Electronic Toll Collection and Record Management System

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Abstract: In this modern era, the cities are connected through well maintained network of roads. In order to keep those roads up to the mark all the time, funds are required, which are generated by the vehicles that use those roads. For this purpose, toll booths are installed at various locations on the roads. In Pakistan, most of the toll booths are working manually, which frequently cause traffic Jam. In this paper, we propose an Electronic toll collection system along with the vehicle record management system. With the implementation of the proposed system, the risk of traffic jam can be reduced, and smooth flow of traffic can be possible. Besides, electronic toll collection system, the vehicle record management system can help in case of an emergency or theft. For instance, if a theft happened through a vehicle which crossed the toll booth, then vehicle can be tracked by inspecting vehicle number and its record can be retrieved, that at what time the vehicle has crossed the toll booth. Hence, the proposed system can help in curbing the theft to some extent.

Keywords: electronic toll collection, RFID, Arduino
Introduction

I. INTRODUCTION

In any country a network of roads plays vital role in overall development. These roads have toll collection booths at various locations. It is generally observed, that there is enormous volume of traffic passing through tolls, which cause traffic blockage [2]. Currently, in Pakistan mostly the toll collection system is working manually. The manual toll collection system usually results in frequent traffic jam. In order to reduce the risk of traffic jam, there is a dire need of automated toll collection system, which may result in smooth flow of traffic. In this paper, we propose Electronic toll collection system based on Radio Frequency Identification (RFID) technology. RFID is a technology, through which unique codes can be assigned and identified to the products from distance, without keeping line of sight [1]. It supports larger sets of codes as compared to bar code [1].

Electronic toll collection system (ETCS) first records the vehicle information with unique code. This information includes vehicle information as well as owner's information. The information is stored in the database and associated with RFID code. Once the information is recorded with unique RFID code, now the owner can get his/ her RFID card recharged from the specified toll booths. When RFID is recharged, the same can be used to pay toll tax just by scanning RFID tag. When the RFID tag is scanned and it has sufficient amount of toll tax available, the amount will be deducted according to vehicle category and the toll barrier will be opened.

Beside the toll collection, the ETCS can also aid in curbing theft or terrorism activities. One of the important features of the ETCS is storing the record of vehicles crossing the toll. For instance, if a vehicle is involved in some illegal activity, the security personal would send the car's information to the nearby toll booths. If the vehicle has crossed the toll, then it's can be deducted from the system by just providing vehicle number. From the time, the vehicle has crossed the toll, it's location can be guessed.

Similarly, the ETCS can also be used in case of emergency. If there happens an incident with the vehicle and the owner can't be identified, then by inspecting vehicle number, owner's information can also be obtained.

Likewise, the ETCS has capability of generating tax deduction reports. Mangers can inspect the ETCS and acquire the reports at any time. Report can be generated for a single day or a period by specifying starting date and ending date.

There are two types of users of the ETCS, namely; toll personals and the mangers. The toll personals are responsible for generating RFID based vehicle record, Recharge RFID card/tag and inspecting any vehicle's information. The mangers are capable of generating reports for specific date or a period and change tax policy at any time.

ETCS has numerous advantages which are listed below:
- Automatic collection of toll tax.

- Free flow of traffic.
- Accuracy rate of the RFID electronic toll collection system is very high.
- Communication through Radio waves so, line of sight is not required.
- RFID reader read multiple tag signals at once.
- Toll deduction by RFID reader is fast process it hardly takes 1 to 5 second only.
- Toll collection by RFID reader gives you always accurate data record.
- Every tag has unique identity.
- RFID tag cannot be cloned, so cannot be cheated.
- Very efficient saving of time.
- Less congestion on the roadways.
- Comparatively less maintenance cost.
- Consumption of oil is reduced.
- Increased capacity of transport.
- Save time and money.
- Provide ultimate transparency.
- Increase accuracy.
- Reduce paperwork.
- Enhance visibility.
- Generates detail reports with time and date.
- Increase security.
- No internet needed.
- Onetime cost.

The rest of the paper is organized as follows: Section 2 discusses related work, while Section 3 elaborates the proposed system. Testing and experimental details are provided in Section 4, while Section 5 concludes the paper.

II. RELATED WORK

Toll tax collection is a common practice in almost every country. Generally, the revenue generated from toll tax is utilized for construction and maintenance of the roads. In order to collect toll, the toll collection points are located at specific distance on major roads. Traditionally, tax collection is done manually, i.e., a vehicle has to stop at toll tax point and the person at toll both receives tax money, then issues a receipt and the opens the barrier for that vehicle. Sometimes, situations happen that the toll payer has big currency note, getting back the remaining amount and counting it takes time, which may result in traffic congestion. There also happen some situations, like an event or festivals which cause heavy traffic flow, resulting in traffic jam at manual toll collection points. In developed countries the toll systems have been automated, however, in Pakistan, manual toll collection is in practice. By keeping in view, the issues of manual toll collection systems, we propose Electronic toll collection system, which has some additional features beside toll collection. Before elaborating the proposed ETCS, we discuss some of the related work found in the literature.

The RFID based toll collection system [2] is a system which is used for the purpose of automated toll collection. However, it does not store the information of the vehicle which paid the toll tax and also it does not generate the report.

The system [3] is used for the purpose of automated toll collection. Conversely, it does not store the information of the vehicle which paid the toll tax and also it does not generate the report of tax payment. The system has an additional feature of sending text message to the owner of vehicle about the tax deduction and the location of toll collection point.

The study [4] embeds the security system with RFID based automated toll collection system. The system is connected with the database of black-listed vehicles. If the vehicle number is detected in the black-listed database, the automated barriers will not open.

The authors [5] proposed toll collection system, with additional feature of vehicle document verification. The system ensures that all the vehicles crossing the toll point have valid documents for the purpose of anti-theft and security.

The study proposed in [6], is based on Vehicle Number Recognition (VNR) system. The VNR is capable of detecting vehicle number using cameras and image processing system. The system is capable of generating automated tax payment receipt; however, it does not provide pre-paid tax payment facility. Hence, requires toll collecting personal at toll collection booth.

In the study [7], the authors explained that the Automatic Toll Collection Using RFID Technology. The microcontroller was programmed using the BASCOM and visual basic 6.0 is used for graphical user interface (GUI). The RS-232 cable is also used for the connection between RFID reader and computer host. GSM is interfaced to the main server which sends the SMS to car's owner for deduction in balance or less balance.

The ETC system used in Bangladesh [8] is known as Automated Toll Collection and Charging System using RFID in Bangladesh. Author further described that the weight sensor can also be used in this system to see if the vehicle is overloaded.

Electronic Toll Collection System [9] uses QR code and RFID registration. In this system, at registration time, user's bank account details are also provided, and the tax is automatically deducted from owner's bank account when QR code is scanned at toll plaza.

In the study [10] the authors present the Gateless Electronic Toll Collection Using RFID. However, the system does not maintain the record of the vehicle's tax payment.

All the systems observed in the literature propose electronic toll collection system with more are less similar attributes. However, the proposed system can not only be used as electronic toll collection system but also toll record managements system. The proposed system also has an additional feature, that if toll collection policy maker allows the vehicle to pass freely if it has crossed the toll by paying toll tax within specified time limit. This time duration can also be changed by policy makers at any time.

III. PROPOSED SYSTEM

The proposed system is comprised of four modules which include RFID interface, user interface, database and

report generation. Each of the module is discussed in subsequent sub-sections.

A. RFID Interface

RFID interface module describes how RFID tag, which is unique code, is communicated to the application and what possible actions are performed in response. The complete scenario is illustrated in Fig. 1 and discussed below.
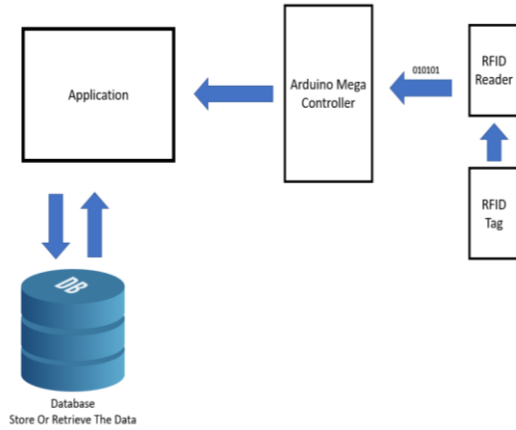

Fig. 1. RFID Interface with application and the database

- Initially RFID card with unique code is scanned by RFID reader, which sends the RFID code to the Arduino controller.
- Arduino creates communication between RFID and the application
- Arduino decodes and sends this code in digital form to the application.
- The application receives the data from controller through serial port built-in Arduino library.
- When data is received, further actions are performed according to user requirement to and from database. These actions include:
    o Add Vehicle
    o Recharge Tax Amount
    o Deduct Tax
        ▪ First it will check whether vehicle is registered or not
        ▪ Whether it has enough balance or not
    o Add new employee
    o Retrieve vehicle information
    o Generate report
    o Update Tax value

B. User Interface

User interface of the ETCS is comprised of two panels; employee panel and admin panel. Employee at toll booth is responsible for registration of new vehicle for automated toll collection, recharging pre-paid RFID card and observe Tax payment.

In admin panel, admin can perform following actions
- View any vehicle information if required for the purpose of security and anti-theft.

- Create, update or delete employee accounts.
- Update Tax values
- Update time duration of Tax relaxation
- Generate report

C. Database module

As the proposed ETCS also manages vehicle and Tax information, in addition to automated toll collection, for the same the database module has been designed. The database keeps the record of registered vehicles, tax transactions including last paid time, recharge and balance information, Tax values according to vehicle type and user information. Accordingly, the database tables have been created as shown in ER-diagram given in Fig. 2. The description of the Tables used in the database module is given in Table I.
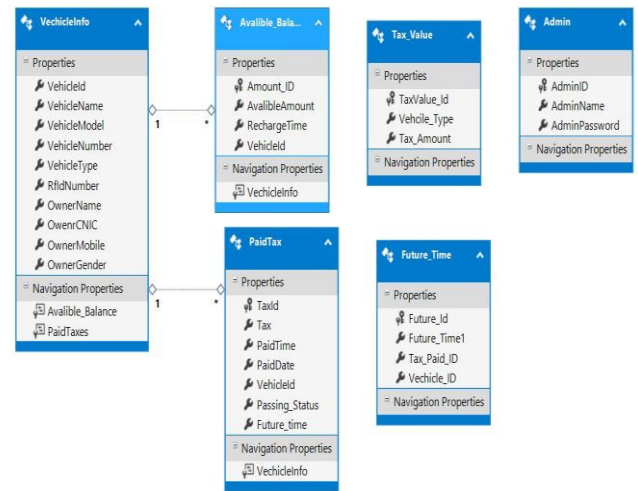

Fig. 2. Database design of ETCS

TABLE I.

TABLE II.   DATABASE TABLES WITH DESCRIPTION

Table	Description
VehicleInfo	This table is used to store the vehicle and owner information
Available_Balance	This table is used to store tax remaining balance information after each transaction
PaidTax	This table is used to store paid tax transaction information
Future Time	This table is used to store vehicle tax paid time information for a few hours. Purpose of this table is to allow the vehicles to pass the toll without paying tax, if it has paid tax within pre-defined time span.
Tax Value	This table is used to manage the tax value information. It can be changed by admin at any time.
Admin	This table stores admin id and password information

D. Report Generation

ITextsharp is an API used for generating pdf reports. It generates reports stored in databases, xml files or combine multiple pdf files [11]. Complete process of report generation is demonstrated in Fig. 3.
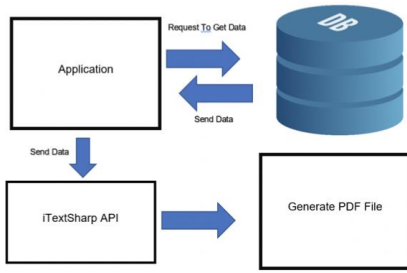
Fig. 3.   Report generation

IV.   EXPERIMENTS AND TESTING

In this Section, we present, experimental usage of ETCS. Each action is illustrated practically in following sub-sections.

A.   Tax Deduction

Main function of the ECTS is automatic collection of toll tax. As the ECTS is RFID based toll collection system, the RFID reader can be mounted at the roof of toll plaza and the user RFID card can be installed on the roof of the vehicle. When the vehicle crosses the toll point, the RFID tag on the roof of car will be scanned. If RFID card has sufficient balance, the toll barrier will be automatically opened. The ECTS application present at the toll booth will show the screen as shown in Fig. 5.

B.   Vehicle Registration

Each vehicle before using the ECTS, need to be registered. Vehicle owner has to buy RFID card and register vehicle information in ECTS. Initially, unused RFID card is scanned, and its tag number will appear in the registration form in ECTS application. The employee will add vehicle and the owner information as shown in Fig. 4.

Fig. 4. Vehicle Registration

C.   Recharge RFID Card

The ECTS is prepaid tax payment system, therefore, each RFID card is recharged before use. In order to recharge the RFID car, the RFID tag is scanned, if the tag is valid and vehicle is registered, then the card is recharged as show in in Fig. 5.

D.   Update Tax Value

The ECTS allows the toll policy owners to change tax value at any time. Admin of the ECTS is responsible for change the tax value as shown in Fig. 6.

E.   Set Time duration

In many toll collection systems, the paid tax is valid for certain duration of time. A vehicle needs to pay tax only once, no matter how many times it passes the toll during that duration. The ECTS facilitates the admin to change valid time duration for tax payment as shown in Fig. 7. If there is no such policy at toll system, then admin can simply set the valid time duration to "zero".

Fig. 5. Vehicle Recharge

Fig 6. Update Tax Value

Fig. 7. Change Time Duration

F.   Report Generation

One of the major functions of ETCS is report generation. The reports can be generated in four different criteria as shown in Fig. 8.

a) Generate report by selecting a time period

This option will generate complete report of tax payment of selected period

b) Generate report of specific date

This option will generate report for the specified date.

c) Generate report of specific vehicle

This option will generate report on the specific vehicle's tax payment

d) Generate All

This option will generate the report of all the paid tax till date. Sample report is given in Fig. 9.

Fig. 8.   Report Generation Form

Fig. 9.   Sample Report

A prototype of the proposed system has been evaluated by testing its all functionalities. The system has capability to scan the RFID card and generate unique RFID code at the time of registration. Once the registration is successful, the RFID card can be recharged for balance. It is also tested that when RFID card has sufficient balance, when vehicle reaches the toll booth, the barrier is automatically opened, and the amount is deducted from the card. When card has insufficient balance, the barrier is not opened. In this case, tax may be paid manually, or card is recharged at the booth.

V.   CONCLUSION

In this paper, we presented the Automated Toll Collection System, which not only automates the toll collection, but also stores the record of tax paying vehicles, which can be obtained when needed. In Pakistan, most of the toll collection systems are working manually.

The manual toll collection systems usually result in frequent traffic congestion. In Pakistan traffic blockage is considered one of the major issues, people suffer from. The ETCS has been developed in order to address this major issue. In order to pay the toll tax, RFID tag which is mounted on vehicle's roof will be automatically read by the RFID reader, which is installed at roof of toll gate. If it has sufficient balance, the barrier will be opened automatically without any delay. Beside automated toll collection, the ETCS has features of storing the vehicle information, which can be used in case of theft or any other incident associated with the vehicle, which crossed the toll. The vehicle and owner information and it's time of crossing the toll can be obtained by providing the vehicle number. In this way, the ETCS can aid in tackling such situations.

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