# RFID BASED AUTOMATIC TOLLGATE SYSTEM (RATS)

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## ABSTRACT

Radio Frequency Identification (RFID) is an auto identification technology which uses Radio Frequencies (between 30 kHz and 2.5GHz) to identify objects remotely. The paper describes a system which does the job of detecting, billing and accounting for vehicles as they pass through a tollgate using RFID as the identification technology. In the design, a frequency of 928MHz is used as it is in the Industrial Scientific and Medical (ISM) band. The system is a great investment in the transport industry. It reduces the common hustles in accounting for the movement of goods from point to point. The design can be further developed to aid the satellite surveillance systems once all toll gates are networked. An RFID tag is programmed with information in the form of an Electronic Product Code (EPC), which can be read over a considerable distance so that its contents identify the vehicle and enhance a transaction to be undertaken with respect to the specific tag identity taking advantage of radio frequencies' ability to travel longer ranges with better data capacities and high speed attained with maximum accuracy. The design has been implemented as a miniaturized prototype.

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## 1 INTRODUCTION

Radio frequency identification (RFID) technology is a non-contact method of item identification based on the use of radio waves to communicate data about an item between a tag and a reader. It uses the unlicensed spectrum space of the electromagnetic radio wave frequency and this band is the Industrial Scientific Medical (ISM) range [1]. It was introduced back in the 1960s but has taken long to become a mainstream technology [2]. This is attributed to the fact that RFID is not as cheap as the traditional labelling technologies like the barcode, though it offers added value in read rates and data storage per label. Stanford, [3] propounds that considering an Electronic Product Code (EPC) tag is underestimating its capabilities. An EPC tag can contain data amounting up to 96 bytes, for example, the GID-96 hexadecimal coded EPC [3]. The technology originated from the military to identify aircraft as friend or foe and is now used in race timing, manufacturing processes, animal tracking and in the supply chain [5]. The technology can also be used in toll collection at toll gates and this enables the tracking of vehicles as well as the goods they carry, in real time. Location tests done prove that RFID is the best technology for tracking items in motion [5]. The technology enables remote storage and retrieval of data [7] and this is why developments towards wireless identification point towards low-bandwidth systems like RFID [8].

The RFID data is stored on tags which respond to the reader by transforming the energy of radio frequency queries from the reader (or transceiver), and sending back the information they enclose. A computer hosting a specific RFID application pilots the reader and processes the data it sends. The ability of RFID to read objects in motion and out of the line-of-sight is its major advantage. The tags can be read under harsh conditions of temperature, chemicals and high pressure [7].

RFID has the potential to change an organization's ability to get real time information on the location of asserts and even personnel. The use of RFID technology reduces operational costs by reducing the need for human operators in systems that collect information and in revenue collection. In manufacturing, a tagged product or part can be traced and this gives better visibility and the bottlenecks in automated manufacturing processes can be easily identified [5].

The product presented in this paper is an investment in logistics. As goods are transported, the senders and the receivers are interested in knowing the location of the transporter in order to plan accordingly. This information can be accessible to the stakeholders in real time if a network of RFID enabled tollgates is put in place. This is achieved by building a network of RFID systems referred to as an EPC network. A complete EPC network consists of the RFID hardware connected to a backbone network of application servers and web servers [9]. The information acquired from RFID hardware can be transferred to the interested parties without delay through the EPC network. The product discussed in this paper reduces delays that may happen if hard cash is used at tollgates. A prepaid system ensures that a paid up vehicle does not have to stop at a tollgate. The sensor is positioned at a position where it can read the information about a vehicle before it reaches the physical barrier and if it is paid up, the barrier opens and the vehicle will pass. Such a product eliminates the need to pay cash at the tollgate and this is very safe and convenient. The product described in the paper uses a mechanical boom gate which receives instructions from a microcontroller. The instruction from the microcontroller is dependent on the status of the vehicle's account as reported from the RFID system. The paper is arranged as follows: section two discusses the current applications of the technology in different fields. Section three discusses our methodology including the state of tollgates in Zimbabwe. Section four discusses the requirements for developing the product at a large scale to enable its deployment on roads, costs of developing such a system and lastly the results of the design and development. The paper ends with a conclusion.

## 2 RADIO FREQUENCY IDENTIFICATION TECHNOLOGY IN THE SUPPLY CHAIN, MANUFACTURING PROCESSES AND IN TOLL COLLECTION

RFID technology allows wireless storage and automatic retrieval of data and it improves security, cuts down on theft and counterfeiting in the supply chain. In the supply chain RFID also helps to reduce out of stock situations which may affect business [10]. It also increases visibility of products in the manufacturing processes, enables tracking of vehicles on roads as well as automating toll collection. A complete RFID system consists of tags, readers, computer networks and systems including middleware and databases. There is an ecosystem of companies that develop platforms to support RFID development and applications. Firms like Wal-Mat, Target and Gillette have been active in developing and adopting RFID [11]. On the roads, it is used to detect the presence of vehicles and retrieve information on the vehicle tag as it passes through the tollgate. This tag reading works as if it were some bar codes being scanned in a shop and the billing automatically done according to the codes received. However bar codes do not have memory block for storing data as in RFID tag and they do not use radio frequency hence have a short reading range [12].

In every RFID system the transponder Tags contain information. This information can be as little as a single binary bit although they normally start at 16 bits, or be a large array of bits representing such things as an identity code, personal medical information, or literally any type of information that can be stored in digital binary format.

## 3 METHODOLOGY

The system was developed in a modular-based method. It contains an identification module, which has the RFID hardware to read tags as vehicles pass through the tollgate. This module sends information to the software module through RS232 serial connection. The software module uses the information from the identification module to determine the actual physical identity of the vehicle using its EPC code and the information is used to tell the boom gate whether to open or not. The boom gate system makes up the mechanical module.

### 3.1 The Identification module

There are seven data lines from the RFID read/write module. The important ones for reading and writing are the lines for transmitting and receiving data in a two way communication between the RFID reader and the computer system. A USB-to-RS232 converter is used to enable connect the RFID module to the Personal Computer (PC) if it does not have an RS232 port. The RFID module is powered from an independent power source, in this case, a 12 V and 3A supply. A tag is passed in the region of the magnetic field produced by the RFID module and a beep sound is produced signalling its detection [7]. The RFID module needs to be configured with certain communication parameters. This can be done using the given specific instructions and can be achieved by using the Demo Application or an independent developed application. The RFID module is connected to the PC via the RS232 port. Figure 1 shows the two ends of the connections.

**Figure 1: Two ends of the RS232 connections.**

### *3.1.1 Components of an RFID Read/Writer system*

To have a complete RFID system, an interrogator, a transponder, an antenna and some tags were used. These form the RFID hardware which is used in an information processing system (IPS) to acquire the total benefit of RFID. An RFID system can detect many different RFID tags simultaneously as long as they are within the read range of the interrogator. The interrogator acts as the sensor as well as an interface between RFID transponders and the IPS. Antennae are attached to the interrogator and perform the actual Radio Frequency (RF) communication which is described above.

A computer hosting the IPS application pilots the interrogator and processes the data it sends [11], [12]. The IPS application monitors, configures and coordinates readers for data collection as well as the execution of business programs as dictated by programmed business rules and logic. The IPS normally is also referred to as the edge-ware or middleware [11] and can be addressed as the intelligent sensor network platform (ISNP) [12]. After configuration of parameters meaningful information has to be taken from the tag. This is briefly explained in section 3.2 on the software module.

## 3.2 Software Module

The microcontroller was programmed using the C programming language and Visual Basic was used in the serial communication between the computer and the RFID as well as with the PIC. A database was developed using Microsoft Access since it can contain up to 32768 records of objects, a size of about 2GB memory space which is sufficient for demonstration. Synchronizing software called Sync Toy was used to demonstrate exchange of data between terminals in the same network. Remote Desktop was also used to test remote connections.

Figure 2 shows three flowcharts which represent the processes involved in the operation of the product. The blocks show the iterations done in the RFID hardware, the visual basic program and the microcontroller.

### *3.2.1 Visual Basic Communication Application*

The Visual Basic Communication application consists of four different parts; the part which communicates with the RFID hardware, the part which communicates with the database, the part which communicates with the Programmable Interface Controller (PIC) and the part which enables addition of new users.

The system was developed with an aim towards enabling it to indicate the registration number of a car as it passes, according to the RFID details taken from the database. The station attendant has a chance to see if there is any difference between the plate in the database as displayed on the application window and that on the car. It also displays the current account balance from the database. There is an automatic deduction of balance which works according to an algorithm in the Visual Basic (VB) code. The deduction occurs with respect to the type of car which has passed. The system shows the status of the gate to see if it is closed or opened. This helps the station attendant to switch to the emergence operation of opening and closing the boom if the RFID system fails. For security, a login window for privacy and authentication was developed to reduce fraud since only authorized users are held accountable for any losses incurred.

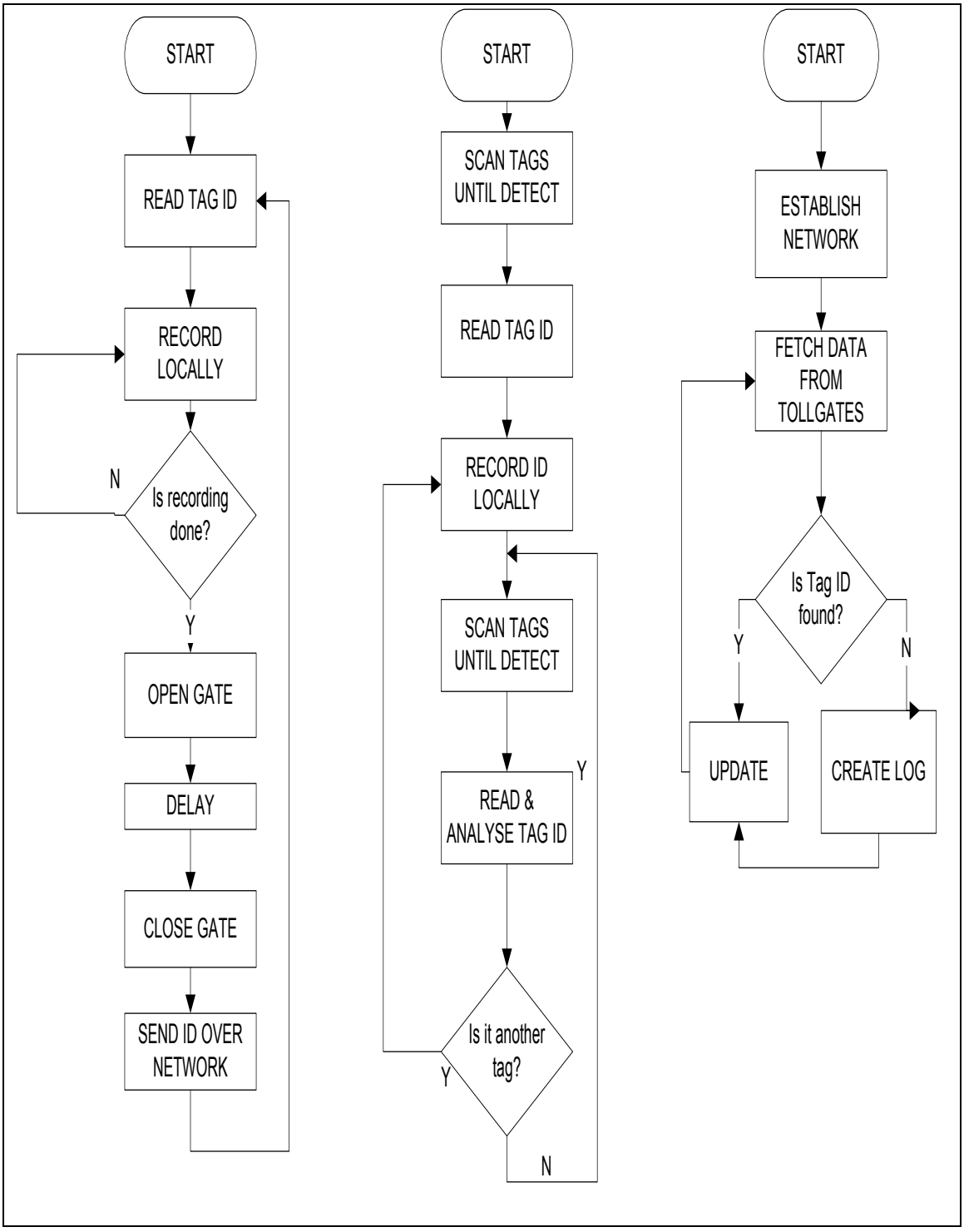


**Figure 2: Steps taken in identifying vehicles and opening gates for entry.**

### *3.2.2 Synchronisation of databases and remote management*

The setup in Figure 3 was successfully tested, where the remote Desktop was configured and a Synchronisation network was set up to update shared files in the two computers.

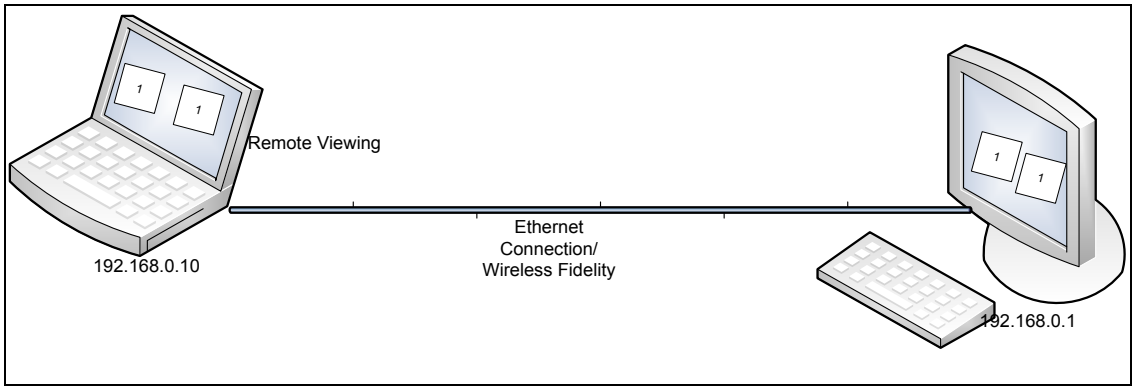


**Figure 3: Desktop Configuration and Synchronisation network.**

Synch Toy application software is used with notepad document, Excel document or an Application like MS Access. This means that if we create a linked file in the remote server, then it can be updated at set intervals. For testing purposes two files MS Access database files were synchronised using Synch Toy. Notepad files are simple to use but lack the security that can be put on Excel and MS Access documents and notepad data is difficult to arrange since it comes as simple text.

### *3.2.3 Remote Desktop*

This setup was successfully configured and tested on two computers. The connection and control is achieved after allocating some static IP addresses on both PCs and opening the protocol port on the Windows Firewall. This requires that all machines in the tollgate system be in the same Local Area Network (LAN). This can be achieved by configuring a Virtual Private Network (VPN) tunnel to the remote network. Anyone in the network can log on to any station as long as he/she knows the password and start viewing or install any necessary file remotely.

## 3.3 The Hardware Design

This involved the designing of the mechanical part, with the aim of having a stable, cheap, light and reliable design. For the prototype, wood was used but aluminium can be used for real life boom. After successful building of the gate system the whole system was integrated for testing. The RFID, server (computer and database), PIC control, power supply and the gate system were joined together.

At the moment Zimbabwe Revenue Authority (Zimra) officials collect toll fees manually at toll gates in Zimbabwe. The proposed system has two gates one using the RFID system and another one with a manual system to allow cars without tags to pay the toll fees manually.

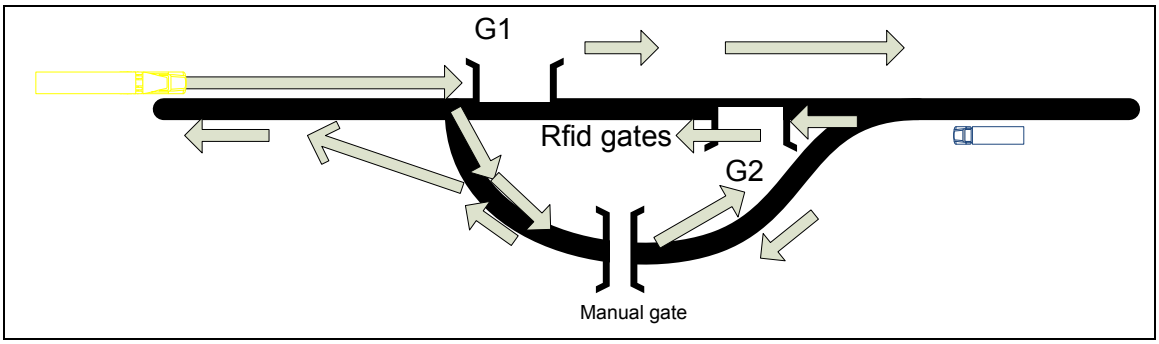


**Figure 4: Tollgate with a RFID gate and manual gate.**

## 4 DISCUSSION AND ANALYSIS OF RESULTS

Discussion of results shall be split into the following sections: accuracy, security, reliability, functionality, speeds of execution, financial requirements and hardware availability as well as user friendliness.

### 4.1 Accuracy

Several tests were run during the Zimbabwe International Trade Fair (ZITF) for the whole week and the RFID system recorded entries accurately. The system managed to identify all the cars that passed through it. The serial communication between the PIC and the computer was also repeatedly tested. The results showed that there were neither unwanted additional bits nor lost bits. There were no instances when the gate failed to open when it was supposed to, neither did it fail to close when it was supposed to. Generally accuracy was high and the authors recommend the use of RFID in identity detection even for car parks and door entrances.

### 4.2 Security

The system proved to be secure since it could not be cracked without the login details. No unauthorized user is supposed to log on to the system, in case they may start editing their balances. However the weakness of the networked tollgate system is that it is prone to the spread of viruses and leaking of information to the outside world. We recommend that further studies be done to reduce this risk. However it is very difficult for subscribers to clone RFID tags and start using them in the road because an unrecorded/unknown tag ID is not allowed to pass. From the flow chart in Figure 2, the gate only opens when the tag ID is read and recorded. The Log On window for accessing the system is shown in Figure 5.

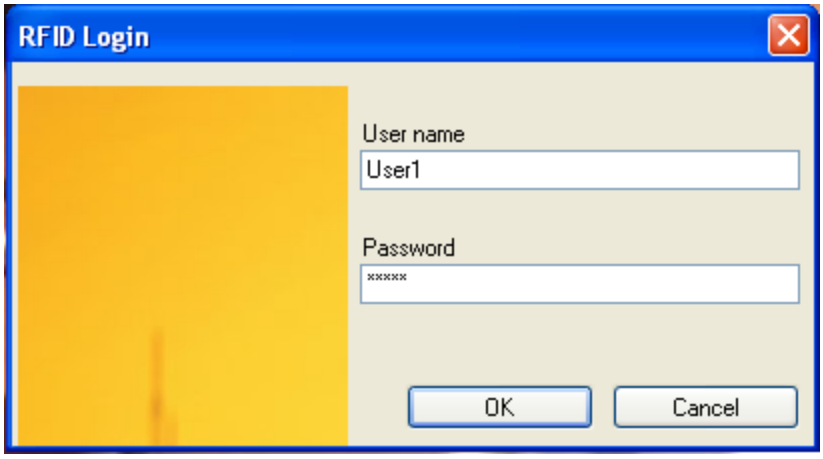


**Figure 5: Login Window for accessing the system.**

### 4.3 Financial Costs

The financial costs of developing a single setup using an RFID system are shown on Table 1. In real application the cost is more as it will be required to install a firewall on the server to increase security. Also each tollgate is supposed to have a serve, a network node and at least a router to create some VPN tunnels for faster transfer of data during synchronization of databases which increases costs.

However, with the losses that can be incurred because of the paper tickets [9], the cost of installing and using the RFID Automatic Tollgate System is very negligible. It must be noted that manual paper tickets can be cloned and reproduced from somewhere.

**Table 1: Financial costs**

| Component/Item | Source/Country | Financial Cost (US$) | Source of funds to make prototype |
|---|---|---|---|
| RFID Read/Writer | Shenzhen, China | 185.00 | Designer and authors |
| PIC18F452 | Midrand, South .Africa | 15.00 | Designer |
| D.C motors | Bulawayo, Zimbabwe | 10.00 | ZITF sponsorship |
| Relays | Bulawayo, Zimbabwe | 10.00 | ZITF Sponsorship |
| RFID tags | Shenzhen, China | 10.00 for 5 | Designer |
| Carpentry and mechanics equipment | Bulawayo, Zimbabwe | 75.00 | ZITF sponsorship |
| Other costs; components and service | | 50.00 | ZITF sponsorship + Designer |
| **Total** | | **355.00** | |

### 4.4 Speed of operation

The experimental results showed that a model car can be recorded and allowed to pass in on an average of 5 seconds. This makes it a faster system that the one used to issue tickets manually. This design was functional at prototype level using low power motors to operate a boom gate. Figure 6 shows the set up being exhibited at the Zimbabwe International Trade Fare in 2011. The design can also include IP Cameras for increased security.

**Figure 6: RFID prototype being exhibited at ZITF.**

### 4.5 Hardware availability

Hardware components for this system were difficult to secure in Zimbabwe. Even an EPC tag cannot be easily found in Zimbabwe hence it limited the number of trial using the systems and further experimentation on the RFID system.

However some of the parts required to build the mechanical and billing side are readily available. In fact the PIC18F452 used here is available in the country although more expensive. Cheap available components include the serial communication adapters, MAX232s, RS232s, resistors, transistors and relays.

### 4.6 User friendliness

Visual basic is very good at designing smart and user friendly windows, just like any other Microsoft Windows application. This can be seen from the graphical user interface image shown in Figure 7.


**Figure 7: Window for entering new users into the system**

## 5 CONCLUSIONS

The RFID Automatic tollgate system designed could automatically detect the identities of the vehicles and performed the billing in accordance to the identity of each vehicle as pre-recorded in the database. The system could automatically open and close the gate as well as automatically emailing the owners of the vehicles. These were the major achievements met in the project, among other objectives also achieved which include tracking of the vehicles and remote database connection. However proper demonstration of some of the objectives did not yield to the wanted extent due to lack of resources for example remote database connection needed a pre-set Virtual Private Network and automatic synchronizing software which was not readily available.

Reading items and objects in motion can be done accurately using RFID. A system developed with a log in windows enables security and the overall cost of implementing the system may seem high but after a year of running the system, very high benefits will be realized. The whole system is very convenient and saves much on time. However when there is no reliable source of power the system just becomes a white elephant and is of no use unless if a solar power supply is installed on site. This decreases reliability of the system and incurs extra

costs on unplanned workforce coming to manually collect the revenue, in which case they will most likely start looting money.

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