

Gateless Electronic Toll Collection using RFID

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Abstract: An effective and efficient utilization of communication link between RF Modems over a wireless channel to facilitate monitoring, authentication and automated toll collection of vehicles on the highways is proposed in the paper. The system is implemented to automatically register vehicles getting on or off a motorway or highway, shortening the amount of time for paying toll in large queues. This paper also introduces the implementation and design of an active RFID tag based system for automatically identifying running vehicles on roads and collecting their data. The architecture and the basic principles of design of the system are presented; including reading equipment (readers and antennas) and active electronic tag. Finally, the effectiveness and efficiency of the system is analysed as a whole.

Keywords: Gateless Tax Collection, ETC- Electronic Toll Collection, RFID-Radio Frequency Identification, Toll booth, COM-Communication Port.

I. Introduction

Electronic toll collection (ETC) is a technology enabling the electronic collection of toll payments. It has been applied over many highways and expressways for faster toll collection and reduced traffic congestion. This ETC system is capable of determining if the car is registered or not, and then informing the authorities of toll payment violations, debits, and participating accounts [2]. The most significant advantage of this technology is that it eliminates congestion near toll booths. It is also a method by which we can track vehicles at tollbooths. Other than this obvious advantage, implementation of the ETC could also benefit the toll operators. The benefits or advantages for the users include:

- 1) Minimized queues at toll plazas by increasing toll booth service turn-around rates.
- 2) Faster and more efficient service.
- 3) The ability to make payments anytime anywhere on the card itself or by loading a registered credit card.
- 4) The well timed notification to users via the push notification that informs them about their current account status.

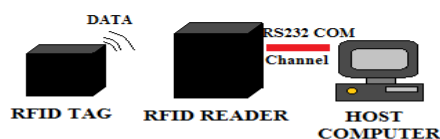


Fig. 1.1 Basic Operation of RFID System

An ETC system extensively utilizes radio frequency identification (RFID) technology. RFID is a generic term used to identify technologies utilizing radio waves to identify people or objects [3]. RFID technology was first introduced in 1948 when Harry Stockman wrote a paper exploring RFID technology entitled, "Communication by Means of Reflected Power" [4]. RFID technology has evolved since then, and has been implemented in various fields, such as in, library system warehouse management, theft prevention attendance system, and so on. Generally, RFID is used for, tracing, tracking, and identifying objects. The whole RFID system consists of a transponder (tag), reader/writer, antenna, and computer host. The transponders/tags are a microchip amalgamated with an antenna system in a compact Toolkit. The system contains a microchip which contains memory and logic circuits to receive and send data back to the reader [5]. These tags are classified as either active or passive tags. The batteries in the Active tags provides a longer read range, on the other hand the passive tags are powered by the signal of the reader and hence have shorter read range [6].

The reader contains two components a decoder along with the RF module and an antenna to send and receive data from the tag. It can be mounted or built as a mobile portable device. The desktop host acts as the interface for IT platform for transferring information from RFID system to the end-user. This host then

transforms the information received from the RFID tag into usable resource for the end-user as shown in Fig 1.1.

II. Related Work

In the literature review of the existing RFID based toll collection system we find the method of collection is not entirely gateless. The ETC system in use across National highways of Ahmadabad, Chennai, and Gurgaon-Jaipur-Beawar has barriers to inspect each vehicle while the tag is being scanned. The ETC system currently in used in India do not provide and external module that acknowledges the toll transaction to the vehicle owner. The system simply scans the vehicle tag and proceeds provided the vehicle is not under any sort of defaulter category.

The ETC system used in Canada is known as the Canada 407 Express toll route (ETR). It is one of the most sophisticated toll roads in the world [7]. In Canada, the ETC system has deployed close barrier at each end of the stretch. The system also is well equipped with optical cameras which record the license plate of the vehicle. The camera specific to this type is called Optical Character Recognition (OCR).

The OCRs are useful in capturing images and recognizing the license plates of the vehicle without transponders (tags). Laser beams are placed at the top the solid infrastructure which detect the vehicle type. In all the projects developed so far, it is not cost effective and the expense of the built infrastructure is recovered from the motorists by increasing the toll bill.

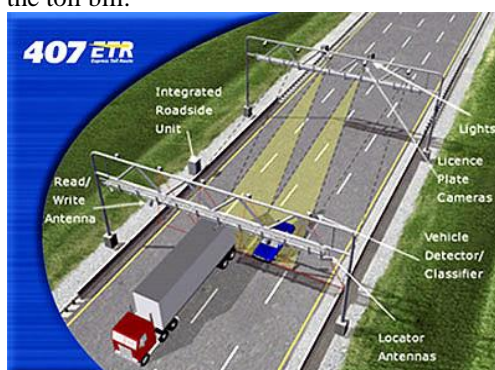


Fig 2.1 Canada 407 Express Toll route

The electronic toll collection (ETC) system operating by radio frequency identification (RFID) equipment supplied by Mitsubishi Heavy Industries, Ltd. (MHI) began commercial operation on an expressway in India's Gujarat state [12]. The country's first interoperable RFID-based electronic toll system was today rolled out on the Ahmadabad-Mumbai National Highway and the system would allow vehicles fitted with electronic tags to sail through six toll plazas [13]. The ETC system is managed by 3 road developers namely- Larsen and Toubro (L&T), IRB Infrastructures and National Highway Authority of India (NHAI). The Toll collection project is equipped with RF Scanners that detect the passive tags operating at frequency of 850MHz-950 MHz at a distance up to 90 feet with a response time of 10 milliseconds. Although the system is cost efficient (with tags available at Rs 150), but it is not a gateless tax system hence the motorist have to wait for the receipt. Also no external module can acknowledge the motorist about the successful transaction and pending balance via cellular mode (push notification).

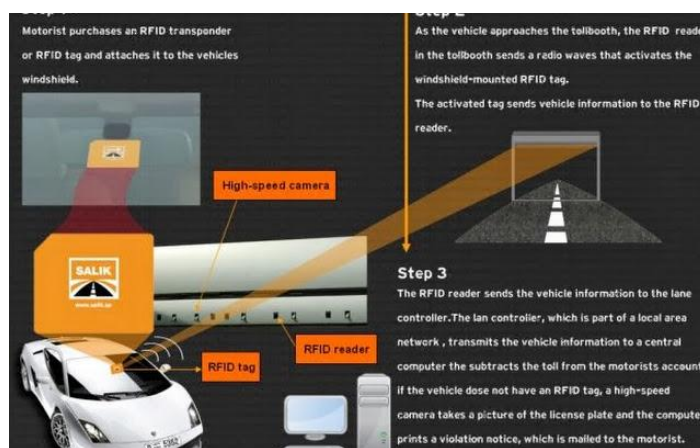


Fig 2.2 Working of Toll Collection at Gujarat Expressway

The ETC system in use in Poland has been proposed by the Motor Transport Institute and the University of Technology, Warsaw. The system has been named as Automatic Toll collection System (NATCS) and consists of National automatic Toll Collection Centre. The NATCS uses a combination of GSM with satellite based Global Positioning System (GPS). The GPS system tracks the distance covered by the vehicle and calculates the fees and rates which then transmits this information to NATCS centre. The NATCS is highly equipped with sensors and camera that capture and recognise license plates. Though the system is well equipped the cost of equipping the car with a transponder as well as a GPS seeks an upward spiral. Hence this expense is recovered from motorists.



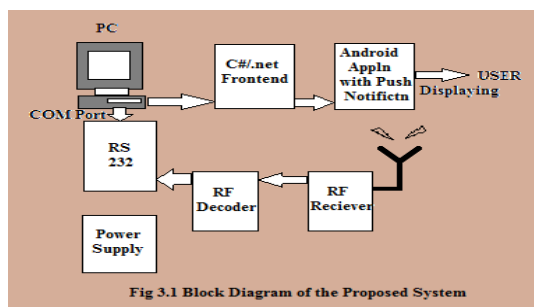
Fig 2.3 Toll Collection Centre at Poland

III. Proposed System

Every mobile vehicle will be attached with a RF tag which contains a unique ID. The tag will keep giving out RF signals. When vehicle reaches the entrance of the toll booth the RFID receiver will detect these signals. The signals are then passed over to the controlling device (i.e. Desktop/Laptop). The reader will receive the signal then the data will be sent over to the COM port of the connected device via the USB cable. Now, with the help of COM port the data is transferred to the mobile device or a laptop. The front-end software developed will display the details of the vehicle owner's account on the screen. Information such as date, time, total balance and license number will be stored in the database. A detailed screen will be prepared from the information retrieved from the database that gives a complete description of the owner's account. By the end of the month the system will give the bill and the total amount pending of the user for the current month will also be printed. This regular bill will be sent to the user via an android application through the notification service.

The vehicle owners who find themselves at the toll booths with insufficient balance will be sent through a separate path where they can recharge their balance to pay their undue amount. Another option given to the users is to recharge their accounts via an SMS; the SMS will deduct the charge from the SIM card and recharge the amount in the users account for the toll booth. The GUI can be used to generate a list of all users who have low balance, so as to remind them to recharge before they travel again. This system also highlights an important factor which most system ignores, it is that many time vehicle users may cross toll booth by mistake or may have urgent business and may have to return. In such conditions, it is unfair to charge them with toll since they have not used the highway or bridge. Hence in order to make the system fair we keep a appropriate time interval within which if the user returns then no balance will be deducted but if he stays for a longer period then balance will be deducted.

3.1 Block Diagram



3.2 Components in the RFID Toolkit

The following are the components included in the RFID Toolkit which are necessary for the proper functioning of the system. They are as follows:

3.2.1 Power Supply

The Power Supply will fulfil the power requirements of all the components attached in the Toolkit. It contains a transformer, filter and rectifier. The system uses 9-10V of Power Supply.

3.2.2 MAX 232

This component is required to convert TTL (Time to Live) logic into RS232 logic and vice-versa. In TTL: logic 1 is +5V and logic 0 is 0V. In RS232: logic 1 is -10V and logic 0 is +10V. This unit provides an interface required for communication between microcontroller and RS232 based devices using serial communication port (COM). The MAX232 IC is dedicated for the logic conversion. The unit is also called as Logic Converter/Level Converter. The unit requires +5VDC for normal operation.

3.2.3 RF Encoder HT12E

This unit is used for the encoding of 4-bit data before passing it in the communication channel. Essentially it creates a serial bit stream out of the parallel bits of input data. After that it transmits data stream to RF transmitter component. The unit requires +5V - 12V DC for its normal functioning. This unit decodes the 4-bit data after retrieving it from the RF Receiver unit. It produces a parallel data from the serial input bit stream. It requires +5 to 12VDC for its normal functioning.

3.2.4 The RF Transmitter

This unit plays an extremely crucial role. It handles the modulation (ASK, CF-434MHz) of the data or packet to be transmitted. After the data is modulated then it is transferred or sent over Air with the help of antennas. The baud rate is normally 1100 bps and the range would be around 80ft. The unit requires +5V - 12V DC for its normal functioning.

3.2.5 The RF Receiver

This unit forms the core part of the system. It demodulates the signal after reception from air as the medium. This component is created with Amplifying unit, Filtering unit, Peak Detection, Sampler. The unit requires +5V DC for its normal functioning.

3.2.6 PC Serial Port Controlling

Serial Communication Port (COM) of PC is also called as RS232 Port. The connector type is 9 and the pin used is D-Type Male connector. Basically we will use only pin no.2 (Rx), pin no.3 (Tx) and pin no.5 (GND) for all communication of the system. Using MSComm Control ActiveX - The MSComm control provides serial communications for our application by allowing the transmission and reception of data through a serial port. MSComm is used as a serial port software interface. MSComm provides us the software interface and insulates us from the functioning of the underlying hardware. Using System.IO.Ports Namespace – this is part of .net framework. This is an intrinsic way of serial port communication. In this namespace we use Serial Port Class. This class provides event-driven and synchronous I/O, access to pin and break states to access serial driver properties.

3.2.7 Database Manager

A database management system (DBMS) consists of software that operates databases, access, and security, providing storage, backup and other facilities. Databases are designed to offer an organized mechanism for managing, storing and retrieving information. They do so through the help of tables. We can use any one of the following software technology for database management. MS Access 2007 allows us to manage our information in one database file. It is easy to use. It is portable and can be easily copied & pasted to any other system and can run without installing the software. MS SQL Server 2000 – it is complex at installation part and easy to use. The database developed on it cannot be easily copied and paste on another system. In addition to this, it requires the software to be installed to use the database files.

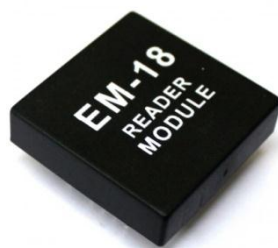


Fig 3.2 RFID Reader Module

Fig 3.2 shows the whole working model of the ETC system. Here, the vehicle owner enters the specific Radio frequency region i.e. the RF transmitter range (up to 80ft). The RF Receiver transmits demodulated signal from the newly activated passive tag on the vehicle. The vehicle is then recognised in the database system and the appropriate amount is deducted. If the vehicle owner is categorized as 'defaulter' then either the owner can recharge his balance via an external module or pay that specific amount at the exit toll. An Acknowledgement notification is sent to the user via a push notification service.

IV Technology & Programming Languages

As microcontrollers form the core of these days digital circuit design in industry, this system uses it for the digital processing and centralized operations. The system makes use of embedded technology which is the future of today's modern electronics. The followings are the various Programming Languages & Technologies that are going to be used in the proposed system.

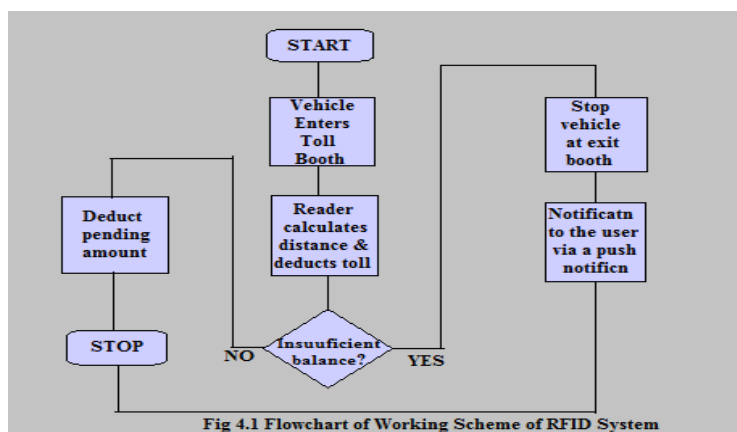
For PC System:

- 1) VB.net 2010 Based Application Software,
- 2) Serial Communication Protocol,
- 3) SQL Based Database.

4.1 Steps of Project Development and Methodology

The following will be flow of steps to achieve the working Prototype Model of the above proposed system.

- 1) Defining the Task,
- 2) Understanding the Need & Usability in industry and market(Market Analysis),
- 3) Prepare a Block Diagram,
- 4) Deducing a Flowchart for the whole process,
- 5) Writing the Software Program,
- 6) Compilation & Burning,
- 7) Testing and Debugging,
- 8) Developing Data Flow Diagram,
- 9) Actual Implementation.
- 10) Finally Running the system and,
- 11) Documentation.



In Fig 4, the Flowchart of the working scheme of RFID System is shown. The user first enters the Toll Booth, and then the RFID reader will read the tag attached to the car. It will look up in the database about the distance to be covered by the car to cross the bridge and deduct amount from the existing balance. If the users account has insufficient balance then there is a facility to recharge the account. Hence these cars will be side-lined where they can recharge their account and continue their journey. On recharging the account or when the balance is deducted the user is notified via a push notification.

4.2 GUI Design and Application

4.2.1 Home Screen

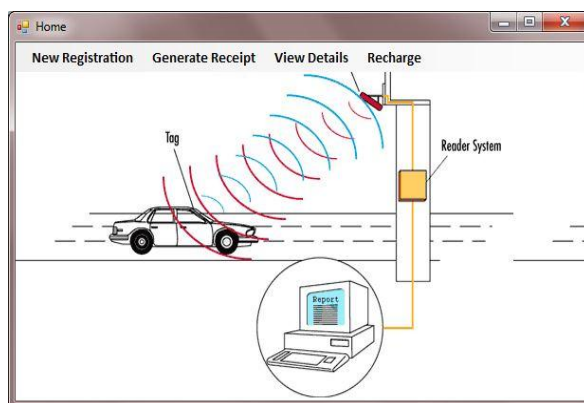


Fig 4.2 Home Screen of GUI application

In Fig 4.2, the home window of the GUI is shown. The GUI contains a basic animation of the working model alongside four tabs. The first tab is the 'New Registration' tab wherein new vehicle registration are made and updated in the database. The second tab is the 'Generate Receipt' wherein a receipt is generated of the transaction. The third one is the details tab which displays the details of any particular vehicle. Lastly the 'Recharge' tab which is used to recharge the balance of that vehicle owner.

4.2.2 Login Screen

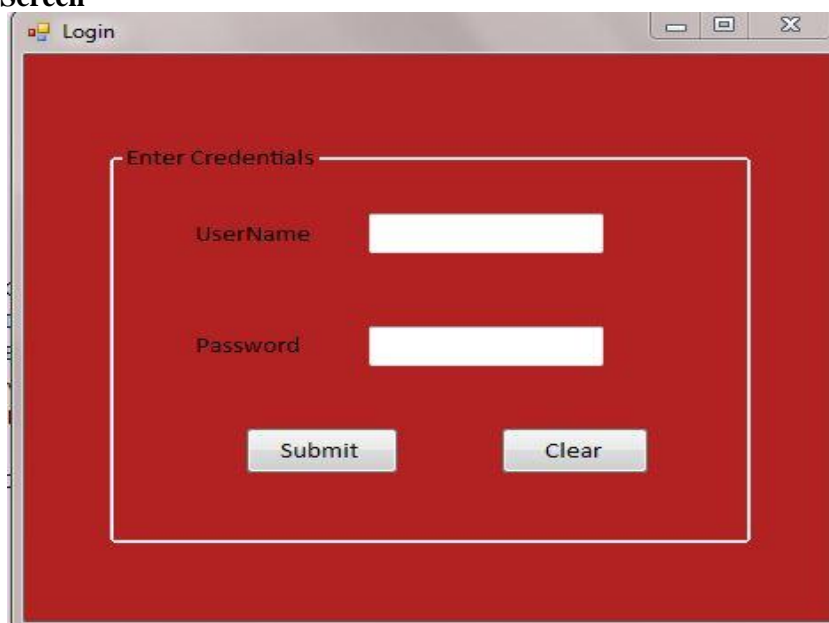


Fig 4.3 Login Screen of GUI Application

In Fig 4.3 the Login window of the GUI is shown. The login screen contains two input boxes to input username and password respectively, this is used to authenticate the user. After successful login the user will be able to view and operate the account (for e.g. View Receipt, Recharge, etc.).

4.2.3 Receipt Screen

Fig 4.4 Receipt Screen of GUI Application

Fig 4.4 shows the Receipt window. The screen shows a Select COM Port input box which is used to select the COM port that is going to be used to connect the desktop/laptop with the RFID Toolkit. After selecting the port and clicking on Proceed button, the connected RFID reader will be configured and the RFID tag will be read and the information will automatically be fed in the Receipt portion of the screen. And the Tag ID will be visible in the second input box i.e. Please Show your Tag box.

4.2.4 Recharge Screen

Fig 4.5 Recharge Screen of GUI Application

In Fig 4.5 the Recharge window is shown. The screen shows a COM port input box which is used to select the COM port that is going to be used to connect the desktop/laptop with the RFID Toolkit. After selecting the COM port the tag can be read. And the account can be recharged with the amount paid by the owner of the tag.

V. Scope and Applications

The application of the proposed system go way over imagination once the system is implemented. Some of the closest things that can be seen happening are:

- 1) The vehicles are automatically identified by the system which can be used to track a vehicle.
- 2) The vehicles are automatically classified as a 2-wheeler, 4-wheeler or a heavy vehicle and toll amount is deducted accordingly.
- 3) The vehicles are tracked on road in real time so as to determine the traffic congestion at that road, and this information is used to guide other users to choose other route so as to reduce congestions.

VI. Enhancements

7.1 Limitations

All systems have some or the other drawbacks, the limitations of our system are as listed below: The system will handle only single toll booth. Multiple RF tags cannot work together. The system will significantly surmount the stationery cost.

7.2 Future Modifications

There is always scope for improvement in any system as research & development is an endless process. The following advancements can be done:

- 1) An email or SMS can be sent to the user when his/her account has low balance so as to remind him to recharge before he uses the highway/bridge.
- 2) The RFID readers could be more sophisticatedly used along the road so that they can determine the traffic at any road and guide the users to use a separate path for efficient traffic handling.

VI. Conclusion

By the implementation of the proposed system not only would we ease the vehicle user's accessibility of Toll Ways, but also minimize the time wastage at Toll Booths. As the vehicles will not have to stop or pause at Toll Booths for payment. This in turn leads to several other benefits for the motorist such as fuel savings and reduced mobile emissions. This technology can be extended to provide many other facilities such as traffic monitoring for surveillance purposes, traffic handling by informing user about which roads have more congestion and it can also be used to track blacklisted cars. The other benefits for the toll operators include:

- 1) The overall toll collection cost will be reduced as the toll collection is now automated and there is no need of manual collection.
- 2) Reduces wastage of resources such as paper which is used for printing tickets and toll passes.
- 3) Expanded capacity without building more infrastructures.
- 4) The toll amount may change from time to time, but changes can be easily implemented as there is no need for printing coupons/tickets.

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