Journal of Theoretical and Applied Information Technology

www.jatit.org

ELECTRONIC TOLL COLLECTION SYSTEM USING PASSIVE RFID TECHNOLOGY

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ABSTRACT

This paper focuses on an electronic toll collection (ETC) system using radio frequency identification (RFID) technology. Research on ETC has been around since 1992, during which RFID tags began to be widely used in vehicles to automate toll processes [1]. The proposed RFID system uses tags that are mounted on the windshields of vehicles, through which information embedded on the tags are read by RFID readers, The proposed system eliminates the need for motorists and toll authorities to manually perform ticket payments and toll fee collections, respectively. Data information are also easily exchanged between the motorists and and toll authorities, thereby enabling a more efficient toll collection by reducing traffic and eliminating possible human errors.

Keywords: *Electronic toll collection, RFID, Motorists, Toll Authorities*

I. INTRODUCTION

Electronic toll collection (ETC) is a technology enabling the electronic collection of toll payments. It has been studied by researchers and applied in various highways, bridges, and tunnels requiring such a process. This 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 obvious advantage of this technology is the opportunity to eliminate congestion in tollbooths, especially during festive seasons when traffic tends to be heavier than normal. It is also a method by which to curb complaints from motorists regarding the inconveniences involved in manually making payments at the tollbooths. Other than this obvious advantage, applying ETC could also benefit the toll operators.

The benefits for the motorists include:

1. Fewer or shorter queues at toll plazas by increasing toll booth service turnaround rates;
2. Faster and more efficient service (no exchanging toll fees by hand);
3. The ability to make payments by keeping a balance on the card itself or by loading a registered credit card; and
4. The use of postpaid toll statements (no need to request for receipts).

Other general advantages for the motorists include fuel savings and reduced mobile emissions by reducing or eliminating deceleration, waiting time, and acceleration.

Meanwhile, for the toll operators, the benefits include:

5. Lowered toll collection costs;
6. Better audit control by centralized user accounts; and
7. Expanded capacity without building more infrastructures.

Thus, the ETC system is a win-win situation for both the motorists and toll operators, which is why it is now being extensively used throughout the world. .

An ETC system commonly utilizes radio frequency identification (RFID) technology. RFID is a generic term used to identify technologies utilizing radio waves to automatically 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 applications, such as in warehouse management, library system, attendance system, theft prevention, and so on. In general, RFID is used for tracking, tracing, and identifying objects.

A complete RFID system consists of a transponder (tag), reader/writer, antenna, and computer host. The transponder, better known as the tag, is a microchip combined with an antenna system in a compact package. The microchip 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. Active tags have internal batteries that allow a longer reading range, while passive tags are powered by the signal from its reader and thus have shorter reading range [6].

Tags could also be classified based on the content and format of information. The classifications range from Class 0 to Class 5. These classes have been determined by the Electronic Product Code (EPC) Global Standard. In the table below, classes refer to a tag’s basic functionality (i.e., it either has a memory or an on-board power), while generation refers to the tag specification’s major release or version number. The class structure for the tags is shown in the table below.

TABLE 1: Class Structure for Tags [5]

EPC Class	Definition	Programming
Class-0 Gen-1	Read only, Passive tags	Programmed by the factory
Class - 1Gen-1	Write once, read- many, passive tags	Programmed by the user and then locked
Class-1Gen-2	Write-many, read-many, passive tags	Programmed by the user and then locked
Class-2	Rewritable passive tags with extra functionality, including encryption and emulation	Can be re-programmed
Class-3	Semi-passive tags that support broadband communication	
Class-4	Active tags that can communicate with other peers	
Class-5	Readers, they can power other tags of Class 1, 2 and 3, can communicate with Class 4 wirelessly	Not applicable

A reader contains an antenna to transmit and receive data from the tag. The reader also contains a decoder and an RF module. It could be mounted or built as a portable handheld device. The computer host acts as an interface to an IT platform for exchanging information between the RFID system and the end-user. This host system then converts the information obtained from the RFID system into useful information for the end-user.

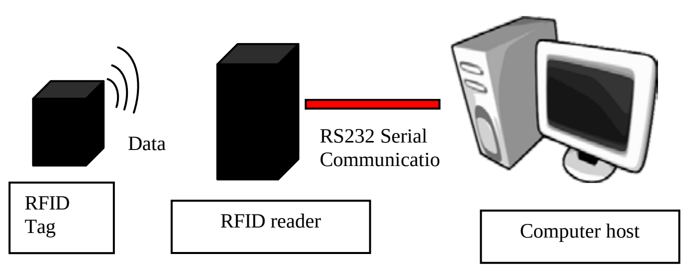

FIGURE 1: Complete RFID System

II. RELATED WORK

The ETC system is currently being used throughout the world. In the United States alone, various states have implemented an ETC system called E-Z Pass [1]. Other countries that have applied the ETC system are Canada, Poland, the

Philippines, Japan and Singapore, among many others.

Some of the applied ETC systems are discussed in the proceeding section.

A. Canada

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]. The Canada 407 ETR is a closed-access toll road, which means that there are gantries placed at the entrance and exit points of each toll. In this system, cameras are equipped with Optical Character Recogntion (OCR). The OCR cameras are used to photograph license plate numbers of vehicles that do not have transponders. The toll bill will then be sent directly to the registered address of the vehicle owners. Other than that, two laser beam scanners are placed above the roadway to detect the types of vehicles passing through the gantries. Nevertheless, this toll road bears a very high infrastructure cost, and the users are the ones who help recover the cost through increments in their toll bills [8].

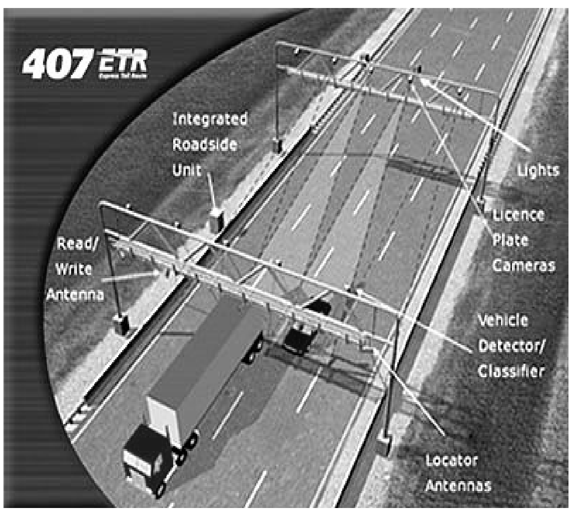

FIGURE 2: Canada's 407 ETR for ETC [7]

B. Poland

The ETC system used in Poland has been proposed by the Motor Transport Institute along with the University of Technology in Warsaw and Dublin. This system is called the National Automatic Toll Collection System (NATCS), and consists of the National Automatic Toll Collection Center (NATCC), control gates, and on-board units (OBU). The NATCS uses a combination of mobile telecommunication technology (GSM) with satellite-based Global Positioning System (GPS). Using GPS technology, the OBUs determine the kilometers that have been driven, calculate the toll fees and rates, and then transmit the information to the NATCS computer center. Each vehicle will be charged from the highway entrance up until the end of the highway. In order to identify the plate numbers of trucks, the system has control gates equipped with digital short range communication (DSRC) detection equipment and high resolution cameras. [9] Due to the technical specifications, this system incurs a high cost for motorists.

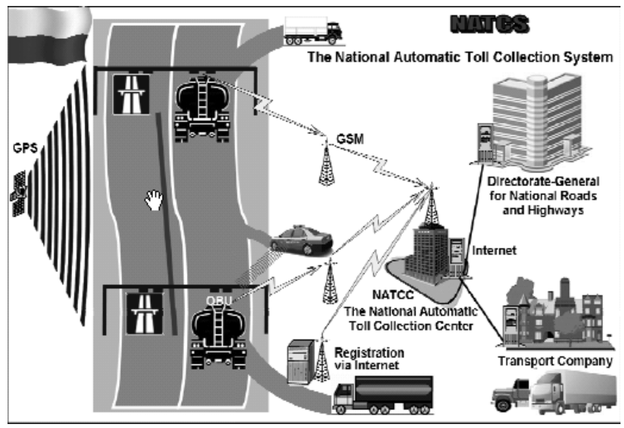

FIGURE 3: Poland's ETC System [9]

C. Philippines

The ETC system used in the Philippines has been implemented at the South Luzon Expressway (SLEX) since August 2000. The ETC is referred to as the E-PASS system, which uses Transcore technology. Here, electronic transponders are placed in front of a vehicle's rearview mirror. Each time a vehicle enters the toll booth, the tag is read by the receiver, automatically identifying the account and debiting the toll fee amount from the corresponding account. Once the amount has been debited, the control gate will lift and the vehicle is allowed to pass through [10].

D. US Patent

In 2007, Tang et al. [11] filed a US patent on their proposed ETC system. Their proposed system provides two lanes: one on the side and the other where overhead-based antennas are installed per lane. Both antennas are used for conducting toll transactions. Of the two, the side antenna will act as a backup in case the overhead antenna fails to capture the signal emitted from the vehicles. In the case of a failure, the overhead antenna will be deactivated, and the side antenna will be activated. If the side antenna also fails, then an error signal will be issued.

III. PROPOSED ETC SYSTEM

The main objective behind this proposal is to create a suitable ETC system to be implemented in Malaysia. The term "suitable" here refers to minimal changes in the current infrastructure with maximum increase in efficiency.

The ETC system in Malaysia has been introduced in the year 1994. It has evolved since then, and many changes have been done. The most recent ETC system consists of the TouchNGo and SmartTAG, referred to as the single ETC system in the country [12]. This system uses IR technology, making it very vulnerable to failure. Other than that, users also have to bear the high cost of owning the two-piece tag required for this system. Thus, Malaysian highway authorities have been looking for alternatives, such as the multi-lane free-flow (MLFF) ETC system [12]. However, this proposed system requires major changes in the infrastructure of the existing toll roads. In contrast, the ETC system proposed in this paper will require only minimal changes. Moreover, the existing toll booths could be re-used with only slight modifications.

Instead of IR technology, the proposed ETC system will apply RFID technology. The concept is based on existing toll booths; however, human interaction is no longer required. The vehicles will be given a passive tag in the form of a sticker which could be affixed on the windshield, just like in the existing road tax system. Each time the vehicle passes the toll booth, the tag will be read and information will be transmitted to the main computer.

Road users also have the chance to choose either a prepaid or a postpaid tag. At the entrance point, the system will record the users' information with their preferred method (i.e., prepaid or postpaid). Then, at the end of the entrance point, the system will calculate the kilometers driven and then deduct payment straight from the tag (for prepaid users); if the balance is not enough, the barrier will still be lifted, but a warning email or an SMS will be sent to the owner. If the owner fails to pay the excessive amount, the tag will be barred. For the postpaid system, a bill will be sent to their respective homes at the end of every month. If the users fail to pay the amount, their tags will also be barred.

Using this system, all problems related to manual toll fee collection will be eliminated, thereby achieving a higher efficiency rate per transaction. This is because this system requires no human interactions that could lead to cheating and human errors. In addition, compared with the existing system, in which motorists need to pay hundreds of Ringgits in order to own the two-piece tag required, the proposed system would only motorists to pay minimal fees as the cost of the whole system is not as high as the existing system.

The proposed system also considers the size issue. All the system requires is a tag the size of a sticker, which could be affixed on the windshield. In this system, the tag used is is capable of withstanding all kinds of weather, and is much more durable compared with the one used in the existing system. The advantages of this proposed system is summarized as follows:

1. Higher efficiency in toll collection;
2. Cheaper cost;
3. Smaller in size compared with the existing system; and
4. Durable tags.

Figures 4(a)-(c) below illustrate the flow of the proposed system.

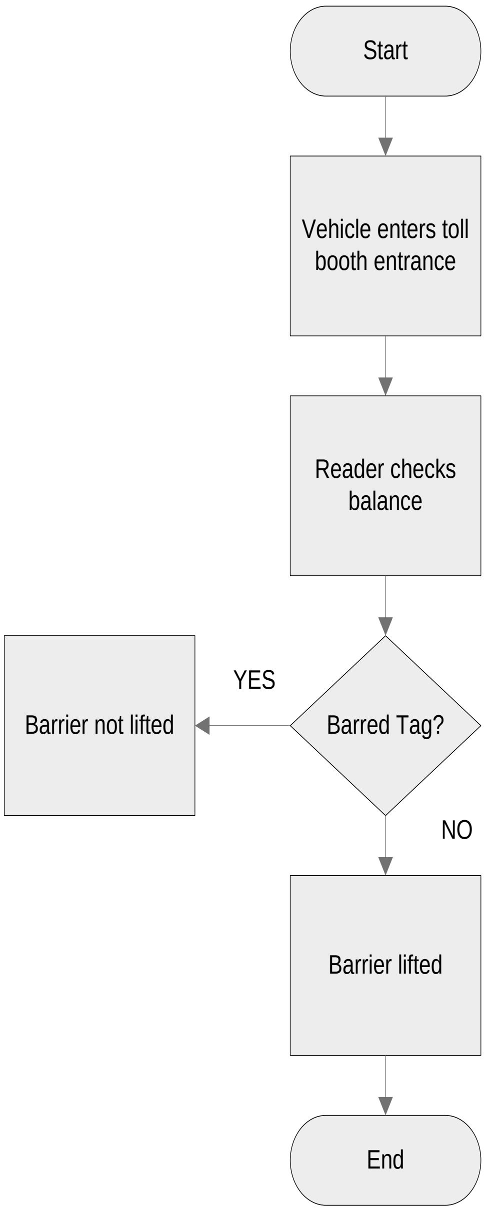

FIGURE 4A: Toll Gate Entrance Flow Chart (Prepaid and Postpaid)

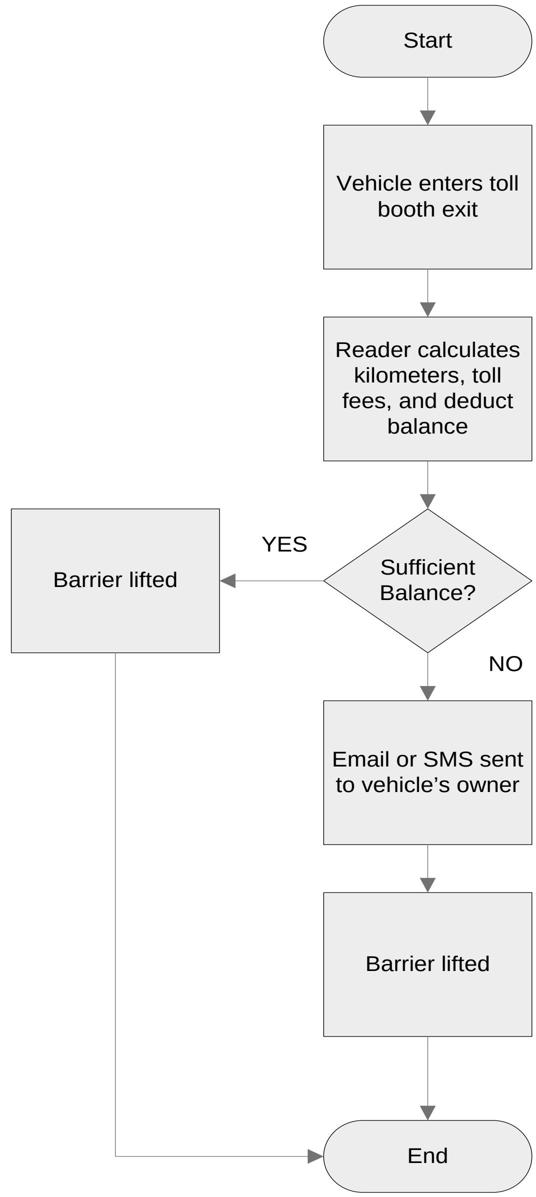

FIGURE 4B: Toll Gate Exit Flow Chart (Prepaid)

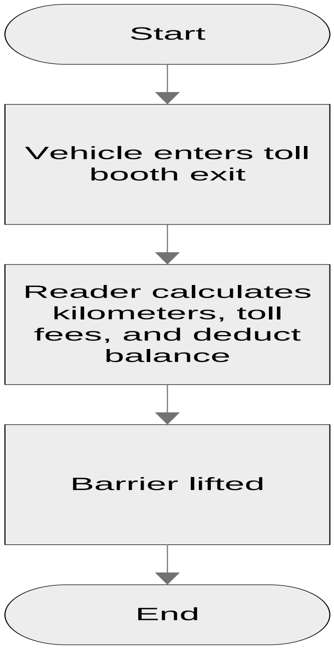

FIGURE 4C: Toll Gate Exit Flow Chart (Postpaid)

The differences among the proposed system and the ones discussed previously are illustrated in the table below.

Table 2: Differences Among the Other Systems and the Proposed System

	Toll Type	**System Used**	**Payment Method**	**Cost**
Canada	Closed Access (Gantries at the entrance and exit points)	OCR, Laser Beam	Postpaid	High
Poland	Closed Access (Gantries at the entrance and exit points)	GSM,GPS	Postpaid	High
Manila	Toll Booth	-	Postpaid	-
US Patent	Two lanes with gantries	Two antennas	-	-
Proposed System	Toll Booth	Passive RFID	Postpaid Prepaid	Low

IV. CONCLUSION

In this article, the authors have discussed various types of ETC systems applied in some countries. The proposed ETC system discussed in this work applies passive RFID technology. By doing so, increased efficiency will be guaranteed since RFID is known as a highly stable technology. With the elimination of human interaction in the entire toll collection process, we can create a better ETC system to be implemented in Malaysia. It can also significantly improve the efficiency of toll stations and the traffic abilities of the toll road.

V. ACKNOWLEDGMENT

This work has been supported by the USM and MOSTI from Techno fund grant.

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