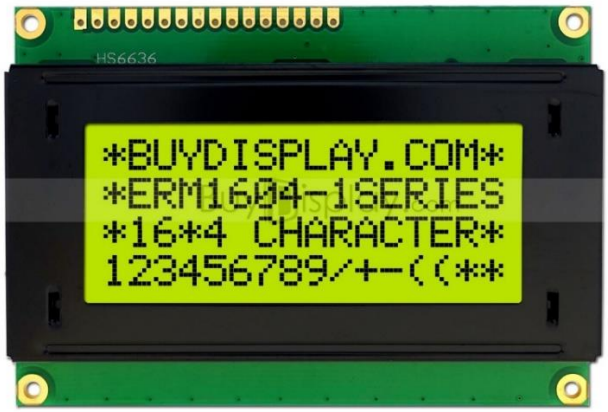

Figure 19: 16x4 LCD Display

A liquid crystal is a material that flows like a liquid (normally organic for LCDs), but whose molecular structure has certain properties that are normally associated with solids. A low-power instrument is the Liquid Crystal Display (LCD). Typically, the energy requirement for the LCD is in the order of microwatts. An LCD, however, needs an external or internal source of light. It is limited to a temperature range of approximately 0C to 60C and lifetime is a concern, as LCDs can degrade chemically.

There are two main kinds of LCDs:

1. Dynamic-scattering LCDs

2. Field-effect LCDs

Field-effect LCDs are usually used in apps where a primary factor is the source of electricity (e.g. watches, portable devices, etc.). They absorb much less energy than the sort of light-scattering. Typically, however, the price of field effect units is greater, And they are restricted to 2 inches in height. Light-scattering devices, on the other side, are accessible in height up to 8 inches. The field-effect LCD is used to display the relevant data in the paper.

The turn-on and turn-off time in all displays is a significant factor. LCD's response time ranges from 100 to 300ms. LCD's lifetime is steadily growing beyond the limit of 10,000+hours. Because the color produced by LCD units depends on the light source, a broad variety of color choices are available.

NO	SYMBOL	LEVEL	FUNCTION
1	VDD	--	DC +5V
2	VSS	--	GND (0V)
3	VO	--	Contrast Adjust
4	RS	H/L	Register select
5	R/W	H/L	Read/Write
6	E	H,H→L	Enable signal
7	DB0	H/L	Data Bit 0
8	DB1	H/L	Data Bit 1
9	DB2	H/L	Data Bit 2
10	DB3	H/L	Data Bit 3
11	DB4	H/L	Data Bit 4
12	DB5	H/L	Data Bit 5
13	DB6	H/L	Data Bit 6
14	DB7	H/L	Data Bit 7
15	LEDA	H/L	DC +5V
16	LEDK	H/L	0V

Table 2 : LCD DISPLAY PIN CONNECTION

3.3.9 CRYSTAL

A crystal is used to provide clock to µcontroller. The value of the crystal used in the circuit is 11.0592 MHz

3.4 SOFTWARE EQUIPMENT

3.4.1 MPLab for PIC

MPLab is a powerful, feature rich development tool for PIC microcontroller. It is designed to provide the consumer with the simplest alternative to develop embedded

system applications without compromising efficiency or control. MPLab provides a successful match featuring highly advanced IDE, ANSI compliant complier, broad set of hardware libraries and comprehensive documentations.

3.4.2 PIC PROGRAMMER

A PIC programmer is a circuit which interface the pc to the microcontroller using the PC parallel, serial or ISB port. It can write information and read it back for verification to the microcontroller. The PIC programmer translates the PC digital logic levels into the appropriate microcontroller logic levels.

Figure 20: PIC Microcontroller Programmer

3.5 METHOD OF CONSTRUCTION

When a driver approaches the toll gate while driving, The RFID tag installed on the windshield of his or her vehicle is detected by the RFID reader at the toll plaza and the data captured from the RFID tag on the driver vehicle will be run through the database

provided at the toll plaza. If the tag is registered / valid the system further checks if there is sufficient balance on the tag and if there is, then the driver account “i.e. *the mobile number*” is debited. After which the tollgate will be automatically opened for the driver to pass through the tollgate.

Subsequently, if the credit finishes a notification will be sent to the registered mobile number to notify the owner to top up his Tag ahead of future trip or transport and the top up payment is simply done via GSM Credit loading.

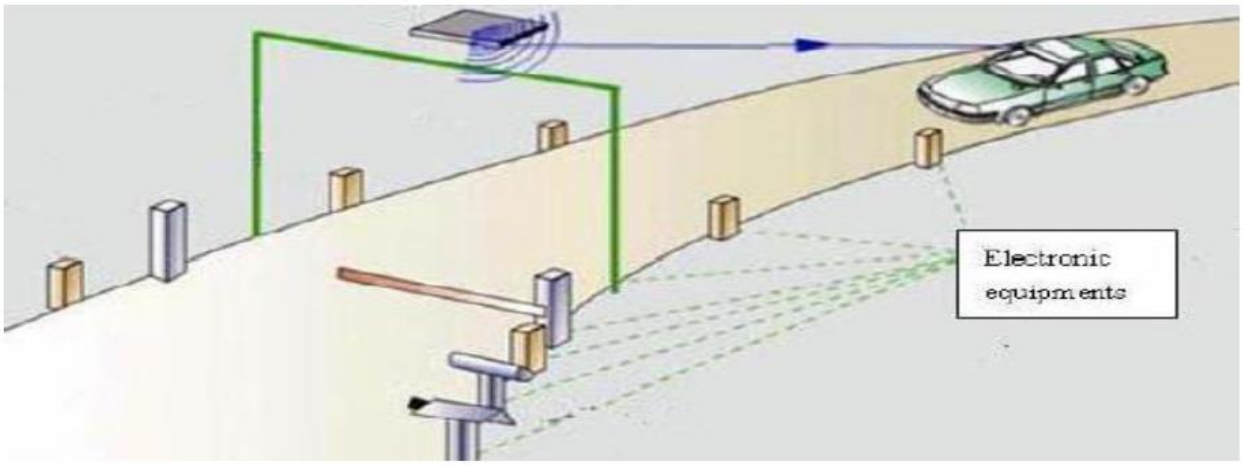

Figure 21: Working Module Prototype

3.7 FLOW CHART DESIGN

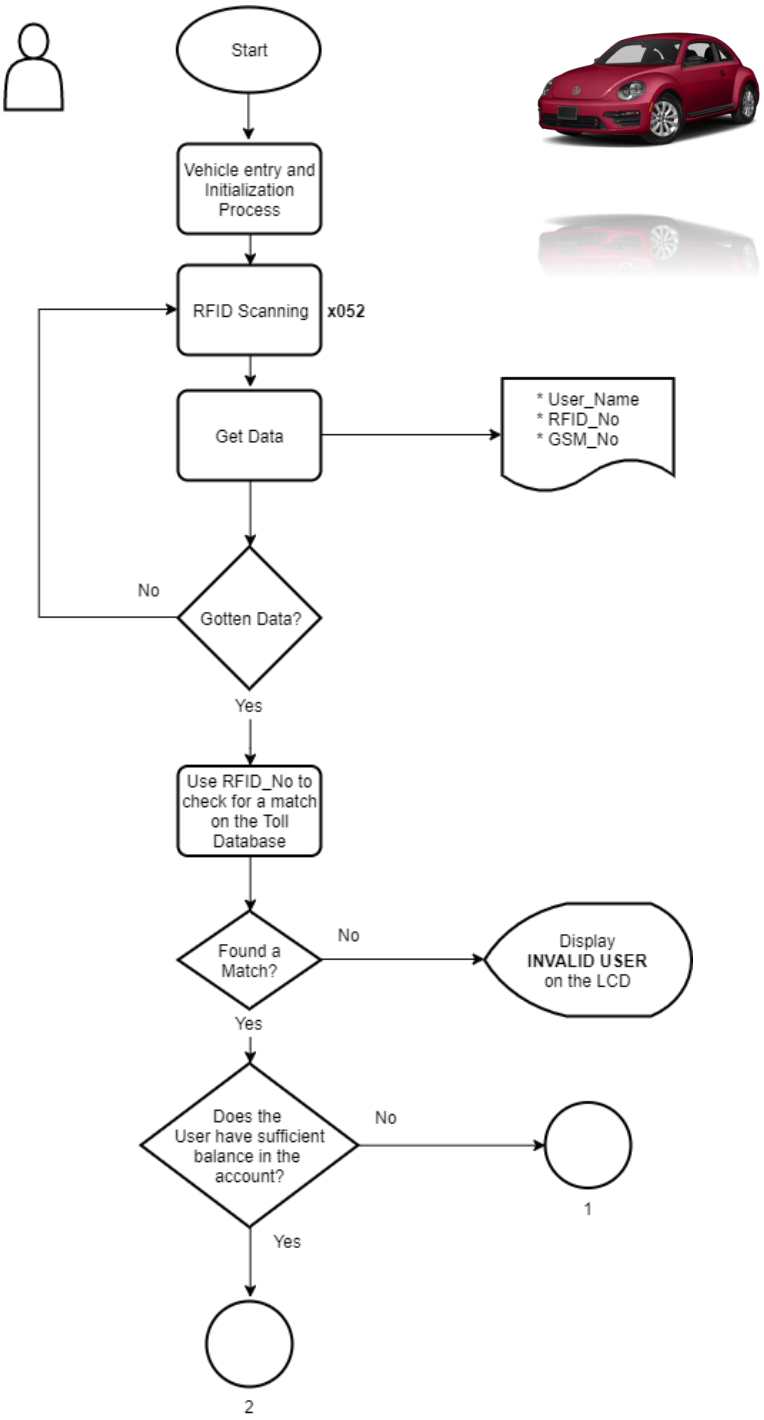

Figure 22: Flow Chart for Toll Collection System

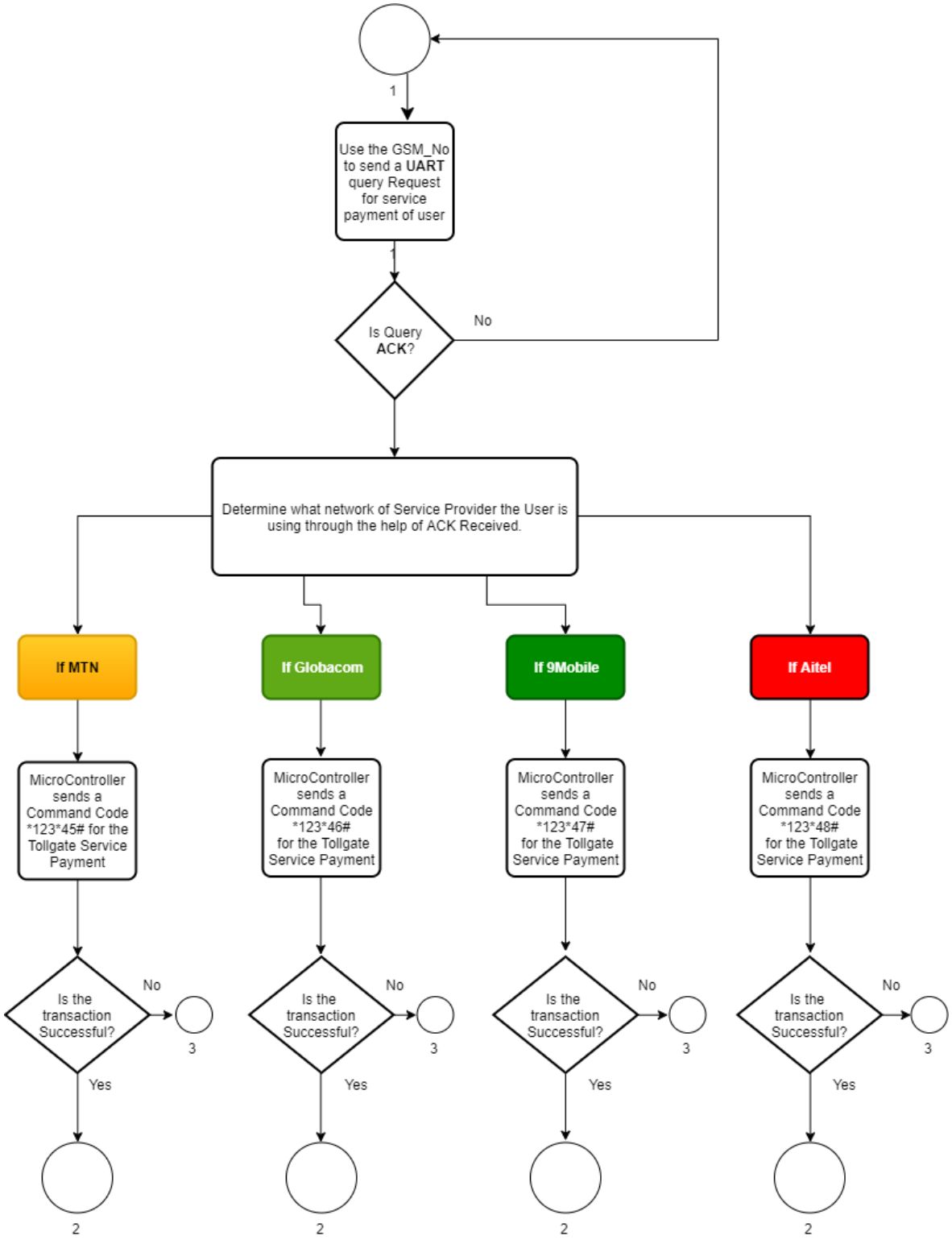

Figure 23: Flow Chart of GSM UART Operations

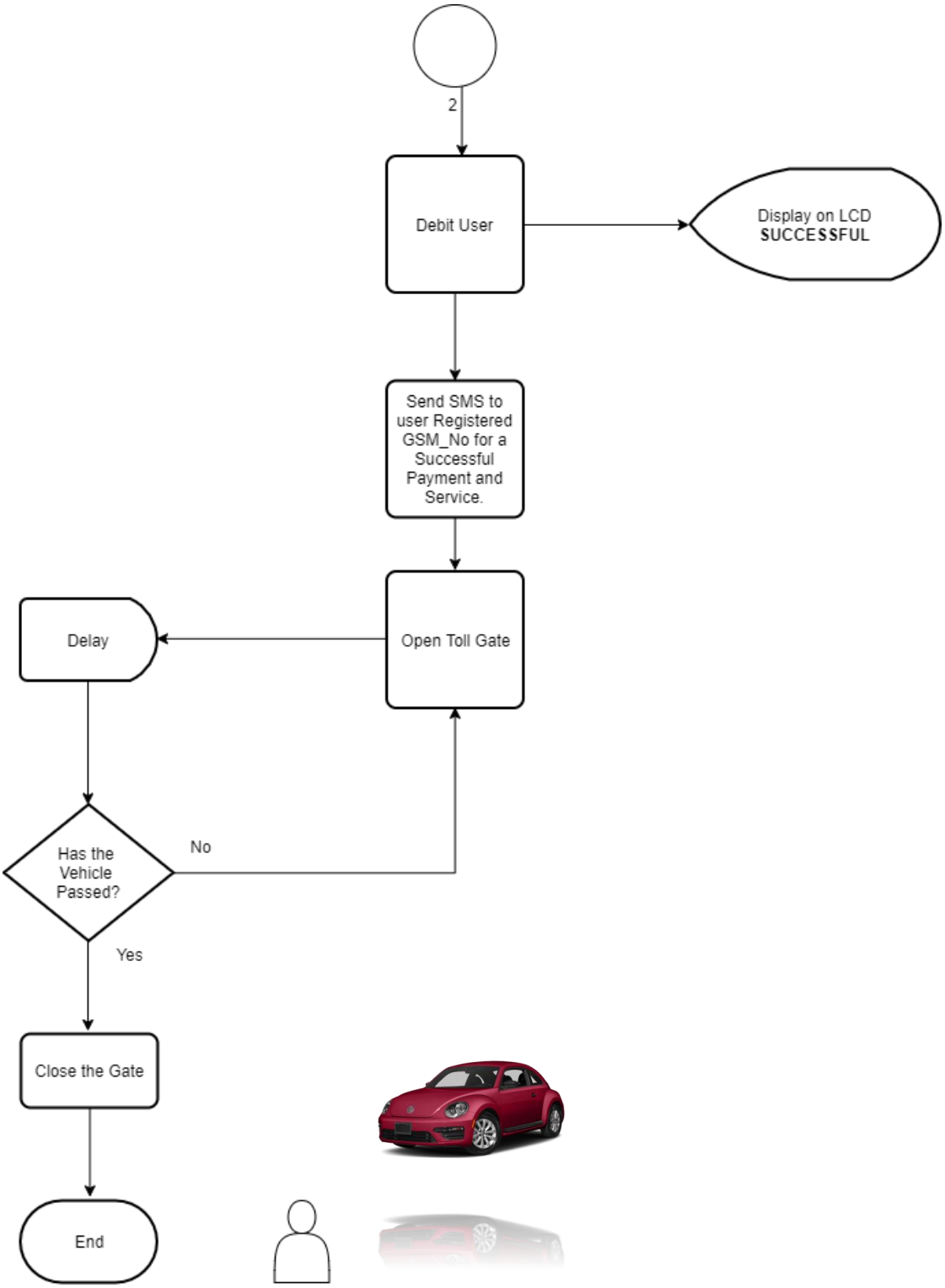

Figure 24: Flow Chart for Successful Operation and Transaction

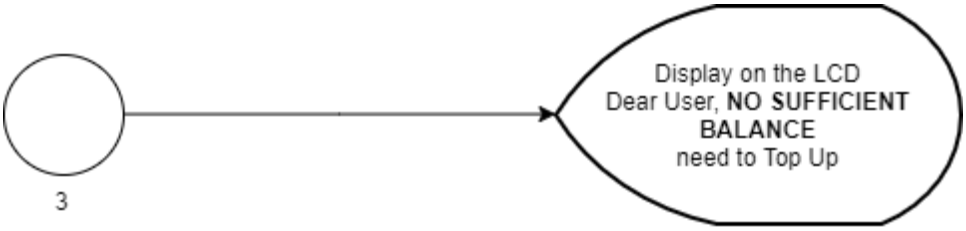

Figure 25: Flow Chart for Non-Successful Operation and Transaction

For New User to Register to the Toll Gate service, Registration can be either done by Card or by SMS.

- Registration by CARD.

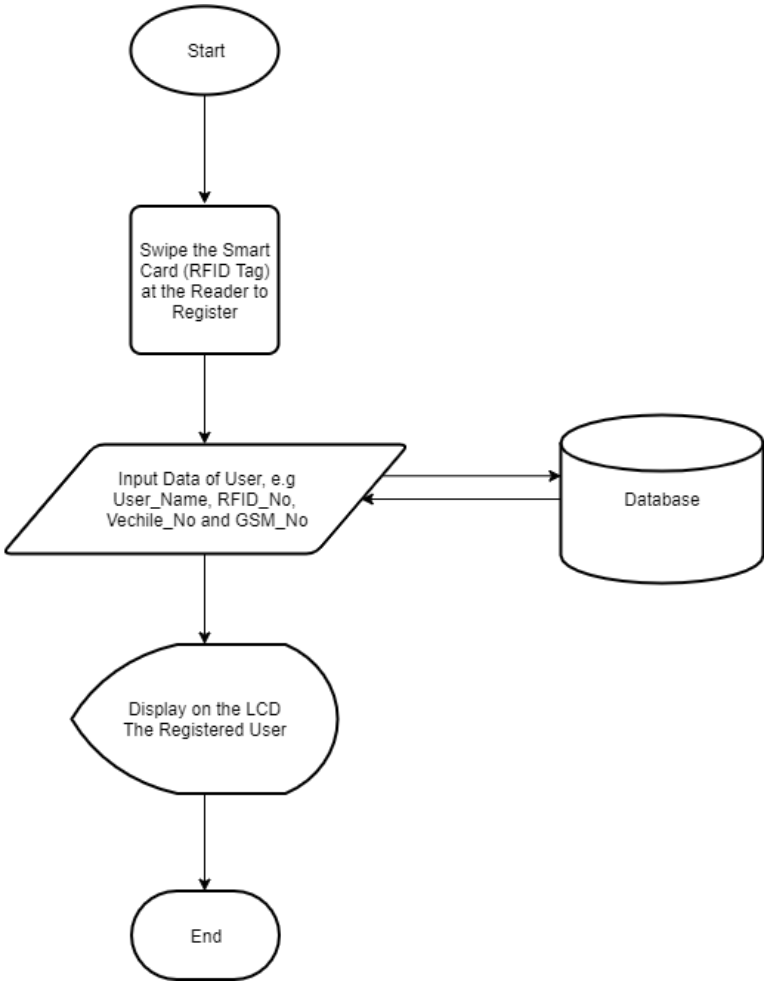

Figure 26: Flow Chart of Registration by CARD

- Registration by SMS

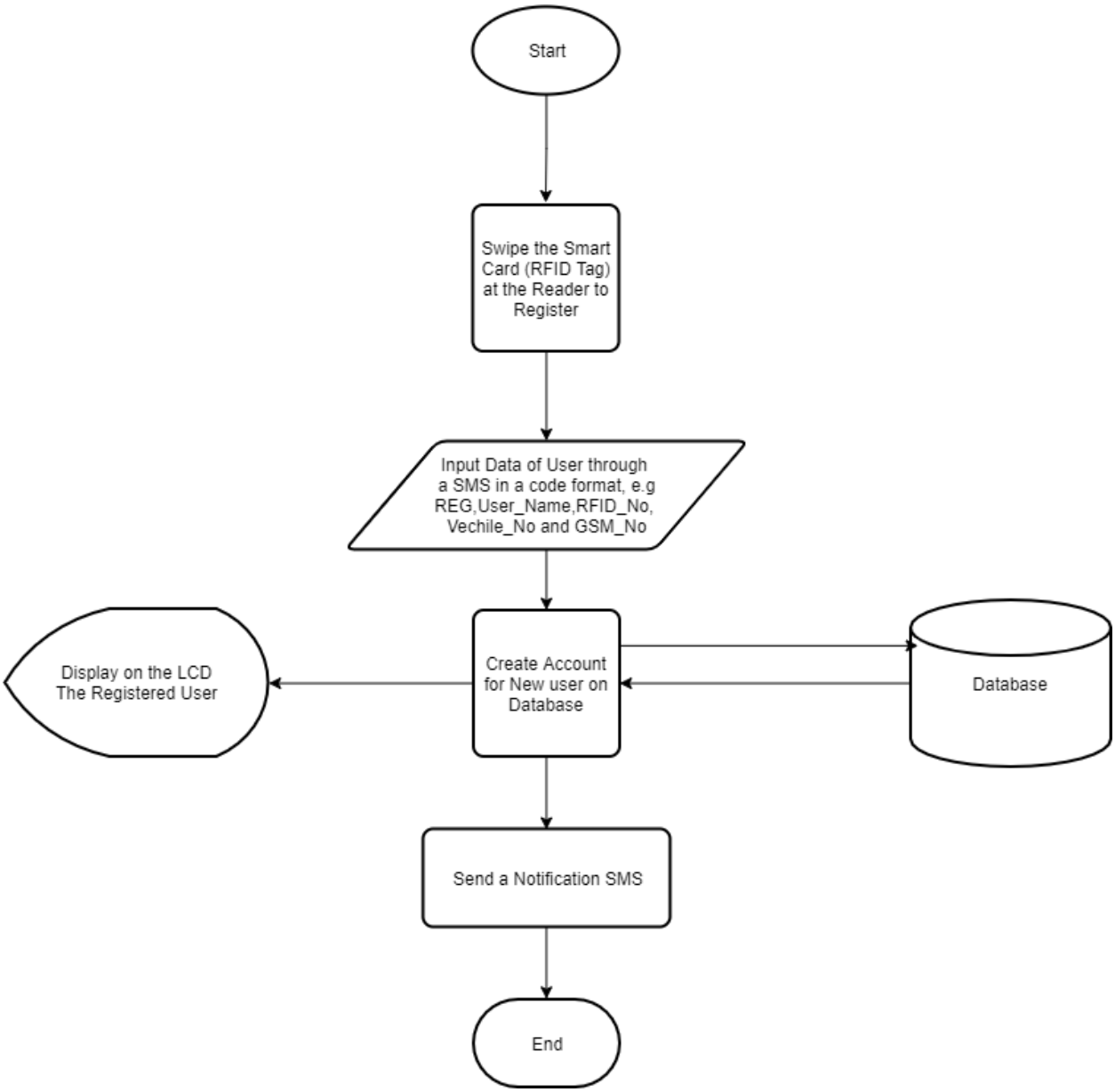

Figure 27: Flow Chart of Registration by SMS

For Users to Recharge or Top-Up account can be done by the flow chart below procedures.

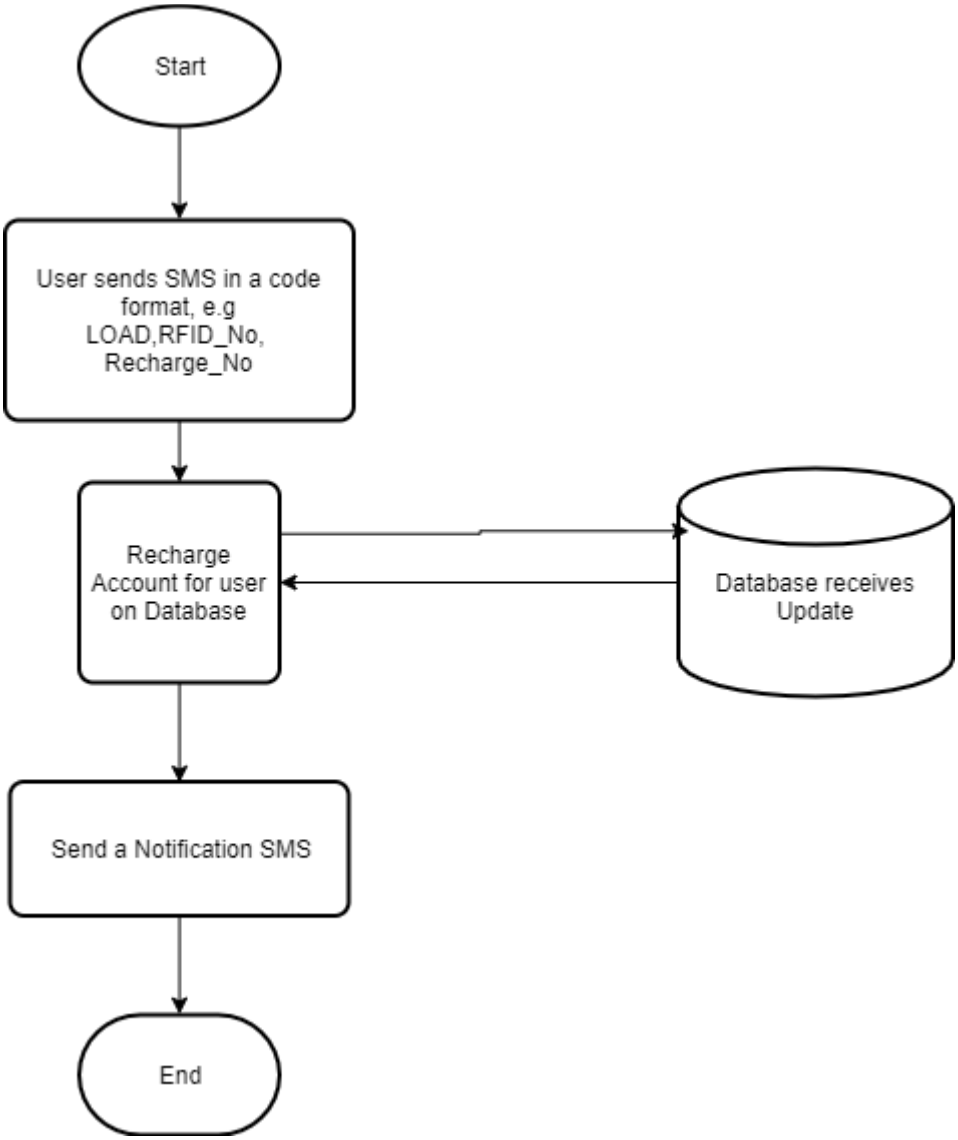

Figure 28: Flow Chart for Recharging Existing User Account

3.8 CIRCUIT DESIGN

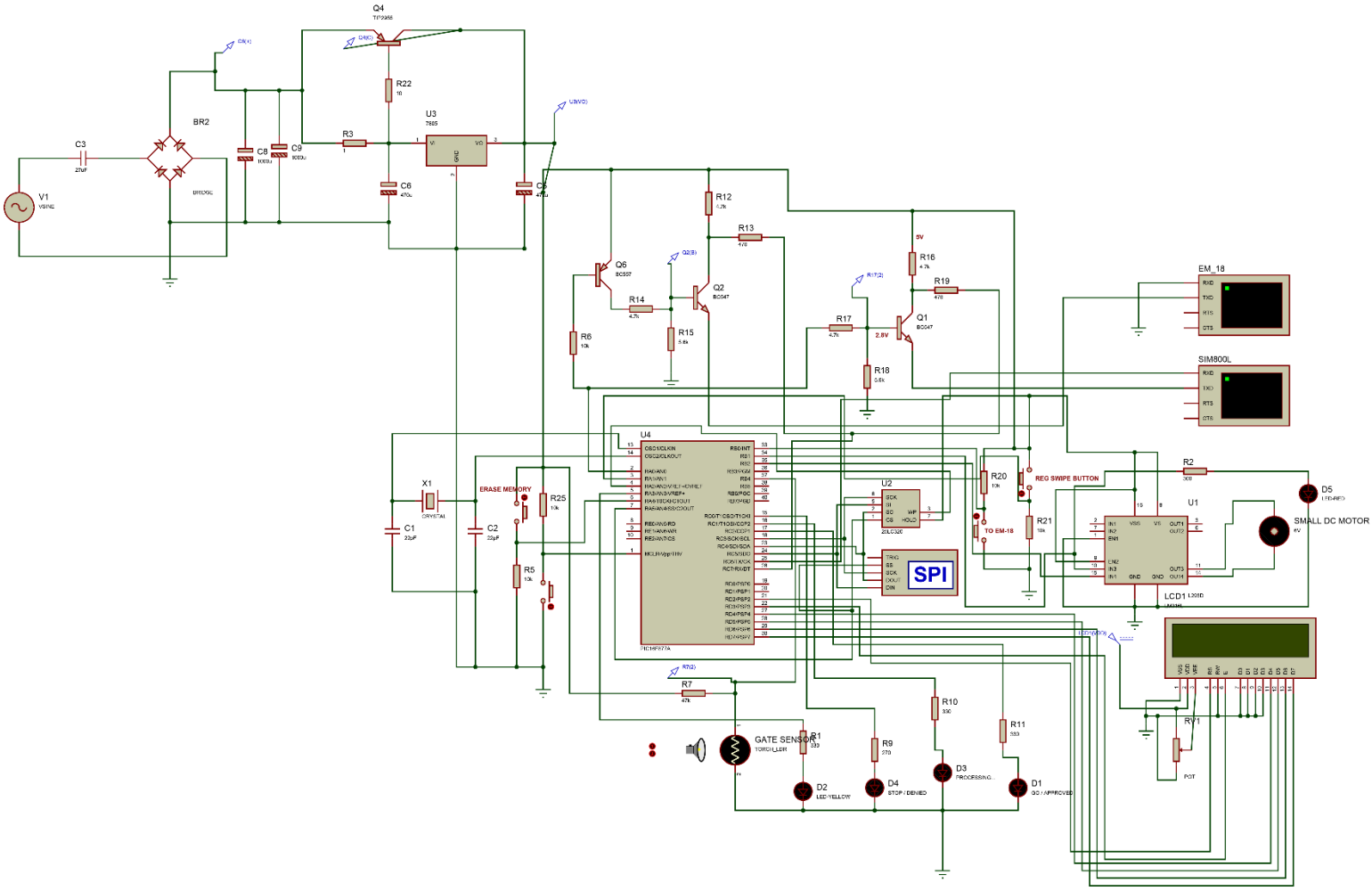

Figure 29: SCHEMATIC DIAGRAM OF A TOLL GATE SYSTEM

CHAPTER FOUR

RESULTS ACHIEVED

4.1 PROBLEM FORMATION

This project looks at the various ways which Toll collection system can be improved. With recent progress in science and technology

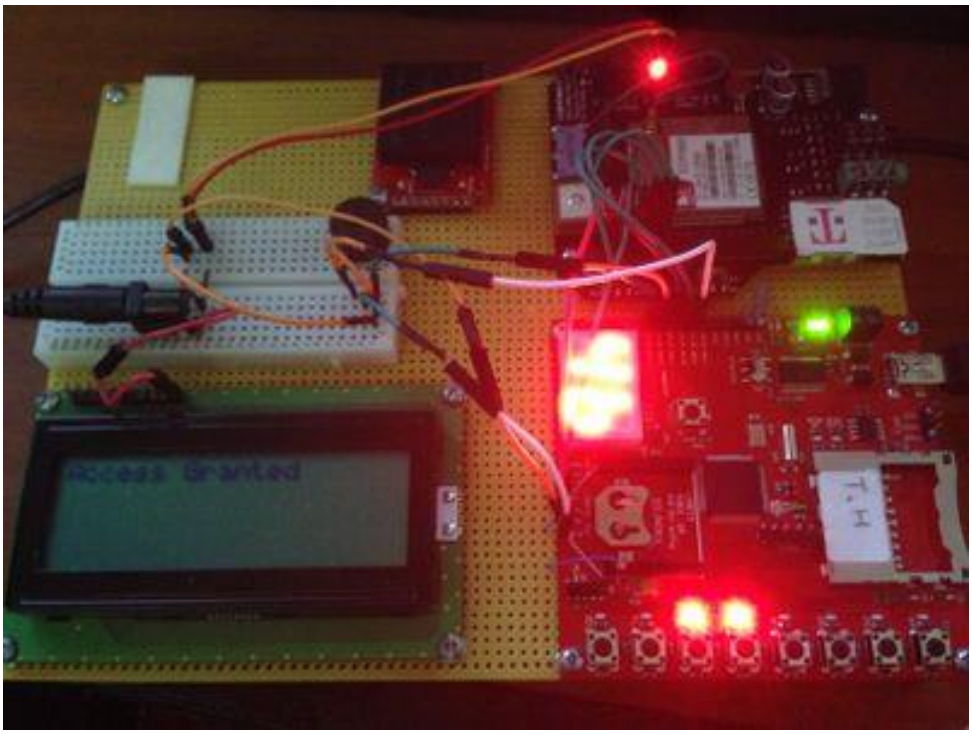

Figure 30: The Complete System

Figure 31: System Display at UART Initialization stage

4.2 DEVELOPMENT STAGES

- **Project design and simulation:** The project is designed and simulated using software such as Proteus, MPLab and Arduino. The design phase created a structured and working plan implemented in construction. Here, exact requirements of every component were determined for optimal functioning of the system.

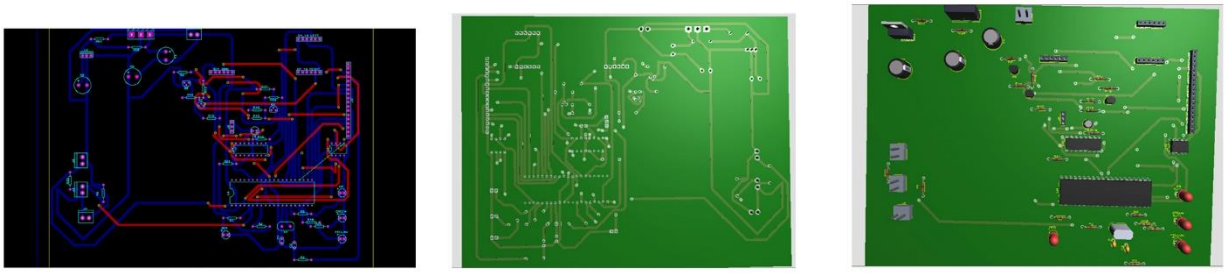

Figure 32: PCB Design Process

- **Purchase of components:** After the design and simulation phase, required components were purchased according to specification
- **Construction of modules:** Project modules were constructed and put together in units in order to be coupled into a single system.
- **Project assembling:** The individual modules constructed during the module construction stage were assembled and coupled together.
- **Testing and synthesis verification:** In this stage, the assembled project was tested and the operation was verified. If the project did not perform as required, it was checked for errors and revised accordingly.
- **Aesthetic modifications:** In this stage, after the project was functioning as required, it was modified to make it more aesthetically pleasing without altering its functioning.

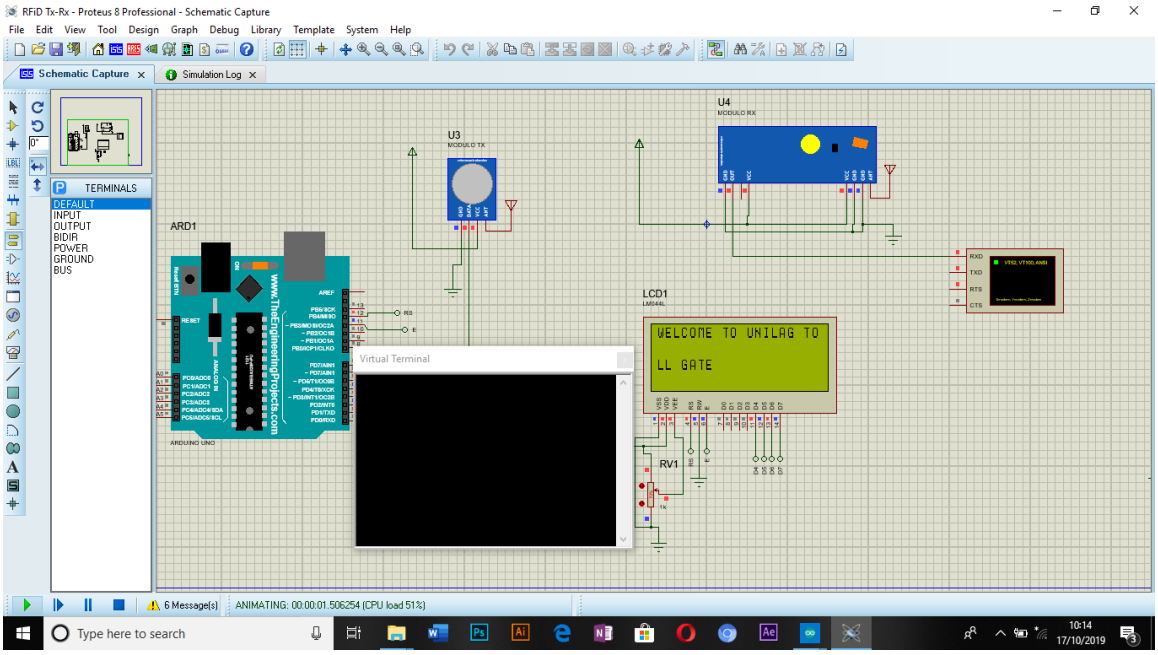

Figure 33: Initial Stage of Project simulation of RFID Stage 1

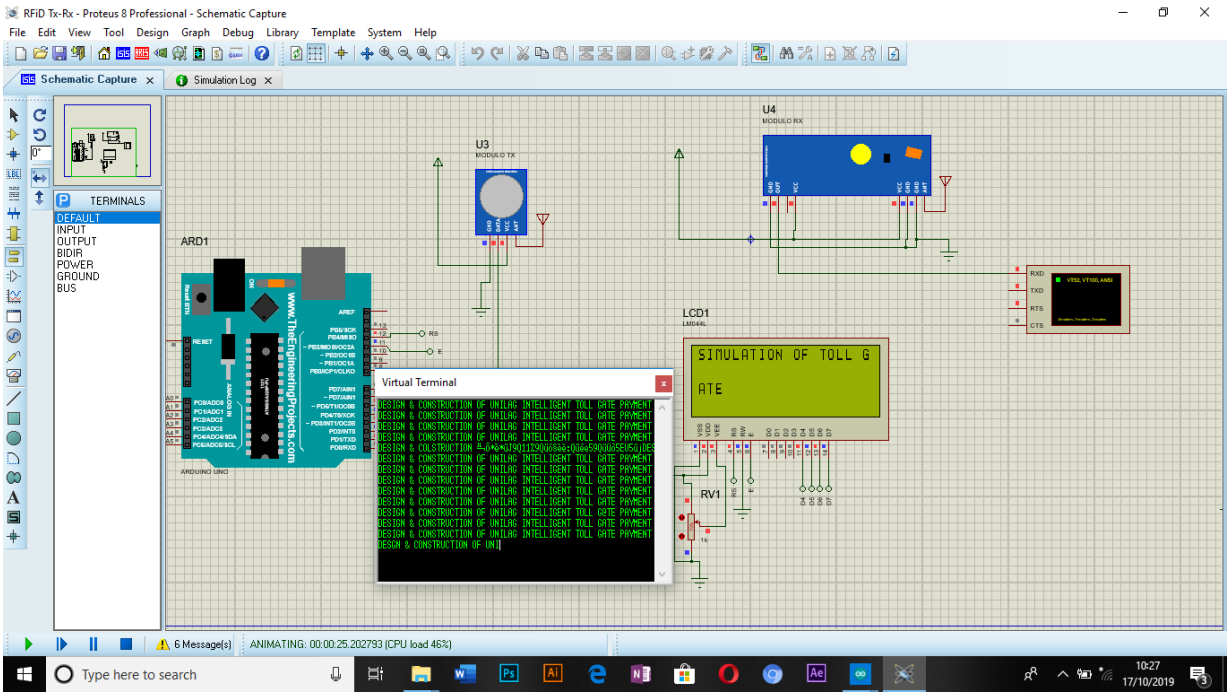

Figure 34: Initial Stage of Project simulation of RFID Stage 2

4.3 CIRCUIT OPERATION

From the previous simulation it's clear that, the circuit RFID Module send data through its tag and reads the data via the RFID Reader to validate transaction and authorize the execution of passage for vehicles at the Toll plaza. In order to make the project construction portable, A power pack adaptor was used to supply the rated voltage and current to each block of the circuitry according to the design specifications through the use of a voltage regulator to step down the voltage to certain values such as 5v, 3.3v, etc.

At initialization after when the entire system is been powered on, the microcontroller enables registration of drivers details by sending a code *(via SMS)* and after successful delivery of the SMS on the GSM800L module the Phone number along with the driver RFID unique number gets stored through the microcontroller chip (pic16F877A) into an external memory *(for the advantage of having more storage space for big data's to be stored in it).*

So, Whenever the driver approaches the Toll plaza with the Vehicle, The RFID tag installed on the windshield of the vehicle is thereby detected by the interrogator (RFID Reader) at the toll plaza and the data captured from the RFID tag on the driver vehicle is run through the database at the Toll Plaza electronics Payment System.

If the vehicle is registered on the system memory already then, the Tag details will be verified further for sufficient balance on the Tag and if otherwise *(i.e. In the case of insufficient balance on Tag account)* the Registered Drivers Phone number will be automatically accessed for debiting the actual cost for the toll payment in form of Airtime or Data via the SIM command codes by the PIC with the aid of the UART communication protocols.

After the verification and payment has been completed, a signal is sent via the microcontroller output pin35 (RB2) to the motor driver integrated circuit (dual H-bridge L293D) to easily drive the DC motor of the Toll-gate for both opening and closing direction.

With further embedding of an IR sensor (Transmitter/Receiver), the closing of the gate timing decision can be more accurately determined by the IR Sensor signals and not any-longer by TBP "*Time Base Parameter*" alone for knowing whether or not the driver has driven past the Toll Plaza for better effectiveness and operation of the Intelligent Toll Payment system.

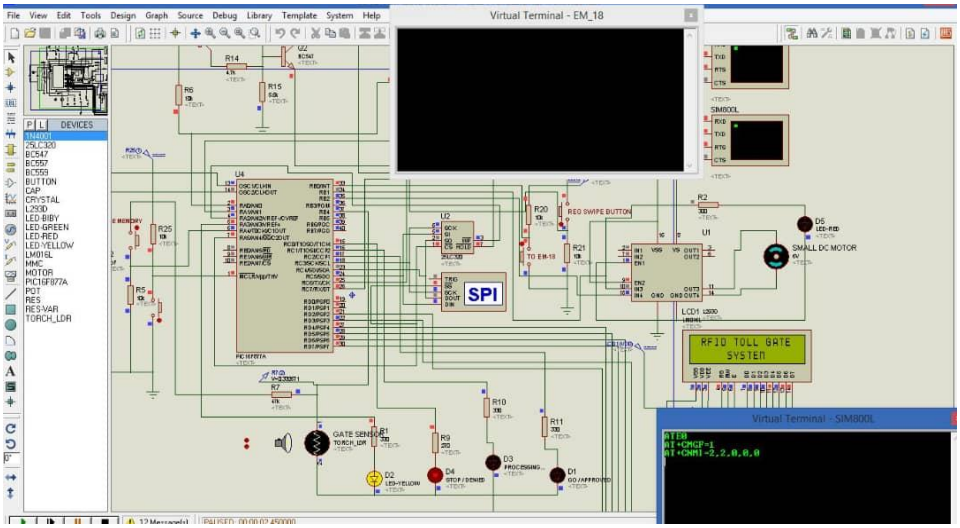

Figure 35: Final stage for Project simulation Stage1

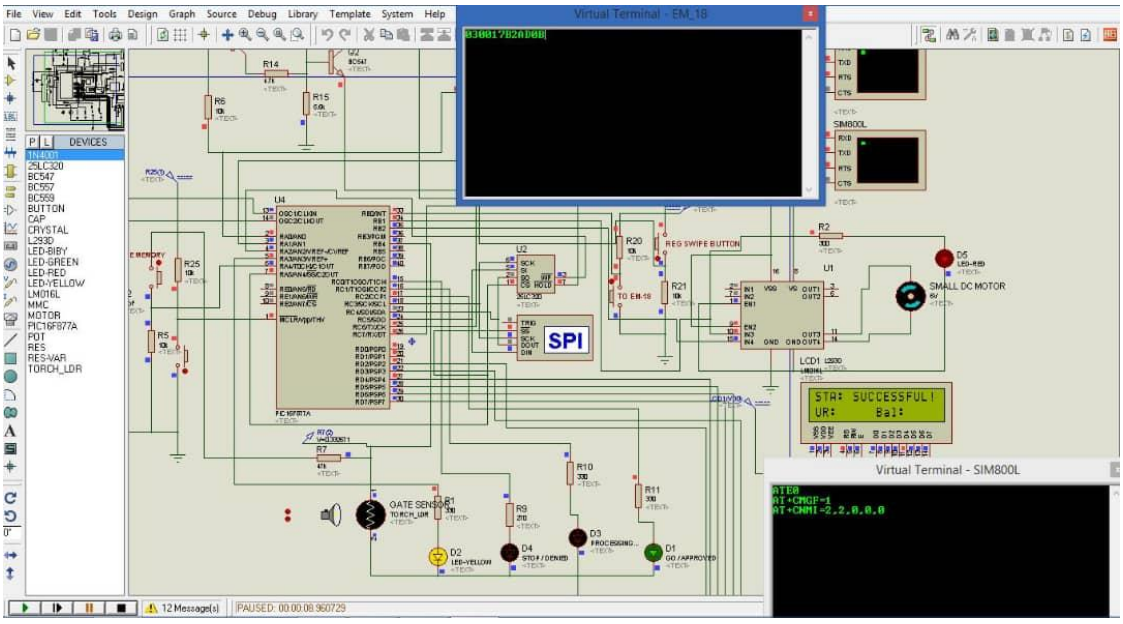

Figure 36: Final stage for Project simulation Stage2

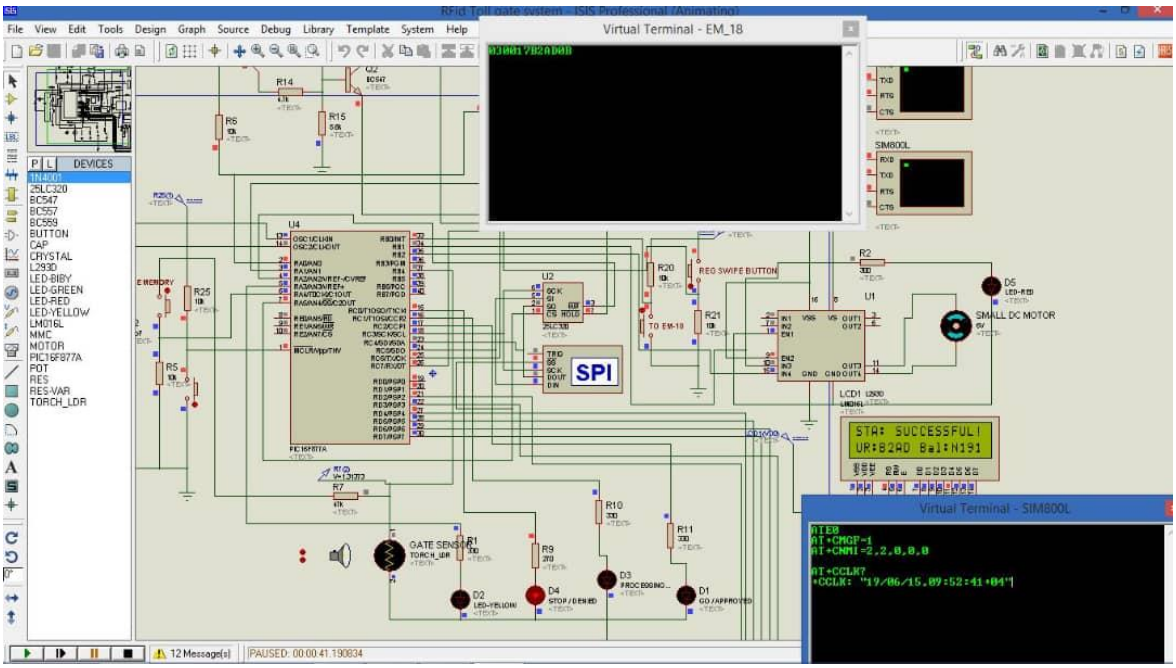

Figure 37: Final stage for Project simulation Stage3

4.4 COST ANALYSIS

COMPONENT	QUANTITY	UNIT COST (NGN)	AMOUNT (NGN)
MICROCONTROLLER	1	2000	2000
RFID MODULE AND TAGS	1	7000	7000
RESISTORS	PACK	30	500
CAPACITORS	PACK	50	500
GSM MODULE	1	5000	5000
DC MOTOR DRIVER L293D	1	500	500
DC MOTOR	1	500	500
VOLTAGE REGULATOR LM7805	1	500	500
POWER SUPPLY	1	1000	1000
LCD	1	2000	2000

CRYSTAL	1	200	200
TRANSISTORS	3	50	150
40 PIECES OF MALE TO FEMALE CONNECTORS	2	500	1000
40 PIECES OF FEMALE TO MALE CONNECTORS	2	500	1000
IR TRANMITTER AND RECEIVER	2	200	400
BREADBOARD	2	800	1600
SMALL DOTTED VEROBOARD	4	80	320
MISCELLANEOUS			30000
TOTAL			**54,170**

Table 3 : COST ANALYSIS

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 SUMMARY OF FINDINGS

By the implementation of the project proposed not only would it ease the user's accessibility of Toll movement but more also minimize the time wastage at Toll Plaza.

This project looks at the various ways at which Toll collection system can be improved.

Firstly, In the absence of a single national toll agency, each participating driver would need to have multiple cards attached to the vehicle, each corresponding to a separate toll authority account of different toll agency for the different regions.

The design helps out in making toll payment more flexible for registration and transaction processes, it also achieves the aim of decentralizing database of user from just one main end to also third part agency of individual users such as the mobile network service providers *(i.e. mtn, globalcomm, airtel, 9mobile)* which greatly saves the users *(vehicle owners)* the stress of reloading or making payment for toll services at the toll payment agency centers in which most of the time are time wasting and stress taking.

Finally, when the system is fully tested and deployed every first-time user can be given a free pass for their first use of toll station and at often time promo code can be encouraged since the system is a digital and intelligent design because this will also help to encourage and engage users with the system.

5.2 CONCLUDING REMARKS

The significance of this paper lies in its various advantages of implementing a GSM Mobile Airtime or Data payment method in making the toll payment services more efficient and faster than any exiting Electronic Toll Collection (ETC) system which are;

- The system flexibility and convenience for users (Vehicle owner/Driver).
- Around 85-90% of the benefits comes from travel time-savings for commuters.
- Since most of operational portion of the project is software based hence the hardware cost is saved and system failure is minimal.
- The wide range of applications where this project can be used efficiently

As seen in Chapter 4 above, all stated objectives have been met through recommended methodology.

5.3 SUGGESTIONS FOR FUTURE WORKS

This project looks at the various ways which Toll collection system can be improved but can be further enchanted by the following suggestions:

- Interoperability of various ETC Systems across the country in order to make the model more intelligent and reliable.
- A machine learning algorithm can be further modeled into the system to understand the user through the data inputs provided for future references and applications.
- Integration of this new technology with all GSM mobile number service provider *(such as 9mobile, globacomm, airtel, mtn)* for a large-scale design implementation and deployment.
- A Big data center should be implemented for keeping track of all Toll User data.
- User should be shown real-time details of their trip and transactions processes during the trip through the implementation of mobile applications such as internet of things(ioT)
- A better facility for both prepaid and postpaid paying method can be implemented.

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APPENDIX

```
// CONFIG
#pragma config FOSC = HS        // Oscillator Selection bits (HS oscillator)
#pragma config WDTE = OFF       // Watchdog Timer Enable bit (WDT disabled)
#pragma config PWRTE = OFF      // Power-up Timer Enable bit (PWRT disabled)
#pragma config BOREN = ON       // Brown-out Reset Enable bit (BOR enabled)
#pragma config LVP = OFF        // Low-Voltage (Single-Supply) In-Circuit Serial Programming Enable bit
(RB3 is digital I/O, HV on MCLR must be used for programming)
#pragma config CPD = OFF        // Data EEPROM Memory Code Protection bit (Data EEPROM code
protection off)
#pragma config WRT = OFF        // Flash Program Memory Write Enable bits (Write protection off; all
program memory may be written to by EECON control)
#pragma config CP = OFF         // Flash Program Memory Code Protection bit (Code protection off)

#include <pic16f877a.h>
#define _XTAL_FREQ 8000000
#include "tolling.h"

unsigned char sig;
unsigned char reg;
unsigned char log;
unsigned char reg_status;
unsigned char byte_message;
unsigned char other_byte_message;
unsigned char log_message;
unsigned char pay_message;
unsigned char phone_no[15];
unsigned char meter[5];
unsigned char ROM_address_tally[2];
unsigned char UR_name[5];
unsigned char bitwise_variable;

unsigned const short tally[] = {0, 55, 110, 165};
unsigned short enable_ROM;
unsigned short write_address; //RAM index number // RAM to ROM transfer authority byte
unsigned short pg;
unsigned short ii; // loop variable for loading ROM
unsigned short reg_sms; // try initialzing plus_bit=0;
unsigned short reg_swipe;
unsigned short ident_sms;
unsigned short charge;
unsigned short he, kd, me, acquire;
signed short sf;

unsigned int pay_size;
unsigned int ql;
unsigned int exx;
unsigned int reg_count; //counter for reg array
unsigned int short_id;
unsigned int dev;
unsigned int collect;
signed int tick;
```

```
void interrupt service(void) {
   if (INTCONbits.INTF == 1) { //INT RB0 trigger response
      PORTAbits.RA0 = 0; //USART selection bit
      INTCONbits.INTF = 0;
   }

   if (PIR1bits.RCIF == 1) {
      PORTCbits.RC1 = 1; // yellow LED

      if (PORTAbits.RA0 == 0) { //Switch to Em_18 USART if True
         reg_count = 12;
         pg = store_in_RAM(9,229); //Was on (7,229);
      }

//=========================================================RCREG Interrupt
      if (PORTAbits.RA0 == 1) { //Remain at SIM_800L USART if selection bit is off
         fix();
         if (RCREG == byte_message) {
            ql++;
            if (ql == word_size) { //REG SMS route
               index++;
               ql = 0;
            }
            garbage = RCREG;
         } else ql = 0;
         if (RCREG == other_byte_message) {
            dd++;
            if (dd == other_word_size) { //Reload route
               index++;
               if(other_word_size == 5){
                  charge = 5;//Signifies that we are taking reload route instead.
               }
               if(other_word_size == 6){
                  sig = 7;//Signifies that we are taking time and date check route instead.
               }
               dd = 0;
```

```
unsigned const char REG_COMP[] = "YOU ARE NOW REGISTERED!";
unsigned const char LOAD_COMP[] = " has been credited to your toll tag account.";
unsigned const char MISMATCH[] = "RECHARGE FAILED! Please type in the correct characters or send
a REG SMS.";

COMMANDS.
SMS REGISTRATION FORMAT: REG,NAME,Tag-no,vehicle-no.
eg: REG,Tobi,45741,KEV123ZG.

SMS PAYMENT FORMAT: PAY,Tag-no.
eg: PAY,45741.

SMS ACCOUNT RECHARGE FORMAT: LOAD,Tag-no,Recharge-code.
eg: LOAD,45741,194CDB64.

// RFID_No = Tag-no
// User_Name = NAME
```