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A Model for an Enterprise Automated RFID-Based Pay and Park System

E. M. Dogo[1], A. Ahmed[2], and M. O. Adelakun[3]
Department of Computer Engineering, Federal University of Technology Minna, Nigeria
[1]eustace.dogo@futminna.edu.ng, [2]aliyu.ahmed@futminna.edu.ng, [3]monsuradelakun@gmail.com

***Abstract*—Traffic management is one of the challenging problems in urban cities as vehicle owners look for where to park and queue to pay for rented car parks usually on an hourly basis. Therefore, the choice of a suitable, reliable and flexible architecture for Radio Frequency Identification (RFID) based pay and park system readily comes to mind. It is assumed in this work that the parking lot is already known and secured by the vehicle owner in a closed car park; this paper therefore seeks to address and automate the billing system for enterprise car parks. To achieve this, a reliable and accurate enterprise star topology networked RFID based system, that computes the amount to be paid by a user which is calculated based on the time the user enters and exits the park, and the amount the park owner is charging at a particular point in time is proposed for the automated pay and park system. The system comprises of both software and hardware components integrated together. The developed prototype system is able to grant authorized users access to the park within 30ms after verification and open the barrier in 30ms whenever the emergency button is pressed for safety consideration.**

Keywords-RFID reader; RFID tag; automated pay and park system; star topology; Arduino

I. INTRODUCTION

A parking lot is a cleared area intended for parking of vehicles or cars. Parking lots are important features of every city in most countries where the car is the major mode of transportation. Places like shopping malls, sport stadium, big organizations such as corporate offices, banks, mosques, churches and other similar places are often characterized by large car parks. Two types of car parking systems are in existence: the manual parking system and the automated parking system. Comparing both manual and automated parking systems, automated car parking systems are more cost effective [1]

Inefficient traffic management system has made many developing countries suffer from traffic congestion. The main factor adding to congestion problem is poor management of car parking system. An efficient parking system whereby a particular space is allocated for parking purpose and users will be registered and made to pay a specific amount before they gain access to the parking lot is needed to combat the problem of traffic congestion [2].

The automatic parking system can be of benefit in so many ways among which are; safety and security, it saves time, money and fuel of car users, it minimizes pollution, thereby making it environmentally friendly, and it also generates more revenue due to its low operational costs and increase productivity [1].

A. RFID Fundamentals and Theory

RFID is a wireless identification technology that uses radio signals for identifying, tracking, sorting and detecting a different range of things which includes people, vehicles, goods and assets without the need for direct contact or line of sight. RFID technology can track moving objects using its radio-enabled scanning devices over a distance of several meters [3].

RFID devices could be divided into two types: active and passive. An active tag requires a power source which is connected to a powered source or usable energy stored a battery. Active tag's lifetime is limited by the battery life. Passive RFID tags, obtain power from RFID reader because they do not have an internal source of power. Passive RFID is more popularly used because the tags don't require batteries or constant repairs. The RFID system can be divided into three parts: Tag, Reader and the Antenna [3].

RFID tag stores RFID data and communicate with the reader by transforming the energy of radio frequency queries from the reader and send back the information enclosed in it. The major merit of RFID is its reader's ability to read the content of tags in motion and out of the line-of-sight. RFID tags can be read under severe condition of temperature, high pressure and so on. RFID technology helps reduce operational costs by reducing the need for human involvement in systems that collects information and in revenue collection [4].

RFID can be used in many industrial applications such as vehicle access control, security in shops, equipment and baggage tracking, fast food shop's activity monitoring, time and attendance monitoring, road toll management, logistics implementation, etc. [5], [6]. Figure 1 shows the RFID protocol layers: physical, network-transport, application and strategic layers.

The three (3) RFID standards of the International Standard Organization (ISO) are: ISO 14443, ISO 15693 and ISO 18000 for contactless systems, vicinity systems and wireless link for diverse RFID application respectively. Standardization of RFID technology remains a challenge, but EPCglobal is an organization in the forefront working on

developing a widely accepted standard for product identification called the Electronic Product Code (EPC) standard, which comprises of format of product identification data storage in an RFID tag, the middleware and database storage information about the tags and the network Object Naming Service (ONS) which is similar to Domain Name Service (DNS), is used to link EPC to detailed object information so that a product number or EPC numbers can be looked up on the internet [6].

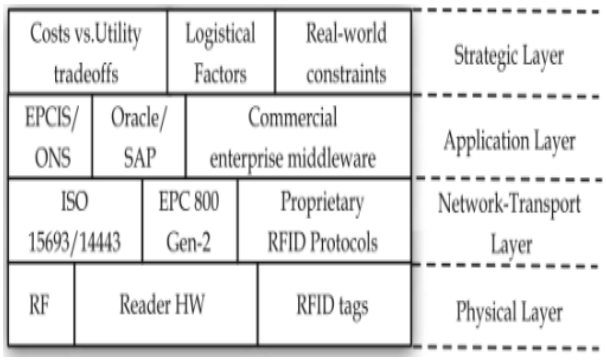

Figure 1. RFID Protocol Layers

In this work, is proposed RFID based billing system which is simple, functional, accurate and has low maintenance cost that computes amount to be paid by a car owner based on the entry and exit time into the car park. Also incorporated in the design is an automated direct crediting system from the car owner's account through authorization or using a credit card on POS (Point of Sale) at the car park in case of insufficient funds in user parking system account and a safety button in case of an emergency exit from the car park.

II. REVIEW OF RELATED WORKS

[7] designed an RFID-based automatic vehicle parking system using AT89S52 microcontroller. The system consists of a vehicle counter, sensors, display board, gate controller, RFID reader and tags. The vehicle owner has to register the vehicle with the park to get RFID tag. Whenever the car to be parked approaches the parking entrance, the RFID tag is placed near the RFID reader installed near the entry gate of the parking lot. As soon as the reader reads the tag, the system automatically deducts the specified amount from the tag and the entry gate Boomer opens to grant the car access to the parking area. The system counter increment by one each time a vehicle enters the park and also decrement each time vehicle leaves the parking lot. The limitation of this work is that the system does not take into consideration the time the vehicle used at the park before deducting the amount to be paid by the user.

A system that informs users about space availability at a particular parking location was designed by [8]. The system helps to save time and fuel wastage used in searching for available spaces at a particular park. The slot availability details were collected using an RFID system and are updated periodically into the database. The system consists of RFID readers, labels and barrier which are installed at the entry-point and exit-point. Drivers do not have to stop at the circulation points and parking tickets were out of usage at the entry- point and exit-point because the system consists of a recharge module. The system was implemented in four stages, namely: writing into the tag, reading from the tag, data feed to the system and tracking the count.

[2] discusses some of the commonly used techniques in parking management and identified the problems present in their methodologies. The paper highlighted the steps followed by users to park their vehicles, which are: entering the park zone, searching for an available parking lot, parking of the vehicle at the empty lot, payment of the specified amount and the user leaves the parking zone.

RFID technology was used to provide a solution to the challenges encountered in a car park management system by [9], [10]. The system is comprised of: RFID readers, RFID labels, computers, barriers and software. The software was used for handling the management, controlling, transaction reporting and operation task for three (3) parking lots located in various parts of a city using a centralized database system. The entry gate and exit gate are under the control of RFID readers, labels and barriers. The limitation of this system is that the system cannot totally check those who are eligible (registered users) to the park before granting access, thereby forcing fine on any vehicle that makes an unauthorized access

[11] provided solutions to challenges encountered in a car park management system using RFID, 8051 microcontroller and IC 24C64 memory unit for storing entries from registered users'. The system is designed to park cars automatically in a multilevel parking area. The vehicle has to be registered at the car park by the owner to gets the RFID tag. When the car to be parked approaches the park entrance, the RFID tag is read by the reader, the system automatically verifies the data and information, then the car is granted access to the parking area and the system increment the parking counter by one. The system lacks an automated billing system.

[12] developed an automatic parking and fee collection management system using image processing for recognizing number plates. Limitations of the system are constantly modification of algorithms for different number plates as a result of character restriction to 3 letters and 4 numbers which were based on one-row plate number scenario. There could also be security concerns with plate number cloning.

[13] proposed a parking system based on Field-programmable Gate Array (FPGA) integrated circuit in order to overcome the problem of traffic congestion and pollution. The system comprises of two main modules: identification and slot checking modules. The identification module identifies the vehicle owner and the slot checking module checks for slot availability. The system operates in the sense that whenever a vehicle enters the parking lot, LCD displays if there is available space in the parking lot or not. If there are still spaces left in the parking lot, the stepper motor rotates and gate opens for the vehicle to enter the parking lot. A RF module was used to transmit and receive slot availability information. Once the host computer (the control unit) programs the FPGA, identification and slot checking module activate.

[14] presented a study that provides solution for the challenges encountered in parking lot management. The

management, controlling and operational tasks of the parking lots were handled by the software. The check--ins and checkouts of the parking-lots were proposed to be under the control of RFID readers, labels and barriers. The system is capable of displaying an occupied space and also free spaces at the park, while [15] developed RFID based system to handle the management of parking lots by integrating hardware and software components, but the network architecture and topology of the system was not addressed.

[16] developed an automated parking lot management system that monitors the activities in the parking lot by managing the parking space through space detection and allocation as well as controlling the entry and exit into the parking facility.

Based on the review carried out on related works with regards to parking system, there is a need to improve on the limitation and recommendation of some past works in order to raise the standard of parking-lots and to enable users appreciate the service rendered by park owners. This model design hopes to solve the problem of delay that users encountered while trying to enter or exits the park by automating the payment and parking system in such a way that access to the park can be granted within a very short period of time and charges by users after their stay at the park can be calculated within the shortest possible time, also proposed is a suitable enterprise network architecture and topology.

III. SYSTEM DESIGN

This section shows the methodology involved in the design of an automated RFID based park and pay system. The design and development of the system are described based on the system overview, hardware design consideration and software design consideration.

A. System Overview

The automated RFID based park and pay system consists of different units which includes identification unit, control database and the barrier controlling unit. A new user will have to be registered with details saved into the database and given a new RFID tag by the personnel at the park. Whenever a registered user comes to the park, the user will have to drive his or her cars close to the park entrance where the RFID reader is installed. The RFID reader, then reads the RFID tag attached to the car. The RFID reader will give a beep sound whenever an RFID tag is at the same frequency with the RFID reader (i.e. the RFID tag is within the range at which communication can be established between the RFID reader and the RFID tag) thereby causing the gate at the park entrance to open for the user to gain access to the park. As the car enters the park, the host computer records the time the user enters the park. Whenever the user is trying to exit the park, the RFID reader also reads RFID tags for the gate to open. The system then records the time the user exits the park and save it to the database. The system was able to deny an unregistered RFID tag access to the park and also a registered card cannot be used to register another user unless the details of the first user has been deleted from the database. Figure 2 shows the block diagram of the system.

B. Hardware Design Consideration

The hardware system consists of the host computer, RFID reader, RFID tag, servomotor, Arduino board and a Push button. The host computer powers the RFID reader and the Arduino board to which both the servomotor and the push button were connected. The servomotor which controls the barrier to the park entrance was interfaced to the Arduino board. The push button (Emergency button) was incorporated into the system which can be used to open the barrier in case the need arise for an emergency exit at the park.

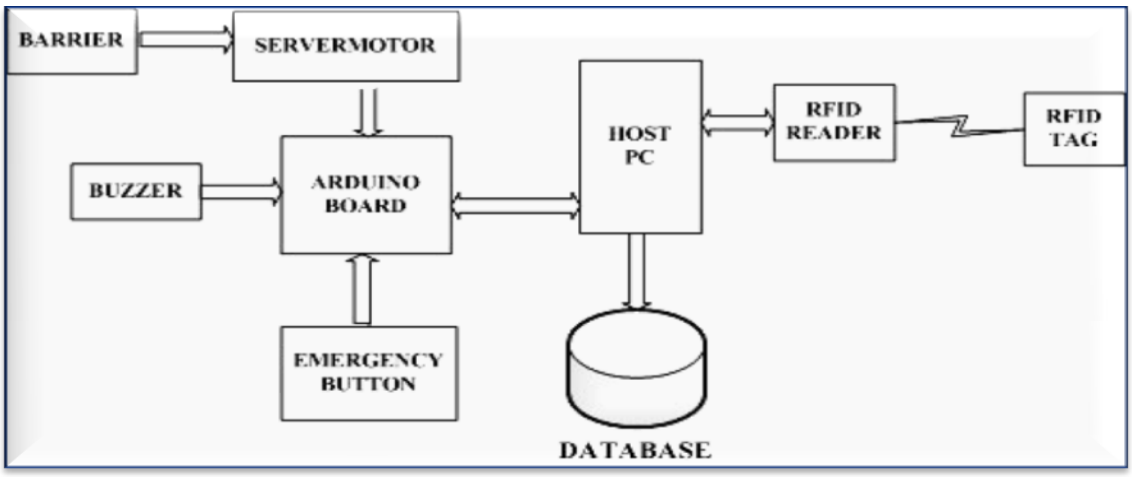

Figure 2. Block Diagram of System

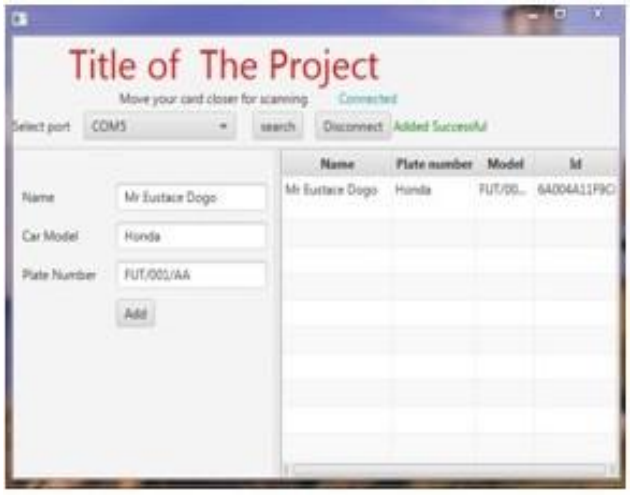

Figure 3. Interface for Users' Registration

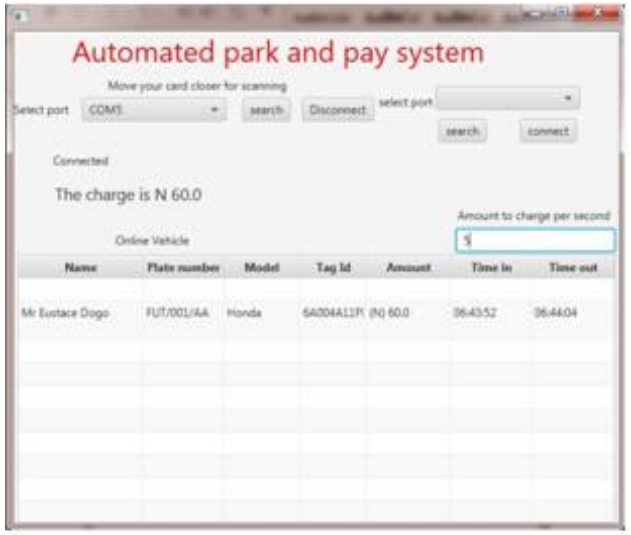

Figure 4. Interface for Users' Billing

C. *Software Design Considerations*

Two different graphical user interfaces (GUI) were designed with the help of the Java programming language. The first GUI is mainly for registration of new users and the other GUI is for billing and keeping users visit and log records at the park. The Arduino board which controls the operation of the servomotor and the emergency button was programmed using C language. Figures 3 and 5 respectively show the interface for registration of new users and the interface for billing users after their stay at the park.

D. *RFID Enterprise Network Topology*

The RFID network topology has detailed and important information about the devices of the controlled RFID network. This information is retrieved from the Edge Controller and used to build its software stack depending on how it is configured and defined

The RFID network topology introduces the concepts of location ID which defines the group of devices which are in the same area or location, reader ID which defines the RFID readers in a particular location, and Edge Controller ID which defines the Edge Controller controlling these locations. This makes a base platform for Enterprise RFID deployment.

The Edge node which is responsible for the Edge domain holds the uppermost degree of scalability for an enterprise deployment. In this domain, unlimited number of controllers could be added to the topology, but in this case about 30 controllers are configured. This then communicates with a single server at any time. The proposed enterprise topology will have the following allocation: one root location, one location per reader, about three RFID readers of the same type per Edge Controller and about 30 Edge Controller per Server.

The layout is configured with the following considerations: There must be a fixed IP address for each reader, edge controller and the server with its fully qualified DNS name. The figure 5 depicts the RFID Enterprise Network topology deployment.

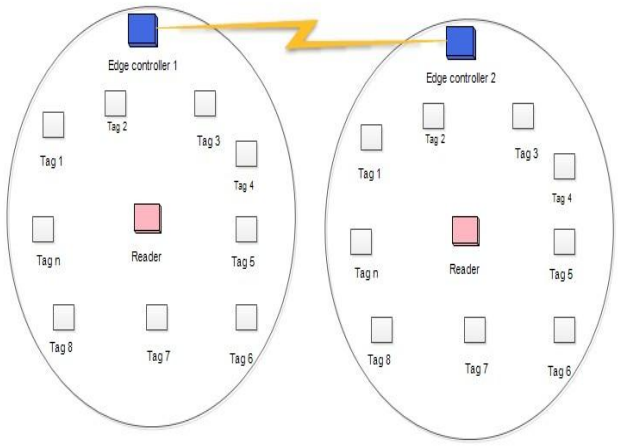

Figure 5. Proposed RFID Enterprise Network Topology

A network architecture for direct billing of user account is proposed as shown in figure 6, which has a direct connection via a fibre link and VSAT link (as redundancy) to the banks via the financial settlement house for seamless transactions. A star network topology is also proposed between the various parks spread across the cities and interstate to the pay and park headquarter where the database is located, there could also be a Disaster Recovery Site (DRS) as backup to the headquarter to improve the overall reliability and to minimize downtime of the system. The dynamic routing protocol is proposed for interconnecting the network devices figure 7 shows the conceptualized network architecture.

E. *System Working Principle*

The system was designed in such a way that it will be easy for the personnel at the park to manage the system due to the non-complex components used. A new user will have to be registered in the database and an RFID tag will be issued to the user for subsequent visit to the park. Details such as: user's name, car model, plate number and RFID tag serial number will be saved during registration. A registered user that has been given an RFID tag will have to

drive close to the RFID reader at a distance of one (1) meter to the park entrance.

The RFID reader senses the presence of the RFID tag, read the unique code on the RFID tag, and then communicates with the host computer to check the database to authenticate the identity of the user. If the authentication of the user's RFID tag is found to be true, the RFID reader gives a buzz sound, and then the host computer communicates with the Arduino board housing the microcontroller to activate the servo motor so that the barrier is opened for the user to gain access to the park and after30 millisecond, the servomotor rotates to its initial state which signifies the closing of the barrier. The host computer takes note of the time the user enters the park and saves it to the database. At the exit side of the park, the user will have to drive close to the RFID reader at a distance of one (1) meter for the host computer to record the time the user leaves the park, which is used for calculating the amount to be paid by a particular user and also for the host computer to communicate with the Arduino board for the barrier to be opened so that the user can exit the park. The amount to be paid by a particular user will be the difference between the time a user enters the park (Time-in) and the time he exits the park (Time-out) multiplied by the appropriate amount to be charged at any point in time. In this work N5 (Five Naira) is configured to be charged per second. The amount to be paid by the user is displayed on the GUI for personnel to know the amount paid by the user. An emergency button was incorporated into the system which can be used to open the barrier in case the need arise for an emergency exit from the park. Figure 8 shows the flow chart of the system.

IV. RESULTS AND DISCUSSION

The prototype system was tested by registering two users with each user given different RFID tag and other user was given an RFID tag that was not registered in the database. The system was able to grant authorized access to both registered users to the park, saved their subscription record to the database and display their bills on exiting the park. The barrier did not open for the other user of the unregistered RFID tag which shows the accuracy and reliability of the designed system. Figure 9 shows the setup of the functional prototype on display.

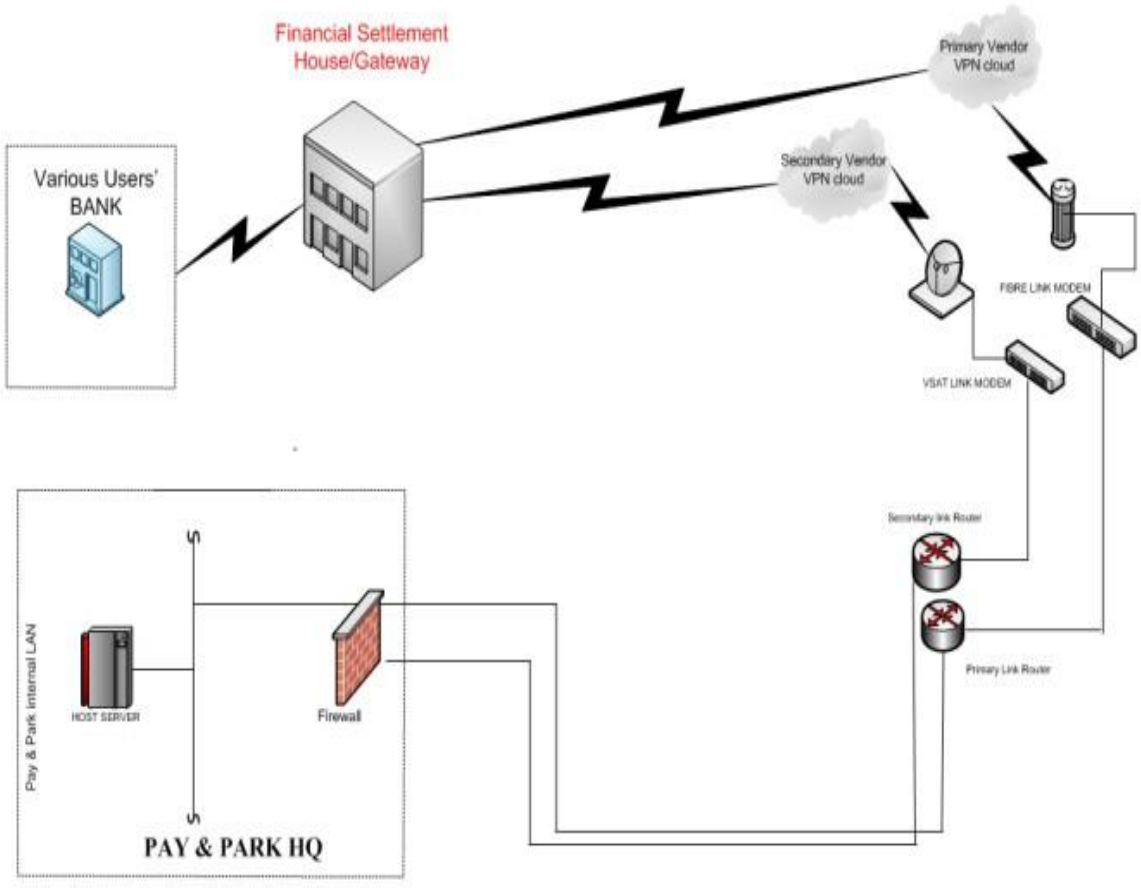

Figure 6. Conceptual Network Architecture of Proposed System

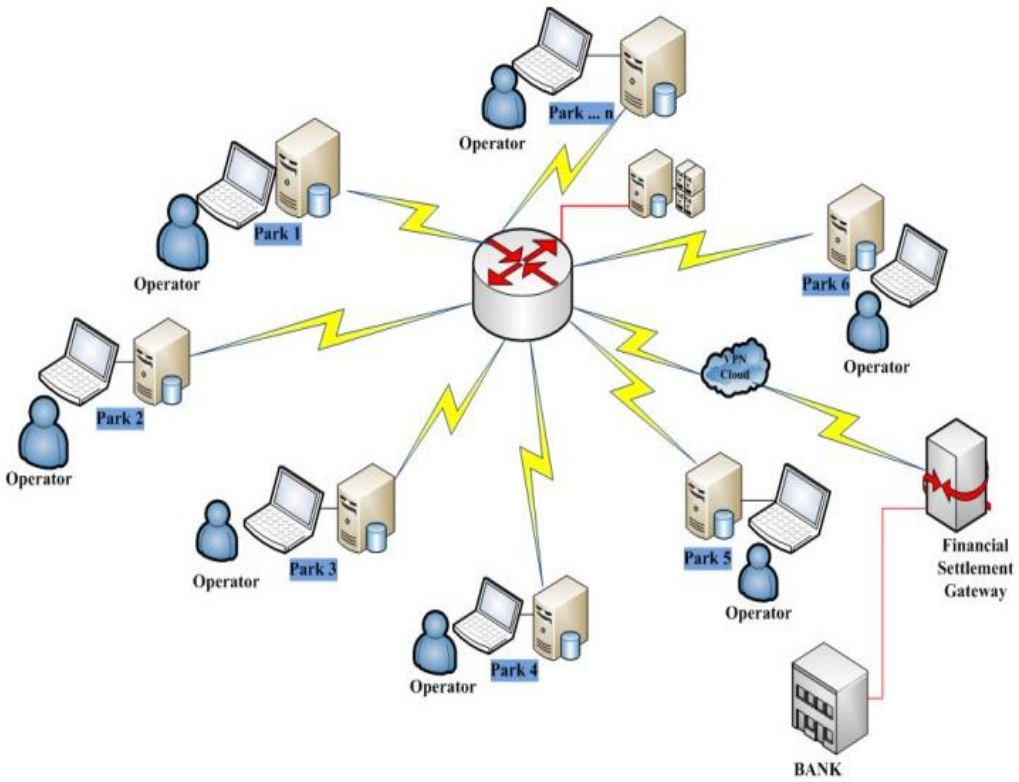

Figure 7. Conceptual Network Design Architecture

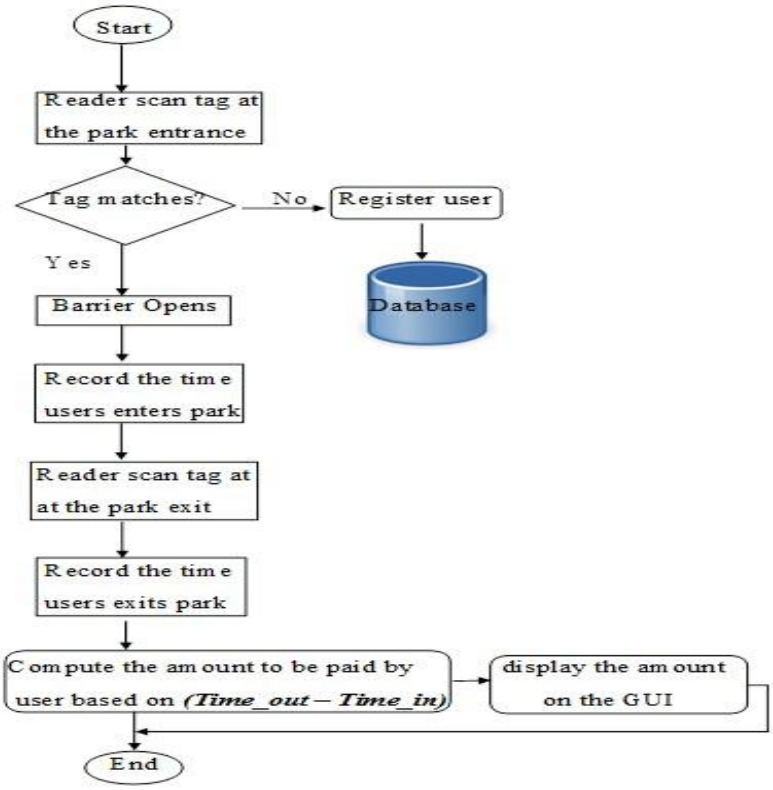

Figure 8. Flow Chart Diagram of the System

Figure 9. Display of Developed Prototype System

A. *System Performance Evaluation*

1) Response Time: This is the time it takes the barrier to open and close each time a registered user drive close to the park entrance (that is, when the RFID tag attached to the car establish communication with the RFID reader installed at the park entrance) and also the time it takes the barrier to open and close each time the emergency button is pressed. It takes thirty milliseconds (30ms) for the barrier to open whenever a registered user is trying to gain access to the park and whenever the emergency button is pressed. Furthermore, it takes 30 seconds for the barrier to close after entry or exit operation.

2) Table of result: The time taken for the barrier to open whenever the emergency button is pressed and also the time taken for the barrier to open whenever an authorized user tries to gain entrance to the park or whenever an authorized user is trying to exit the park is summarized on table 1.

TABLE I. RESULT FROM TESTING THE PROTOTYPE SYSTEM

S/N	Action Performed	Barrier Response Time (s)
1.	Park Entry	0.03
2.	Park Exit	0.03
3.	Barrier closure	30
4.	Emergency button Activation	0.03

V. CONCLUSION AND FUTURE WORK

This work presents the design of an automated RFID based park and pay system. The system is feasible, user friendly, accurate, universal in application, cost effective because maintenance to be carried out after the deployment is minimal and quick expected Return on Investment (ROI). Deployment and testing in real situation will be the focus of future study.

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