To study the implications of Electronic Toll Collection System using RFID Technology

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Abstract :

Transportation is the backbone of any country's economy. Due to increasing number of vehicles on the road, problems such as congestion, air pollution and many others have become a major factor of concern. Traditional toll collection booths require a number of operations like stopping the vehicle, lowering the window, finding the correct coinage or valid card before travelers can continue their journey. This research paper describes the Electronic toll collection system based on Radio Frequency Identification (RFID) technology. As time and efficiency are a matter of priority nowadays, the traditional method has to be reformed. In order to overcome the major issues of traffic congestion and time consumption RFID technology is used. RFID reader fixed at tollgate frame reads the tag attached to windshield of vehicle. The object detection sensor in the reader detects the approach of the incoming vehicle's tag and toll deduction takes place through a prepaid card assigned to the concerned RFID tag that belongs to the owners' account. Electronic toll collection system (ETC) has various advantages compared to traditional method.

Keywords : Toll, Traffic congestion, Electronic Toll Collection system (ETC), RFID tag, RFID reader, Prepaid Card

Introduction :

Typical toll collection methods are manual collection, automatic toll collection via coin machines, and electronic toll collection (ETC). Manual toll collection is the simplest form of toll collection, in which a collector operating from a tollbooth collects the toll. Automatic coin machines allow collection of several methods of payments such as coins, tokens, smart cards, and credit cards without the need for a collector. Considering the current scenario, the numbers of vehicles passing through a tollbooth are substantially high; hence there is a need for an alternative solution for the toll collection method on the national highway which should be cost effective and efficient.

Electronic Toll Collection (ETC) has become a technically feasible and financially attractive alternative to finance and maintain highway construction projects and their ongoing maintenance operations. Beyond replacing cash collections to improve revenue accountability, ETC has evolved to support the digital age with technologies that safeguard toll revenues. It provides an improved patron experience by mobility, safety, convenience and even support for a "greener" world by reducing pollution. ETC is now a necessity and a daily part of many commuters lives.

ETC is the latest method for collecting tolls which aims to eliminate the delay on toll roads. Although it has been in use for more than 20 years, ETC continues to evolve. The ETC method allows vehicles to pass through a toll facility without requiring any action or stopping by the driver. ETC lanes improve the speed and efficiency of traffic flow and save drivers' time. An ETC system is capable of electronically charging a toll to an established customer account. As compared

to other methods ETC is eco-friendly and economically beneficial. An ETC system commonly utilizes radio frequency identification (RFID) technology. Radio frequency identification (RFID) is a generic term that is used to describe a system that transmits the identity (in the form of a unique serial number) of an object or person wirelessly, using radio waves. The waves coming from the RFID reader are not dangerous and are similar to those waves coming from car radio.

Components of RFID :

RFID is an automated data-capture technology that can be used to identify, track, and store information contained on a tag. A radio frequency reader scans the tag for data and sends the information to a database, which stores the data contained on the tag. A complete RFID system consists of a transponder (tag), reader/writer, antenna, and   database.

Figure 1: Main Components of an RFID System
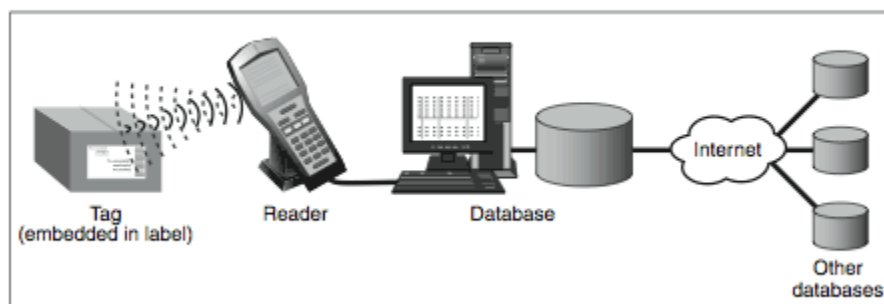
Source: GAO.

RFID Tag: An RFID tag, or transponder, consists of a chip and an antenna. A chip can store a unique serial number or other information based on the tag's type of memory, which can be read-only, read-write, or write once read-many(WORM). The antenna, which is attached to the microchip, transmits information from the chip to the reader. 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. Tags can also be classified based on the content and format of information. The classification ranges from Class 0 to Class 5 as follows :

Class-0 Gen-1 :- Read only, Passive tags
Class-1 Gen-1 :- Write once. read-many, passive tags
Class-1 Gen-2 :- Write many. read-many, passive tags

Class-2 :- Rewritable passive tags with extra functionality, including encryption and emulation
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 and3,can communicate with Class-4
Wirelessly

RFID Reader: In order for an RFID system to function, it needs a reader. RFID reader is a scanning device that is capable of reliably reading the tags and communicating the results to a database. A reader uses its own antenna to communicate with the tag. When a reader broadcasts radio waves, all tags designated to that frequency and within range will respond. A reader also has the capability to communicate with the tag

without a direct line of sight, depending on the radio frequency and the type of tag used.

Features of RFID :

- RFID systems can provide error-free, wireless data transmissions that are both battery-free and maintenance-free.
- RFID reader has High speed data capture ability that is time required to read the ID is about 10 ms.
- RFID has Simultaneous multi-tag reading ability to read about 10 to 50 tags per second.
- The stored data can be altered during sorting or they can capture the workflow or process information.
- RFID systems can usually work effectively even in harsh environments with excessive dirt, dust, moisture, and extremes of temperatures.
- RFID tags are electronically programmed with unique information.

- RFID tag cannot be duplicated hence, offers Security.
- Each paper-thin tag contains an etched antenna and a microchip with a capacity of at least 64 bits.
- Tags are available in one of three types: read-only; write-once, read-many (WORM); and read-write.
- Tags are read-only if the identification is encoded at the time of manufacture and not rewritable.
- Reading and writing is possible without line of sight, using electric and electromagnetic wave transmission.
- The read-many (WORM) tag's main advantage over a read-only tag is that information in addition to the identification number can be added; however, this information must be something that won't need to be changed.

Working of RFID Technology :
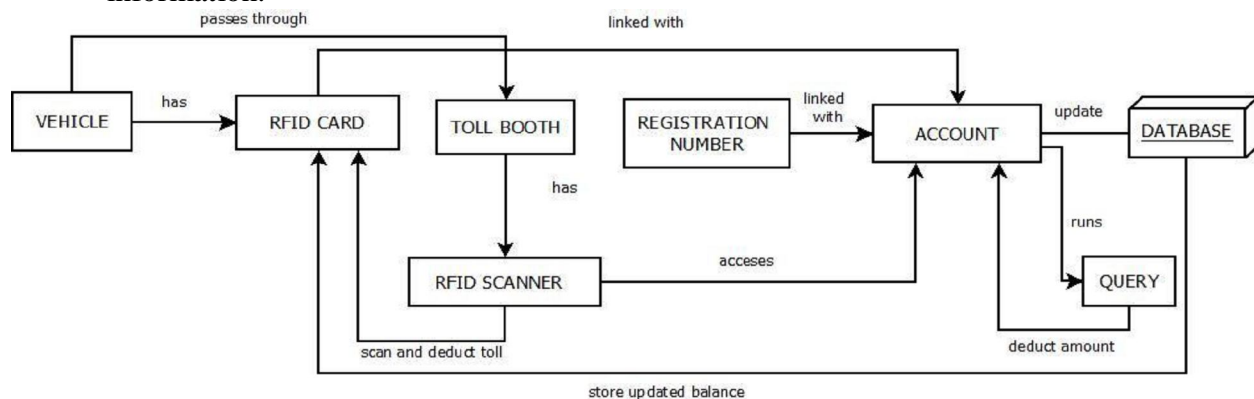
Whenever any person buys a vehicle, one first needs to get his or her vehicle registered at the RTO office. RTO officials will not only assign a number plate to it but also will give a RFID enabled tag. This card will have a unique ID feasible to use with that vehicle only. They will also create an account for the use of that particular smart card and maintain transaction history in database. User needs to deposit some minimum amount to this account. Every

time a registered vehicle approaches the toll booth, first the Infrared sensors will detect the presence of the vehicle. It will in turn activate the RFID circuit to read the RFID enable tag fixed on the rear-windshield of the vehicle. Transaction will begin; depending upon the balance available toll will be deducted directly from the user's account. The software further updates the details in the Centralized database server. It

also triggers mechanism to generate the bill and will be sent to user as a text message.

Working of Electronic Toll Collection System using RFID technology involves the following steps:-

- **Automatic Vehicle Identification (AVI) :** The AVI system is used to determine the identity of the vehicle which is passing through ETC tollbooth by using RFID tag for charging the toll to the corresponding customer. While passing through toll lane, a receiver communicates with the tag installed on the rear-windshield of the vehicle and reads the vehicle information.
- **Automatic Vehicle Classification (AVC) :** AVC system contains sensors installed at the toll lanes which is used to identify the type and class of vehicle for charging proper toll. Charge depends upon vehicles' weight and size. The vehicle type may include light vehicles or the heavy vehicles. A vehicle class can be determined by the physical attributes of the vehicle, number of occupants in the vehicle, number of axles in the vehicle.
- **Violation Enforcement Systems (VES) :** VES captures images of the license plates of vehicles that pass through an ETC tollbooth without a valid ETC tag. To identify and record violations, special cameras are used to take photographs from the violating vehicle's license plate. VES helps in tracking of theft vehicle.

Implications of ETC :

The manual method of toll collection is a lengthy process that involves many tasks like stopping at the toll, giving change to the tollgate operator, collecting receipt and change. The main issue in this method is waiting in long queues which results in more fuel consumption for the vehicles, as the vehicles has to be in deceleration and reacceleration. The concerned tollbooth operator also has to maintain the record of the daily cash flow in the system which may be tedious. Thus the labour cost involved in this process is more. In current scenario of manual method sometimes the driver becomes confused about the queuing and after long waiting of time he comes to know that it was not a proper queue which results in different issues like quarrelling and traffic congestion. Due to Corruption at toll plaza less transparency occurs in this method.

Besides this, the ETC method using RFID technology results in faster and more efficient service, fewer and shorter queues, cashless, paperless transaction and better audit control. Implementation of ETC provides substantial reduction of fuels thus diminishing air pollution. By using ETC the lane throughput is increased and queuing delay is minimized. It also provides anti-theft solution system module which prevents passing of any defaulter vehicle.

Benefits of ETC :

1. Congestion reduction -- The toll transaction rate is highly increased due to the use of ETC system. Since the vehicles do not stop at the toll facility, the throughput is highly increased. This has considerable effect on the congestion of the toll plaza. As the proportion of the ETC users increases the congestion in the manual as well as the automatic lanes is also reduced. The average number of vehicles waiting in the queue reduces and so the average waiting time is reduced.

2. Increased Capacity -- It is observed that the capacity of the electronic lane increases by three fold. The toll plaza would be able to accommodate the increasing traffic without requiring building additional lanes.

3. Fuel saving -- The deceleration, acceleration and idling is completely eliminated. This results in gas saving for the patrons using ETC. Besides the elimination of acceleration and deceleration results in

reduction of the operating cost of the vehicles.

4. Operating cost saving -- Over a period of time, the toll collecting cost is reduced. There is reduction in the man-hour required as the system does not require any human interaction for the toll transaction.

5. Time saving -- ETC users do not stop for paying toll, thus there is considerable saving in the travel time. Besides the travel time reliability is increased as the travel time can be estimated fairly accurately.

6. Emission control -- Due to the elimination of the acceleration and idling, vehicular emissions are reduced. Though this benefit only effect the surrounding area it is seen that there is an increase in the highway financing by building toll plazas. In many non-attainment areas as declared by Environment Protection Agency (EPA), ETC seems to be one of the possibilities for air pollutant reduction.

7. Enhanced cash handing -- There is no cash transaction for the ETC lane so cash handling is reduced so difficulties with cash handling is eliminated. Thus aid in enhanced audit control by centralizing user accounts.

8. Payment flexibility -- The patrons do not have to worry about searching for cash for the toll payment. Since the patrons set up account for ETC usage it gives customers the flexibility of paying their toll bill with cash, check, or even credit cards.

9. Enhanced data collection -- Information such as vehicle count over the time of the day, date, time etc can be obtained due to the deployment of this technology. This helps in making decisions regarding the pricing strategies for the toll providers. It also helps planner to estimate the travel time that aid in designing decisions.

10. Incident reduction -- It is observed that there is reduction in the number of incidents caused near the toll plazas. Due to various advantages of electronic toll collection system using RFID technology the mental stress on driver is minimized leading to less number of incidents.

Scope of Electronic Toll Collection System using RFID technology in India :

The study shows that many developed countries are effectively using ETC technology. In India ETC technology is at development stage. Ministry of Road Transport and Highways has aimed to make all toll-plazas on national highways across India ETC enabled. This will greatly enhance user experience and enable fuel saving worth Rs 86,000 crore. Indian Highways Management Company Limited (IHMCL) has signed an agreement for provision of Central Clearing House (CCH) with Axis Bank and ICICI Bank. The Ministry has decided to roll out ETC programme in the country under the brand name "FASTag". The dedicated ETC lanes will have color coding for distinct identity recognized as "FASTag lanes". ICICI Bank and Axis bank, engaged for providing CCH services, would distribute RFID based "FASTag" through their franchises/agents and at points of sales near the toll plazas. Road users can enroll and get "FASTag" affixed on their vehicles at designated toll plaza locations or Point of Sale (POS) stations of Axis bank and ICICI bank. If this system is implemented precisely and rapidly at all the national highways then it will help to grow India's economical condition.

Conclusion and Observations :

1. Government should make it compulsory for automobile or vehicle manufacturers to install RFID tags on every vehicle.

2. Government should frame a fix policy and make it compulsory for toll collection agencies to maintain centralized server at government office and to implement RFID based readers.

3. Government should take support of RBI and banking authorities to have

direct deduction of toll amount from individuals account.

4. ETC is useful for increasing central government economy.

5. Every vehicle owner must cooperate with government policy and change the mentality and should take this with positive spirit.

6. Electronic Toll Collection system using RFID is effectively used for tracking of vehicle.

7. It is an efficient and reliable way to collect, manages, analyze and store information of tollbooth.

8. ETC using RFID provides a precise solution for the issues such as traffic congestion, air pollution and fuel consumption which are at high risk.

9. It also provides healthier and eco friendly environment and longer vehicle life.

10. ETC using RFID removes bottlenecks and ensure seamless movement of traffic.

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