A Review on Automatic Toll Collection System

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Abstract

One of the most crucial elements for any country's development is logistics, or transportation. Since India is one of the world's largest nations, road transportation plays a vital role in the country's economy. For any government, having fast road transit becomes essential, and toll plazas are essential to this. The most commonly used toll systems in India at the moment are the manual toll collection and fastag systems. Toll plaza processing times rise as a result of their need for a toll collector or attendant. The Automatic Toll Collection System, or ATCS, is a tool used to automatically collect taxes. Here, radio frequency is used to help in identification. An RFID tag will be attached to a car. This tag is nothing more than an allocated unique identification number. The RTO, or traffic controlling body, will assign this. We shall keep all of his basic data and the amount he has paid in advance for the TOLL collection in line with this number. At the toll collection facility, the reader will be positioned strategically. His prepaid balance will be reduced by the tax amount each time the car passes the toll collection centre. This essay discusses several automated toll collection systems that are intended to improve overall transportation efficiency, ease toll payment procedures, and lessen traffic congestion. The suggested method computes toll fees automatically by utilizing cutting-edge technology including mobile communication, GPS, and RFID (Radio Frequency Identification).

Keywords: Radio Frequency Identification**,** Global Positioning System, Electronic Toll Collection, Dedicated Short-Range Communication, Automatic Number Plate Recognition, National Electronic Toll Collection, National Payments Corporation

1. Introduction

Transportation system efficiency is critical to both economic growth and societal convenience in today's fast-paced society. Toll collecting systems are essential elements of contemporary transportation infrastructure, serving as a means of controlling traffic volume, financing road upkeep, and providing smooth travel for millions of commuters across the globe. Conventional toll collection techniques, which depend on either manual transactions or RFID-based technologies, have shown themselves to be progressively unable to meet the growing needs of expanding populations and increasing volumes of traffic.

Automatic toll collecting systems have become a viable solution to these problems, providing improved accuracy, efficiency, and convenience. By removing the need for actual toll booths, expediting transactions, and reducing traffic on roads, these systems transform the tolling experience by utilizing

cutting-edge technology like GPS, mobile connectivity, and machine learning algorithms. The goal of this review article is to give a thorough overview of the most recent developments in automatic toll collection systems. Through an amalgamation of current developments, essential techniques, and execution tactics, this article aims to clarify the fundamental ideas propelling the progression of these inventive toll schemes. It will also examine the numerous advantages enjoyed by all parties involved, including governmental organizations, transit authorities, service providers, and—above all—commuters. Review topics will include technological architectures, operational frameworks, economic ramifications, regulatory concerns, and societal impacts related to automated toll collection systems. It will investigate the convergence of transportation engineering, information technology, economics, and policy via a multidisciplinary lens, illuminating the intricate relationship between technology, infrastructure, and governance in determining the direction of tolling systems in the future.

Key topics to be addressed in this review include:

Technological Foundations: A thorough examination of the backend processing algorithms, GPS location, wireless connectivity, and vehicle identification sensors that power distance-based toll collection systems.

Operational Modalities: Examination of the many operating modalities used in distance-based tolling, such as cellular network-based and satellite-based systems, as well as the advantages, disadvantages, and deployment concerns of each.

Economic and Financial Implications: Evaluation of distance-based toll collection systems' financial sustainability, cost-effectiveness, potential for revenue generation, and economic feasibility with an emphasis on comparisons with conventional tolling techniques.

Regulatory and Policy Frameworks: Analysis of the laws, rules, privacy issues, and standards of interoperability that control the implementation and functioning of remote based tolling programs in various jurisdictions.

User Experience and Societal Impact: Evaluation of the convenience, accessibility, equity, social justice, and environmental sustainability of distance-based toll collection systems, as well as their effects on society.

2. Different Automatic Toll Collection System

Systems for automatically collecting tolls use a variety of technologies to make toll payments easy and eliminate the need for human interaction. The following are a few varieties of automated toll collection systems:

- RFID-based Systems
- DSRC (Dedicated Short-Range Communication)
- ANPR (Automatic Number Plate Recognition)
- GPS-based Systems
- Mobile Payment Apps
- Satellite Tolling

2.1 RFID-based Systems: Radio waves are used in Radio Frequency Identification (RFID) technology to transfer data between a transponder (tag) on the car and a reader device at the toll booth. The toll is

immediately taken out of a prepaid account connected to the transponder when the car goes through. RFID technology is used by US systems like Sun Pass and EZ Pass [5].
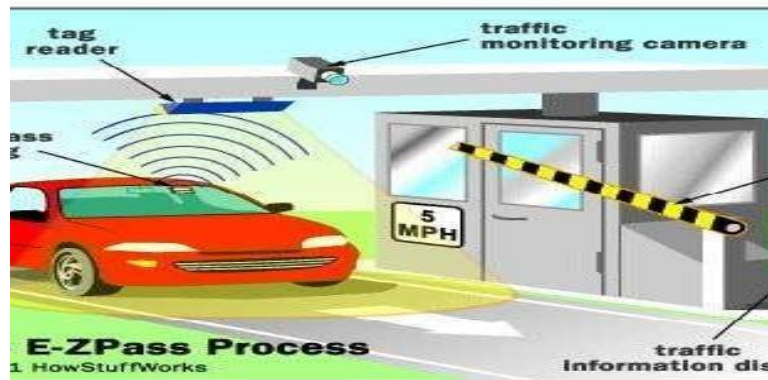

Figure 2.1 RFID based Toll gate system [1]

The manual toll collection method can be replaced with an RFID based toll plaza system. By using this technique, toll tax is taken out of the owner's account and details on the vehicle going through the toll gate are obtained. This can enable the car to pass through tollgates without stopping. This lessens traffic on highways where congestion is caused by clogged traffic streams. This results in a more convenient tollgate transaction and lowers pollution levels, fuel consumption, and waiting times [1].
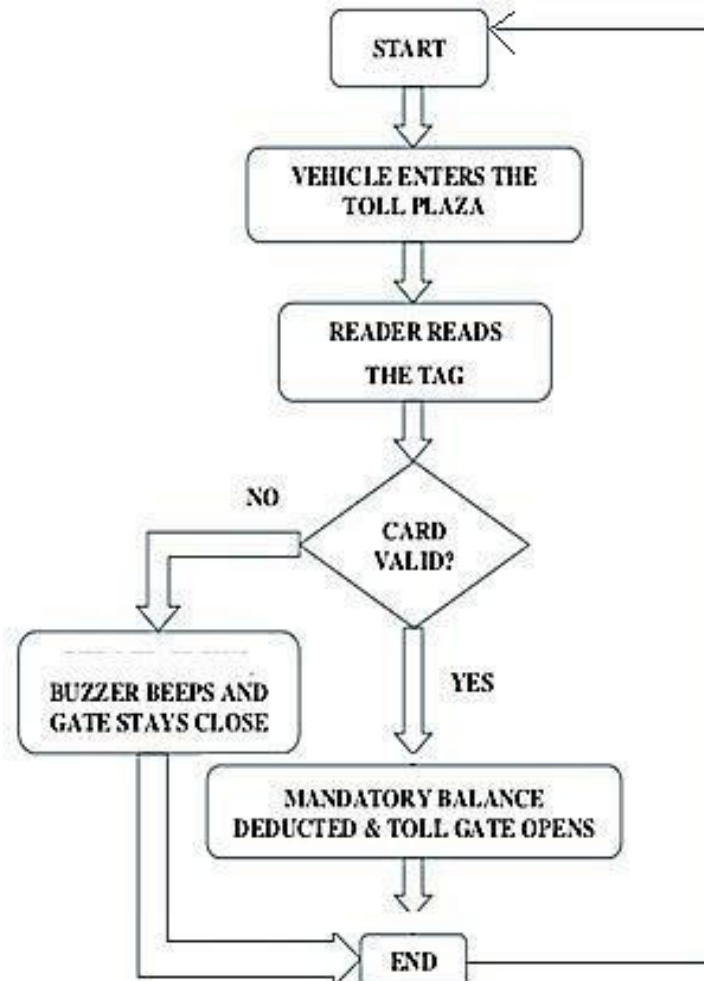

Figure 2.2 Algorithm for RFID system [1]

The benefits and drawbacks of RFID based system are as follows:

Benefits:

- Efficiency: RFID technology reduces waiting times and improves traffic flow at toll booths by enabling rapid and automatic toll collection without the need for human interaction.
- Increased Accuracy: Compared to manual toll collection techniques, RFID technology offers precise and dependable data on vehicle movements, minimizing errors and possible revenue leakage.
- Integration Potential: RFID systems have the ability to be combined with other transportation management systems, including electronic toll collection (ETC) networks. This allows for streamlined operations and interoperability between various toll roads and transportation networks.

Drawbacks:

- Privacy Concerns: Because RFID tags can be used to track the movements of vehicles, some drivers may find it uncomfortable to be continually watched.
- Tag Installation: Drivers must buy and correctly install RFID tags on their cars. Some drivers, particularly those who don't frequently use toll roads, may find this to be inconvenient.
- Technological Obsolescence: RFID-based toll collection systems could eventually become outdated when more sophisticated, newer technologies surface, which could require expensive upgrades or replacements. This is a risk inherent in any technology.

2.2 DSRC (Dedicated Short-Range Communication): DSRC technology facilitates communication between roadside equipment and a vehicle-mounted transponder, much like RFID technology does. Electronic toll collection systems such as Fastrack and IPass frequently use it.
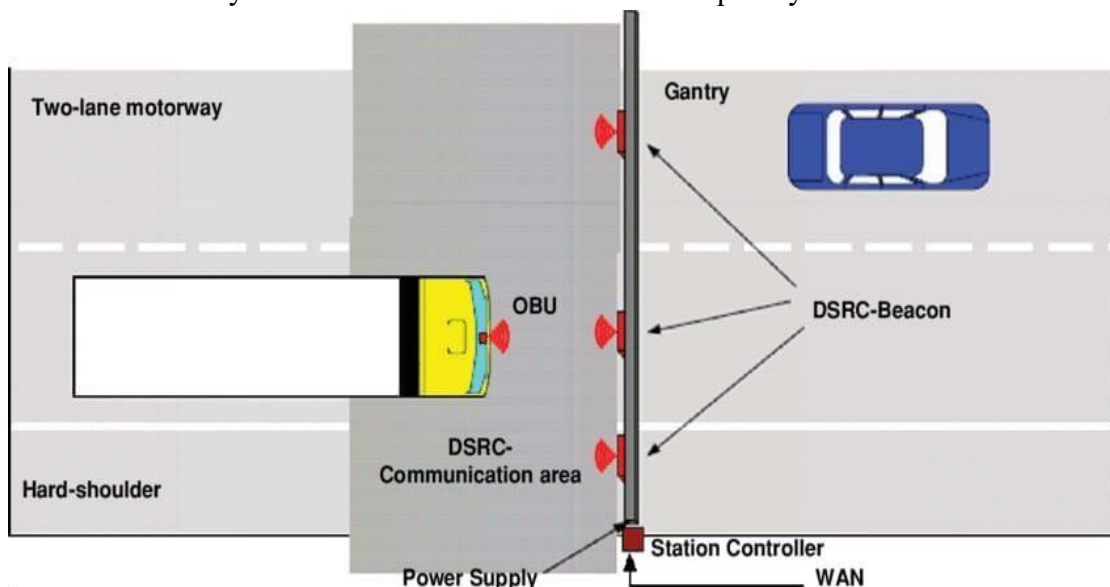

Figure 2.3 DSRC system [3]

One complicated problem that commonly arises in large cities is congestion. Congestion affects not just arterial routes but even toll roads. On toll roadways, the present toll gate system requires electronic payment processes. The medium is a FASTag with an RFID basis. The driver must stop at the automated toll gate in order to tap the electronic toll card while using this technology. On the other hand, the relatively lengthy reading time frequently results in increased traffic jams. The goal of this research is to create a DSRC-based system that will reduce traffic jams [3].

The benefits and drawbacks of DSRC based system are as follows:

Benefits:

- Fast Transaction Speed: By enabling quick and efficient toll transactions, DSRC helps to reduce traffic at toll plazas by facilitating fast communication between the vehicle and the toll collection system.
- Convenience: Drivers can pass through toll booths without stopping with DSRC-based toll collecting systems, which facilitates smoother traffic flow and shorter travel times.
- Interoperability: Drivers can use the same electronic toll collection (ETC) device on a variety of toll roads and bridges thanks to DSRC technology, which makes it easier for different tolling agencies and systems to communicate with one another.

Drawbacks:

- Compatibility Problems: Although DSRC promotes interoperability, there may be problems with compatibility between various tolling systems and ETC devices, particularly when moving between areas with various protocols or technologies.
- Restricted Coverage: Drivers traversing various locations may find that DSRC based toll collecting systems are not widely used, and their coverage is restricted to particular regions or toll highways.

2.3 ANPR (Automatic Number Plate Recognition): While ANPR systems and LPR are comparable, ANPR systems may include more sophisticated capabilities, such as character recognition algorithms and infrared cameras for nighttime operation, to reliably scan license plates. Globally, they are extensively employed in toll collection systems [5].
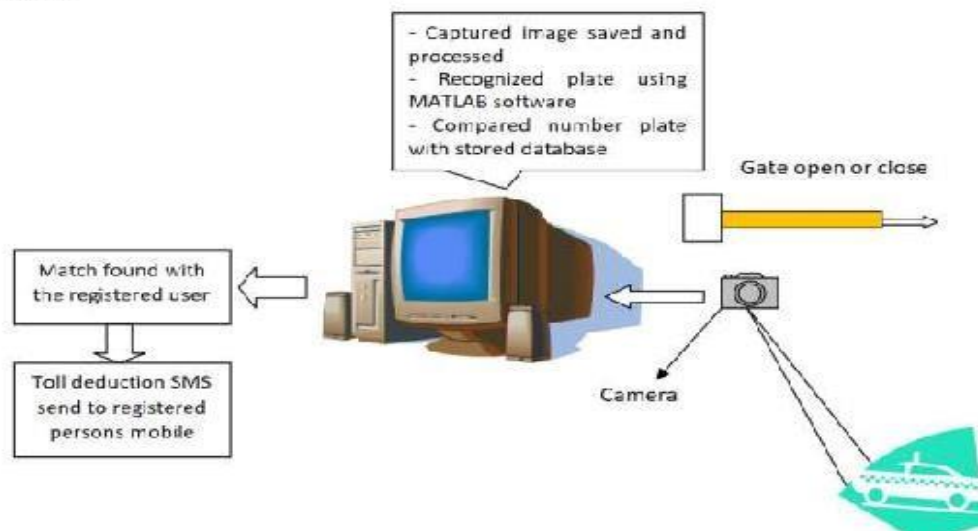

Figure 2.4 Proposed ANPR system model [6]

The suggested system paradigm is depicted in Fig.2.4 which combines the vehicle number plate database kept in the central system with the ANPR algorithm for number recognition. When an IR sensor detects the presence of a car, a digital camera takes a picture of the vehicle. The ANPR algorithm handles the processing of it. Next, a database that has been stored is compared with the identified number. The toll gate will open and permit a vehicle to pass through if the customer's vehicle number plate shows Access Granted."
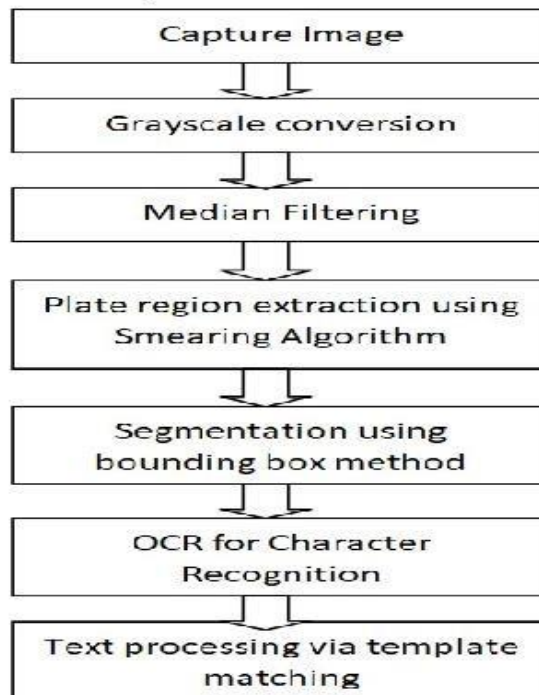
Figure 2.5 Image processing flowchart for ANPR [6]

Another instance states that the toll gate will remain closed and display the message "Attention required" if the customer's car is unregistered or unlicensed. The user's account will be debited for the toll amount, and they will receive an SMS on their mobile device informing them of this. System processes images using MATLAB software [6].

The benefits and drawbacks of ANPR based system are as follows:

Benefits:

- **Increased Security:** Toll Road security can be improved by integrating ANPR systems with security databases to identify vehicles that are associated with criminal activity or that have outstanding warrants.

- **Data Collection:** ANPR systems are capable of gathering information on vehicle movements, traffic patterns, and toll income. This information is useful for revenue management and transportation planning.

Drawbacks:

- **Privacy Issues:** Because ANPR technology records and continuously monitors vehicle movements, privacy issues are brought up. There are worries that this information could be misused for illegal person tracking or spying.

- **Technical Restrictions:** In some situations, such as inclement weather, dim lighting, or obscured plates, ANPR systems may have trouble correctly obtaining license plate numbers, which could result in inaccuracies in toll collection.

2.4 GPS-based Systems: Certain toll collecting systems use GPS tracking to monitor a car's movements and identify when it enters or leaves a toll zone. The amount of the toll is then determined by the distance travelled. While GPS-based tolling is less widespread for highway tolls, it is employed in certain urban congestion pricing schemes [8].

The toll collection system, particularly in India, has a number of issues, including lengthy wait times and people trying to get out of toll plazas. Only 300 vehicles can be serviced by these systems in an hour, therefore significant traffic jams might happen if more vehicles arrive at that plaza than that capacity. Our solution to this problem is to use GPS to establish geofences by providing the latitude and longitude of the toll plaza corner. The owner of the car may be debited from the account by comparing the position of the vehicle and the toll plaza.
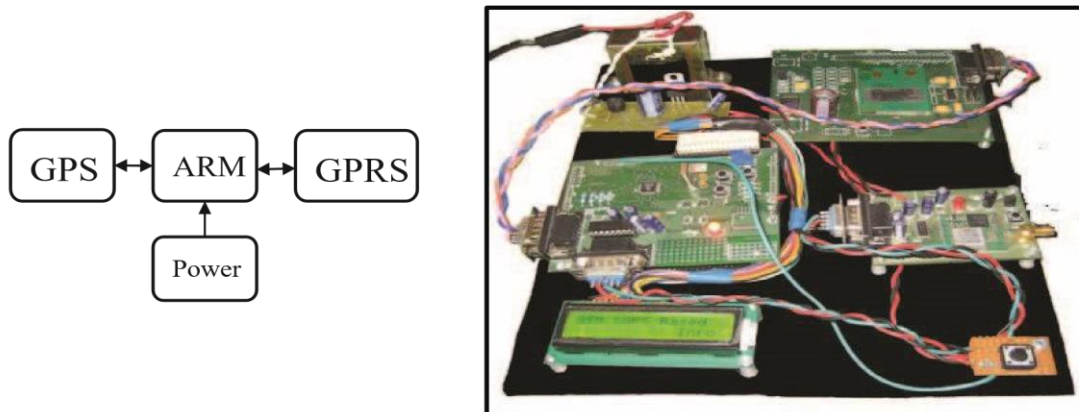

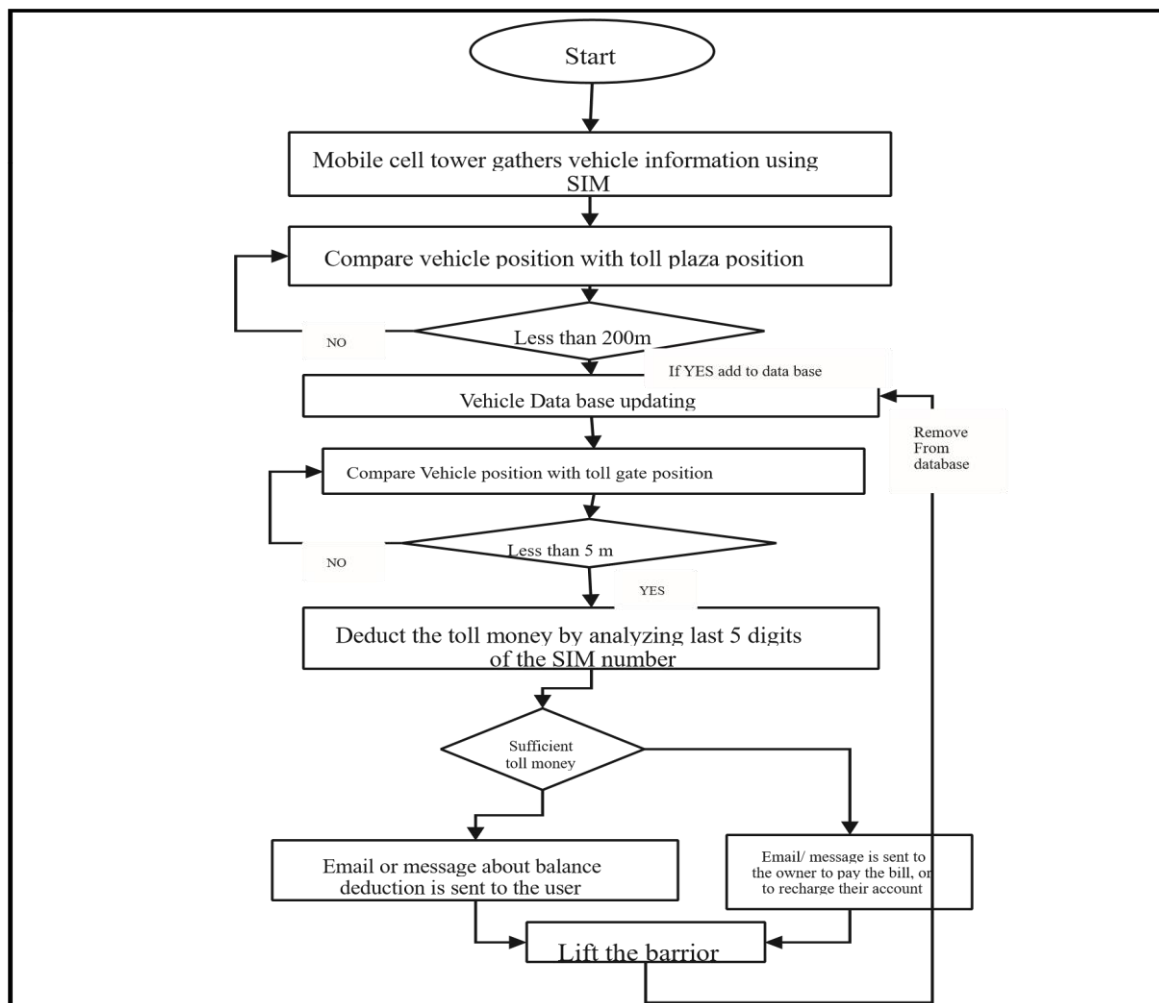**Figure 2.6 Block Diagram and Hardware of the card in the vehicle [9]**

Figure 2.7 GPS-based system flowchart [9]

The benefits and drawbacks of GPS based system are as follows:

Benefits:

- **Lessening of Traffic Congestion:** By removing the requirement for cars to stop at toll booths, GPS-based toll collecting systems can help reduce traffic congestion. As a result, travel times are shortened and less fuel is used on highways and toll plazas.
- **Cost Savings:** GPS-based solutions can lower the administrative expenses related to running toll booths by optimizing the toll collection process. This may result in cheaper toll prices for users as well as cost savings for toll operators.
- **Increased Accuracy:** GPS technology allows for exact location tracking, which can lead to toll estimates that are more accurate depending on variables like time of day, kind of vehicle, and distance travelled. This can lessen toll collection errors and guarantee fair toll pricing.

Drawbacks:

- **Privacy Issues:** Because GPS-based toll collecting systems necessitate continuous tracking of vehicle movements, there are privacy issues with the gathering and application of location data. It's possible that users are reluctant to provide toll authorities or other third-party service providers access to their location data.
- **Security Risks:** Hacking and spoofing attacks, in which malevolent actors alter GPS signals to avoid paying tolls or interfere with system operations, can pose a threat to GPS-based toll collection systems. To reduce these risks, it is crucial to guarantee the security and integrity of the GPS-based tolling system.

2.5 Mobile Payment Apps: Given how common cell phones are, a lot of toll companies have mobile apps that let drivers use them to pay their tolls online.
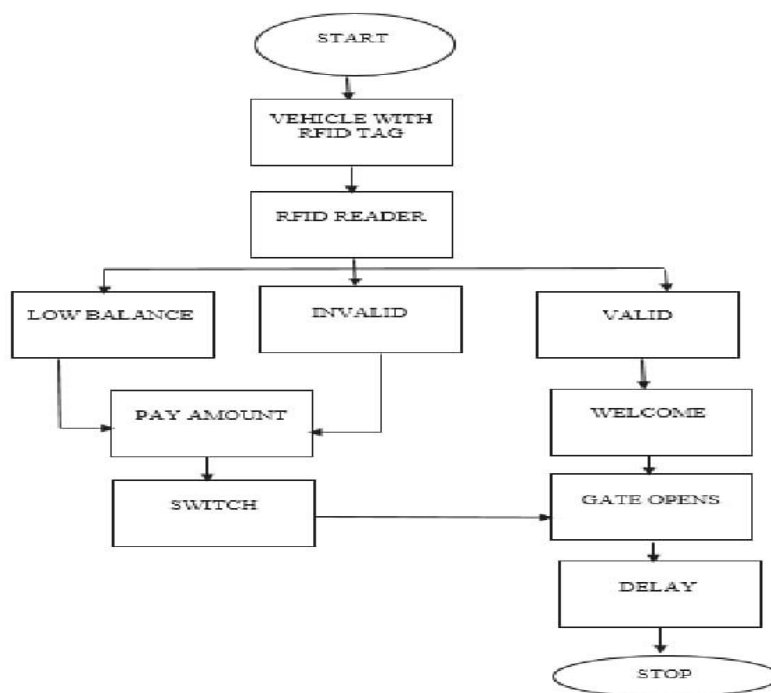

Figure 2.8 System flow chat for mobile payment application [14]

These apps usually deduct money from a linked account and calculate toll charges using a combination of GPS and payment processing technology. We are developing a brilliant approach based on Android app communication to reduce this traffic and time consistency. The three modules of this application are Tollgate, Client, and Admin. Clients register on this app and pay their tollgate fees, which reduces human labour and consequently boosts the pace at which vehicles pass the toll booth. The admin will then validate the tollgate with his or her details. Additionally, it permits cars to just pass through the booth [14].

To satisfy the electronic tolling needs of the Indian market, National Payments Corporation of India (NPCI) created the National Electronic Toll Collection (NETC) program. It provides a nationwide, interoperable toll payment solution with clearinghouse services for dispute resolution and settlement. When it comes to the National Electronic Toll Collection (NETC) system, interoperability refers to a shared set of procedures, corporate guidelines, and technological requirements that allow users to pay with their FASTag at any toll plaza, regardless of who owns the toll plaza.

Figure 2.9 NETC Transaction flow through mobile payment apps [15]

The benefits and drawbacks of mobile payment app-based system are as follows:

Benefits:
- Quicker Transactions: When compared to conventional cash or card payments, mobile payment apps enable quicker transactions. This may contribute to less traffic jams at toll booths, resulting in more efficient traffic flow and shorter travel times.
- Lower Costs: By implementing mobile payment technologies, toll booth maintenance and cash handling expenses can be decreased. It lowers the possibility of theft or fraud and does away with the requirement for physical currency handling.
- Accessibility: Many people, even individuals who might not have access to credit cards or traditional banking services, can use mobile payment apps. Users can quickly pay for tolls as long as they have access to the internet and a smartphone.

Drawbacks:
- Technology Dependency: Smartphones, internet access, and payment processing networks are just a few examples of the technological infrastructure that mobile payment systems rely on. Payment errors or delays could result from any interruptions or technical problems with these services.
- Security Issues: Hacking, malware, and illegal access are just a few of the security risks that mobile payment apps could face. Concerns over the security of their money and personal data may arise from users when using these apps for transactions.

- Transaction Fees: For toll payments, certain mobile payment apps may impose transaction fees or other service charges. This could raise the total cost to consumers, especially those who frequently use toll roads.

2.6 Satellite Tolling: Automated toll collection is made possible by utilizing satellite communication in immersion technology. In order to track cars and determine toll amounts based on where they are in relation to toll zones, these systems use satellite positioning.
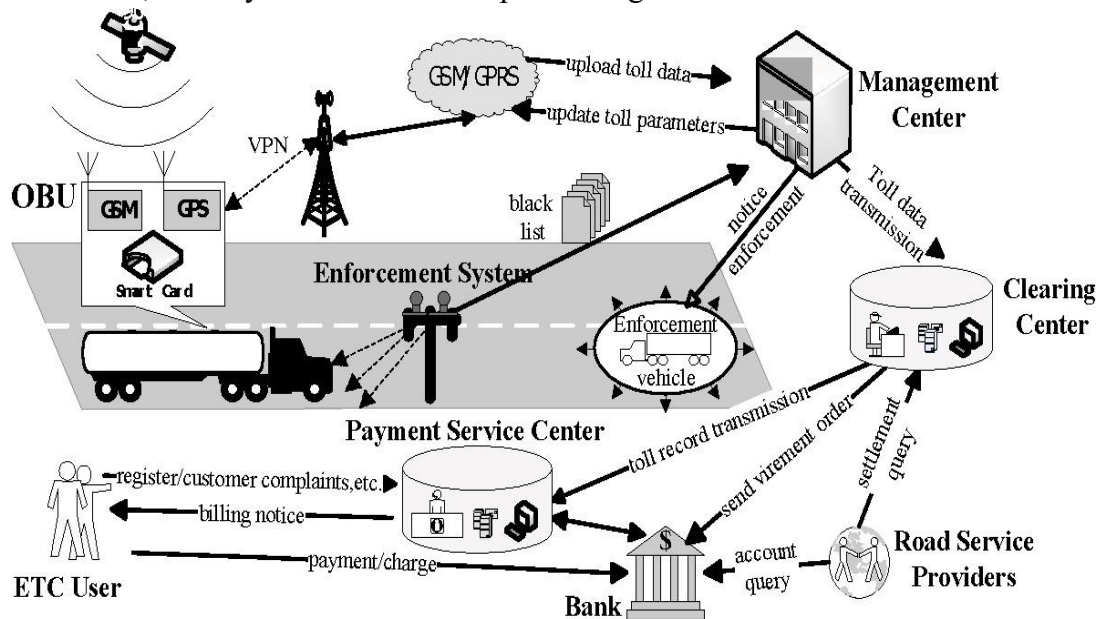

Figure 2.10 Architecture satellite based ETC system [16]

Fig. 2.10 depicts the system architecture of the GPS-based ETC system, which consists of five main components: the money payment centre, the control unit, the manual toll collecting team, the interface hardware device, and the transaction management unit. The following protocol describes how the GPS-based ETC system operates: Drivers register, install an interface hardware device, apply for a pre-paid or post-paid card, and head to the money payment centre. When a vehicle enters a toll region, an interface hardware device uses GPS to compare the current vehicle location coordinate with a virtual toll node point that is stored in the device's storage. The integrating hardware device establishes a wireless communication channel via the GSM module following logistic determination. Through the mobile network, an integrating hardware device uses the GSM module to transmit transaction messages to the control system. Following an audit, the control system returns transaction information to the interacting hardware device and records toll data. When the interacting hardware device gets the transaction result and shows it, everything is operating as it should. In the event that a transaction error occurs, there may be an issue with the interface device or improper installation. If the car does not install an Interfacing hardware device or if the Interfacing hardware device is in an abnormal state when the vehicle passes the charging zone, the violation will be handled. All information is cleared by the transaction control unit. Toll records and clearing data are gathered by the Money Payment Centre for account inquiries. Issue Configuration and Notes GPS is used to obtain latitude and longitude as input. Vehicle Location is the output. Result: Getting a notification regarding the balance deduction [16].

The benefits and drawbacks of satellite tolling are as follows:

Benefits:

- Lessened Environmental Impact: Satellite-based toll systems can lessen emissions and promote environmental sustainability by cutting down on waiting times and vehicle idling.
- Enhanced Revenue Collection: By lowering the possibility of fraud and toll evasion, these solutions can improve the accuracy of revenue collection.
- Scalability: Satellite-based systems are appropriate for toll collecting on roads and expressways because they are easily scalable to cover a wide geographic region.

Drawbacks:

- Technology Dependency: These systems mostly rely on satellite technology, which is prone to disruptions from bad weather, malfunctioning hardware, or outside influence.
- Privacy Issues: Since satellite-based toll systems detect the movements of cars, there are privacy issues with data gathering and monitoring.

3. Result and Discussion

Serial No.	Name	Method	Impact	Authors (Year)
1.	RFID	The simplest ETC technology is radio-frequency identification (RFID), which is equipped with an IVU (in-vehicle unit) mounted on the car's front windshield. It has a cash card inside to pay the toll. This is scanned by the RFID frequency scanner at the toll booth. It may be paid for in advance or after.	It is less expensive than any other ETC technologies in comparison.	Neeharika Bakhla, Abhishek Kumar, Fanilal, Jayparkash (2018) Chattoraj et al. (2017)
2	DSRC	The 5.9 GHz band is used for dedicated short-range communication (DSRC), which is one-way or two-way wireless communication across short to medium distances. In 2003, it was employed in ETC in Europe and Japan.	Blind spots, traffic data gathering, collision warning, impending vehicle warning, and other features are all possible with DSRC.	N. Kishore Chandra Dev, D.S.N. Sindhu, A. Lavanya, B.T.S.N.S.Vivek, Ch.Balaji (2023)

3	ANPR	Automatic number plate recognition (ANPR) is the technique that uses optical character recognition on photographs to scan car registration plates and create vehicle position data. Police departments all throughout the world employ ANPR for law enforcement, including confirming that a vehicle is registered or licensed.	This method detects disqualified or suspended drivers in addition to unregistered and stolen automobiles. It is additionally useful for enforcement of speed limits. It facilitates easier car tracking.	Dr. P. B. Mane, Gayatri Bade, Varsha Patil (2019) Ajanthan (2013)
4	GPS	GPS and GMS are the cornerstones of the Global Navigation Satellite System (GNSS). It has many different applications. The user pays technique is the basis of tolling.	It can greatly increase tax collection, lessen its negative effects on the environment, and improve transportation efficiency. However, careful planning and execution are required to fully achieve these advantages.	Sudheer Kumar Nagothu (2016) Numrich (2012)
5	Mobile Payment App	A mobile payment software that incorporates automatic toll collecting enables customers to make payments conveniently and without using cash or paper toll cards. It also simplifies the toll collection procedures for toll operators, which eases traffic flow and reduces congestion.	It is a big step toward improving consumer comfort, updating transportation infrastructure, and increasing toll operators' operational efficiency.	Shridevi Soma, Pavitra (2019)
6	Satellite Tolling	Automatic toll collecting systems that use satellite based tolling usually make use of Global Navigation Satellite Systems (GNSS), which include the GPS (Global Positioning System) and other comparable systems like Galileo or GLONASS.	This system is a paradigm shift in the tolling infrastructure; it offers many advantages in terms of accuracy, efficiency, and user experience, but it also poses issues that need to be properly handled in terms of privacy, security, and equity.	Ms. Kirti A. Lonkar, Ms. Pratibha P. Kulkarni, Ms Monalisa Dash, Mr. Abhishek Dhawan, Mr. Hemant, R.Kumbhar, Mr. Monika, P.Gagtap (2014)

4. Conclusion

This study provides an overview of various Automatic Toll Collection (ATC) systems and their effects on transportation industries. The first section of this study lists the pertinent ATC technologies that have been identified and are widely employed in developed nations. With time, automated toll collection systems have developed to provide a range of choices suited to various situations and requirements. The choice of system is based on various considerations, including cost, coverage, accuracy, and scalability. Each type has pros and cons. Additional advancements in automated toll collection are anticipated as technology develops, with the goal of enhancing driver convenience and streamlining traffic on toll roads.

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