Smart GPS-Based Toll Collection System

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***Abstract*— In the context of the rapidly advancing digitization landscape, especially prevalent in developing nations like India, the need for efficient toll collection systems has become increasingly apparent. The proposed Smart GPS-based Toll Collection System represents a significant stride towards addressing this imperative need. By integrating GPS technology with an Arduino board, this innovative system revolutionizes toll collection processes. The users can be charged precisely for the distance they cover on highways, thus eliminating instances of overpayment and providing a fairer tolling experience. This system operates by marking entry and exit coordinates, leveraging a GPS-based distance algorithm to accurately calculate the distance and toll fees and display the same on an LCD. Computation is carried out in real-timewithin an Arduino Board, ensuring transparency and reliability in toll calculations. By streamlining toll collection processes and eradicating errors, the Smart GPS-based Toll Collection System offers a transparent, efficient, and equitable alternative to conventional tolling methods, contributing to alleviating traffic congestion and enhancing the overall travel experience for commuters.**

***Index Terms*—Arduino, GPS, LCD Display, Toll Gate**

I. INTRODUCTION

The undertaking ambitions to revolutionize tolling infrastructure the usage of GPS technology, particularly through a "Smart GPS-Based Toll Collection System." At present, the FAS Tag system uses Radio Frequency Identity (RFID) technology for automated toll payments. FAS Tags are fixed to vehicle windscreens, and when a vehicle crosses a toll plaza, the RFID reader scans the FAS Tag, and deducts the toll amount robotically from the linked pay as you go. But, the proposed Smart GPS-Based Toll CollectionSystem is an innovative approach that streamlines toll collection strategies, eliminates congestion, reduces operational expenses, and complements consumer experience. by automating transactions and promoting cashless payments. In nowadays speed-paced highways wherein efficiency and convenience are critical, conventional toll collection techniques have end up a bottleneck in clean traffic drift. Long queues, guide transactions, and bulkyprocesses waste time and make a contribution to environmental pollution and multiplied fuel consumption. but, the advent of Smart GPS-Based Toll Collection System structure heralds a new technology in transportation control.

The creation of the Smart GPS-Based Toll Collection System marks a giant development in transportation management This innovative project leverages GPS era to automate toll collection methods, disposing of the need for bodily toll booths and guide transactions, as well as the current Fastag machine. As cars prepared with GPS devices approach toll zones, their area and identity are communicated to a centralized manipulate gadget, allowing accurate toll rate calculations based totally on factors consisting of distance travelled, and relevant toll charges.

II. LITERATURE REVIEW

According to Goutham K., Goutham, and Megalan Leo, a GPS-based system might significantly reduce traffic congestion at toll plazas [1].

Automated toll collection systems have consistently demonstrated their effectiveness in enhancing traffic flow efficiency. This method is recognized as one of the most straightforward solutions for alleviating traffic congestion. In the current system, vehicle owners are required to register their bank accounts with RFID technology. Consequently, a predetermined amount isautomatically deducted from their accounts, independent of the distance travelled by the vehicle. This approachstreamlines the toll payment process, ensuring a more efficient experience for users [2].

Widad Ismail and KhadijahKamarul Azizi focus on the application of RFID technologyin toll collection systems in their research. Their work emphasizes the benefits and effectiveness of using RFID forstreamlining the toll payment process. This approach enhances the efficiency of toll collection and improves overall traffic management [3].

S. Nandini and P. Premkumar highlight the utilization of Dedicated Short- Range Communication (DSRC) in tollgate systems globally. This system incorporates a mobile application that facilitates the transmission of transaction information. An automated toll gate mechanism is integrated, which sends notifications to vehicle owners. The proposed solution also leverages GPS technology to improve operational efficiency [4].

According to the research conducted by Ramya V., Palaniappan B., and Karthick K., their proposed system incorporates an infrared (IR) obstacle sensor mounted at the front of the vehicle. This sensor measures the distance to nearby barriers, typically within a range of three feet, and relays this information to themicrocontroller to alert it of any

potential obstacles. The microcontroller responds by turning on an alarm to alert the driver and having the ability to halt the car. The car also has a gas sensor fitted inside to keep an eye out for any dangerous gases. The sensor notifies the microprocessor if the concentration of these chemicals rises over permissible limits. The microcontroller then sounds an alarm and texts the driver and any passengers within the car [5].

Rekha's research focuses on the design and development of a theft preventionsystem for vehicles. This system utilizes a GSM-based embedded framework that is installed within the car [6].

Themicrocontroller, connected to the vehicle's engine, also interfaces with a mobile communication system. In the event of a theft, the owner can use the information provided by the system for further action. The data is transmitted to a central insurance processing system, which allows the owner to connect with the mobile device linked to the hardware installed in the vehicle. This setup enables the owner to remotely disable the engine or stop the vehicle immediately by interpreting signals received on the mobile device. After entering a secure password, the system can return to its normal state. The secure password is known to the central processing system as well as the owner of the vehicle [7].

The principal concept of this design is to integrate embedded systems and mobile communications to create a compact, affordable solution that houses all of the features on a single chip. The owner can report a stolen vehicle to the central processing system, which can then use SIM tracking to identify the vehicle and contact local law enforcement and prevent further movement [8].

The system can also halt the vehicle by contacting a designated number. The research conducted by Pany J.K. and Choudhury R.D. discusses the design and implementation of an embedded system aimed at preventingor mitigating car theft. This system is based on GSM technology and is installed within the vehicle's engine. The microcontroller is connected to a GSM modem, which facilitates communication with the owner's mobile smartphone. The primary objective of this device is to restrict unauthorized access to the vehicle while utilizing GSM communication to keep the owner informed about the vehicle's status. The system also addresses aspects of network security, emphasizing the integration of mobile communication with embedded systems [9].

The study conducted by Joshi B., Bhagat K., and Desai provides a comparative analysis of various modernautomatic toll collection systems in relation to traditional tollcollection methods [10]. Their research highlights the advantages of automatic systems, particularly those utilizing RFID technology, such as FAST Tag and the Automated Toll Collection System (ATCS). These systems employ unique RFID tags affixed to vehicles to facilitate seamless toll payments. Additionally, they propose an innovative image processing-based toll collection system aimed at enhancing both flexibility and reliability in toll transactions [10].

Ahmed S. and colleagues emphasize the importance of digitization in Bangladesh to keep pace with ongoing development and economic progress. In order to address traffic issues and enhance system transparency, the paper introduces automated toll collection system based on RFID technology.

This system aims to eliminate errors, delays and fuel consumption by enabling smooth toll transactions without stopping at the gates. The research focuses on an electronic toll collection system based on RFID technology in vehicle identification for toll collection.

The proposed RFID system utilizes tags affixed to digital number plates, giving RFID readers access to thestored data. This approach reduces the need for physical ticket distribution and collection, enabling seamless information sharing between vehicle owners and tollauthorities, thereby ensuring transparency and minimizing manual errors [12].

El Husseiny's study focuses on adescriptive case study of the Cairo-Alexandria desert highway, which was tailored specifically for this investigation [13].

The study involved in-depth interviews with two key groups: the "Arab Constructors Company," responsible for the highway's construction, and various trucking companies that utilize this route. Additionally, a focus group with freight forwarding firms was conducted to identify current challenges on the Cairo-Alexandria desert highway and explore potential solutions. The findings indicate that, despite assertions that implementing Intelligent Transportation Systems (ITS) could significantly benefit multiple sectors, there are numerous obstacles to their adoption within Egypt's transportation framework [14].

Balamurugan K., Elangovan S., Mahalakshmi R., and Pavithra R. highlight the current process of inspecting vehicles for licenses, insurance, and registration documents which creates considerable challenges for individuals. This often leads to traffic congestion, which prolongs wait times and increases fuel consumption at toll booths. Their research focuseson the effectiveness of an Automatic Toll Collection and Check-Post System that utilizes Radio Frequency Identification (RFID) and GSM technology. This system employs passive radio frequency technology for efficient vehicle identification. The approach under discussion makes it possible to significantly reduce the amount of time vehicle owners and toll collection agencies must spend manually distributing tickets and collecting tolls. This enables the toll authority and vehicle owners to easily share information about toll payments. Consequently, this leads to improved transparencyin toll payments with reduced manual effort and fewer human errors, making the development of a smart transportation system more straightforward [16].

In their research, Nagaraja B.G., Rayappa R., Mahesh M., Patil C.M., and Manjunath T.C. provide a system that stores certain information, such as a unique ID, on an RFID tag that is attached to the car. When the system meets all necessary criteria, this information can be saved in a database along with timestamps. Each user is responsible forsecuring the unique ID associated with their vehicle. The RFID tag is read by the scanner as the vehicle moves closer to the toll booth, and the account balance is checked using both an RFID and a GSM module to determine the toll amount. To enable user management of the system through SMS or phone calls, a GSM network is integrated with the ATmega328 Arduino controller, which also plays a role in preventing vehicle theft [17].

It is known from the work of Saijie Lu, Tiejun He, and Zhaohui Gao that in recent years, the DSRC technique has been replaced with the global positioning system technique used to ETC. Compared to more conventional DSRC-based technology, this novel approach to Expressway Network electronic toll collecting is entirely different [18].

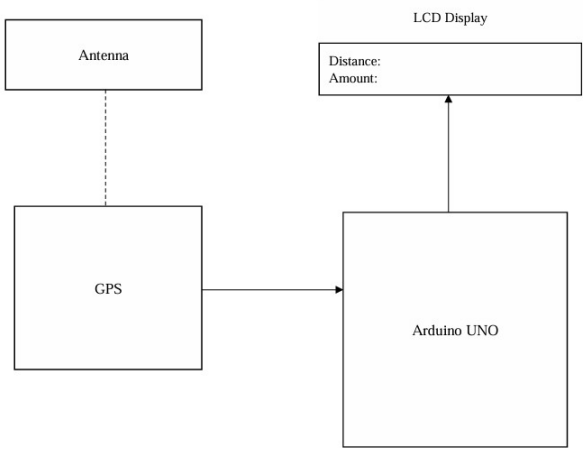

Fig.1.Block Diagram of Smart GPS-Based Toll Collection System

III. IMPLEMENTATION OF SMART GPS BASED TOLL COLLECTION SYSYTEM

When traveling on toll roads, individuals typically pay a fixed fee set by the government, which can often be arbitrary. The proposed system allows travelers to pay based on the actual distance they travel, eliminating the need for traditional toll gates and reducing congestion at toll plazas. This is particularly beneficial as traffic jams at toll booths lead to idling vehicles, resulting in increased emissions. By addressing these issues, the new system effectively overcomes the shortcomings of existing toll collection methods. The Smart GPS-Based Toll Collection System employs an Arduino board as its central processing unit, which receives real-time location data from a NEO 6M GPS module. The Arduino is programmed with a database of toll road coordinates stored in its memory. As the vehicle travels on the toll road, the GPS module continuously calculates the distance within the designated toll boundaries using the stored coordinates. The Arduino constantly compares the vehicle's current position with the toll road coordinates, initiating distance tracking once the vehicle enters the toll road. When the vehicle exits the toll road, the GPS module signals the Arduino to cease distance measurement. At this point, the Arduino computes the total toll amount based on the distance traveled and a predefined rate, displaying both the distance and the calculated toll on a 16x2 LCD screen. This feature allows drivers to review toll information, including distance and total charges, before making a payment. The system's capability to monitor vehicle movement within the toll road and accurately calculate the distance traveled, along with the LCD display of this information, aims to ensure a transparent and precise toll collection process for drivers. The code is designed to establish an intelligent toll collection system utilizing an Arduino board, GPS module, and LCD display. It calculates toll fees based on the distance a vehicle travels within specific toll zones. The code initializes essential components, including the GPS module for receiving location data (latitude and longitude) from satellites, the LCD display for providing real-time updates to the driver, and the Arduino UNO microcontroller as the central processing unit. Constants such as baud rate, Earth radius, and thresholds are defined. Within the code, a loop continuously reads GPS Data and processes it using the TinyGPS++ library. If valid GPS data is obtained, the system calculates toll fees and displays pertinent information. The system tracks the vehicle's movement by calculating distances between successive GPS coordinates. Using the Have sine formula, the calculate Distance () function determines the great-circle distance between two points on Earth. The total distance traveled by the vehicle is accumulated in total Distance. A fixed toll rate per meter (toll_fare_per_m) is applied to determine the total toll amount (total fare).

The LCD screen presents the total distance traveled along with the corresponding toll amount, providing real-time updates for transparency. The system checks if the vehicle has reached a predefined checkpoint, such as a toll booth exit. Upon reaching this checkpoint, the system can trigger specific actions, such as displaying toll information. The code also addresses scenarios where GPS data may be unavailable or invalid; if insufficient GPS data is detected, the system displays an error message and halts execution. This system will eliminate the need for toll booths, manpower and reduce congestion. The components used to implement the proposed system are:

Arduino Uno Board: Arduino is an open-source hardware and software. It produces microcontroller kits to implement the construction of digital and interactive objects and projects those can manage physical things and sense items. Arduino Uno is a kind of microcontroller board based on Atmega328. This board has Digital I/O pins -14, Analog input pins – 6, a power jack, ceramic resonator-A16 MHz, USB Connection, RST Button, and an ICSP Header. All of these support the microcontroller board to perform further operations by connecting it to the computer using USB.To communicate with other electronic devices, the program must be launched using the Arduino IDE and dumped into the microcontroller. In this proposed system, we have connected the GPS Module in order to retrieve the co- ordinates.

GPS Module (NEO 6M): It is a Global Positioning Satellite System used for navigation. This module is fittedin a vehicle to obtain the real-time location of the vehicle. This module gives the co-ordinates only when there is no obstacle in the line of sight of the vehicle. The GPS Receiverpresent at the Earth’s surface will receive all the information.This GPS Module is a tiny device that receives signals from GPS Satellites orbiting the Earth. These signals allow the module to determine the vehicle’s latitude and longitude. NEO 6M series is a family of GPS Receivers with u-box 6 chipset and is known for its high performance and accuracy in determining geographical locations. It possess functions like high sensitivity, fast acquisition time, multiple GNSS support, low power consumption and a compact size. It receives a current of up to 21mA and voltage near to 1.65V 3.6V. It operates at a wide range of temperature, between -40C to 85C. All thecharacteristics that it possess will help us achieve the accurate and fast results. The GPS is a group of satellites. They are referred to as geosynchronous because they rotate around the Earth's atmosphere at the same speed as the planet's rotation. They take twenty four hours to revolve around the Earth. Radio signals will be transmitted from the GPS Satellites above to the GPS Receivers on Earth. Four dimensions are calculated by each satellite: time, Z (elevation), X (latitude), and Y (longitude). Depending on the application and requirement,

The GPS receiver will translate the received signals into meaningful information.

LCD Display: An LCD Display is a Liquid Crystal Display. It is a thin, flat panel technology used in the screens of digital devices. They used cathode ray tubes (CRTs). LCD's don not emit light themselves. They instead manipulate the light to produce images. In this proposed system, the readings of distance travelled in meters along with the fare amount in rupees are displayed on the LCD Display.

Potentiometer: A potentiometer is often represented as pot. It is a three-terminal adjustable resistor. It also acts like a variable voltage divider. It can control the amount of the voltage flowing through a circuit. Potentiometers are very versatile. In the proposed system a potentiometer is used to control and adjust the contrast of the LCD Display so as to display the readings of the system. A potentiometer will have GND, VCC, and Output pins.

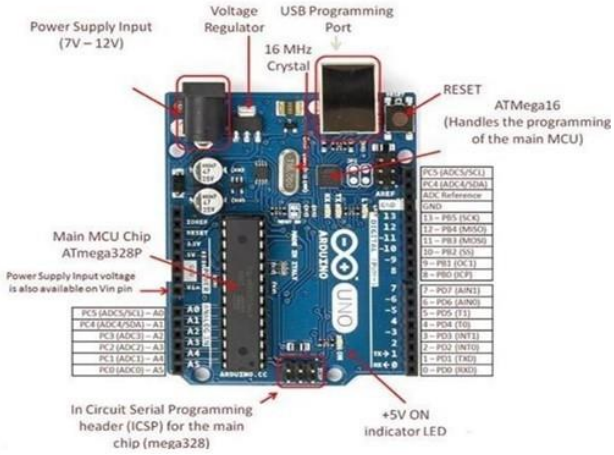

Fig. 2. Arduino Uno Board

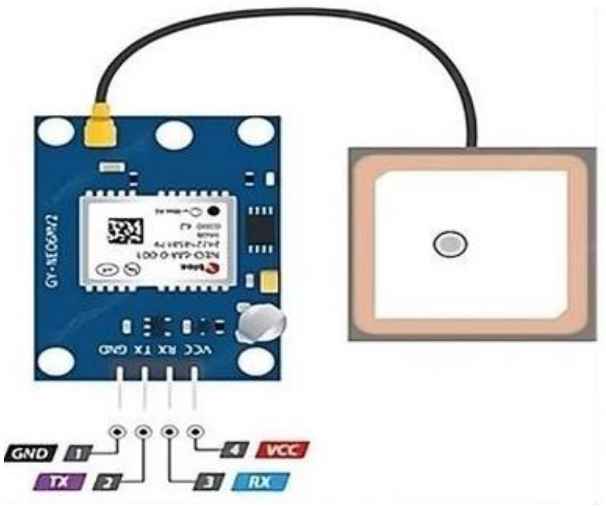

Fig. 3. NEO 6M GPS Module

Fig. 4. LCD Display

Fig. 5. Potentiometer

IV. FLOWCHART DESCRIPTION

The flowchart begins with the "Start" process, which initiates the system. The first decision point checks if the GPS data is valid. The system indicates an error if the data is erroneous. The system retrieves the coordinates if the data is correct; if not, it initiates the coordinate retrieval process. Next, the system checks if this is the first setof data available. If it is not the first data, the system checksif the vehicle checkpoint has been reached. If the vehicle reaches no checkpoint, the system loops back to retrieving coordinates that is the initial coordinates. If a checkpoint is reached, the system calculates the distance travelled and updates the total distance before calculating the total amount.If it is the first data available, the system sets the initial coordinates and then moves on to check if a checkpoint has been reached. Upon reaching a checkpoint, the system stopsthe distance calculation. Finally, regardless of the path takenafter setting initial coordinates or updating the total distance, the system converges at displaying the distance and amount on the LCD.

In the proposed system, for every meter of the distance travelled the amount would be fared as 1.25 Rupees.

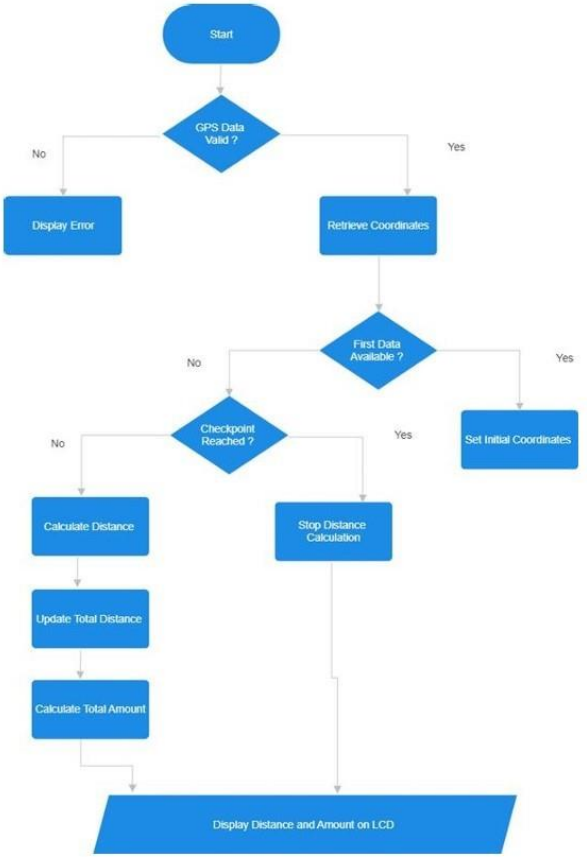

Fig. 6. Flowchart of Smart GPS-Based Toll Collection System

V. RESULTS AND DISCUSSION

The proposed system of Smart GPS-Based Toll Collection System is implemented to compute the precise toll fee automatically using the real-time distance travelled by the vehicles on the toll road. Below are the images demonstrating the results of the system and the final prototype with all the hardware components connected where LCD Display shows the distance traveled on the toll road along with the charge that is to have fared upon the user of the toll road by which the users can be charged precisely for the distance they cover on highways. The distance travelled and the computed toll amount are shown on the 16x2 LCD screen by the Arduino Uno microcontroller, which functions as a centralized system that computes the total toll amount depending on the distance travelled and a pre-defined rate. This allows the driver to view the toll information, including the distance covered and the total toll charge,before proceeding with the payment. The system's ability to track the vehicle's movement within the toll road and calculate the precise distance traveled, along with the display of this information on the LCD, aims to provide a transparent and accurate toll collection process for the drivers. The Smart GPS-Based Toll Collection System, utilizing a GPS Module, allows the users of the highways to be charged precisely for the distance they cover on highways, thus eliminating instances of overpayment and providing a fairer tolling experience. This system operates by marking entry and exit coordinates by seeking the latitude and longitude coordinates, leveraging a GPS-based distance algorithm to accurately calculate the distance and toll fees and display the same on an LCD. The LCD screen shows the total distance traveled and the corresponding toll amount for the distance traveled where the vehicle uses the toll road. The system checks if the vehicle has reached a predefined checkpoint (e.g., toll booth entry or exit). If the checkpoint is reached, the system can trigger specific actions and will display the final readings which are distance in meters and the amount that is to be paid in rupees.

Fig. 7. Initial Readings of Smart GPS-Based Toll Collection System

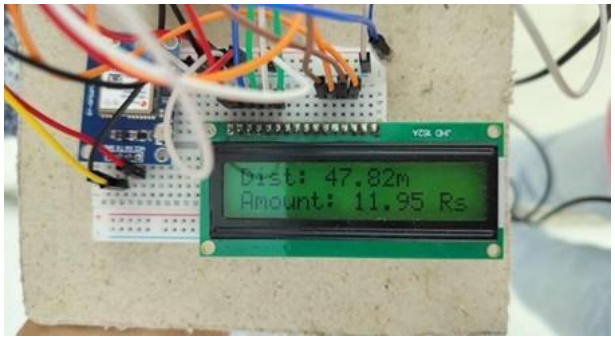

Fig.8. Distance and Fare readings after travelling for a certain distance at the endpoint (checkpoint)

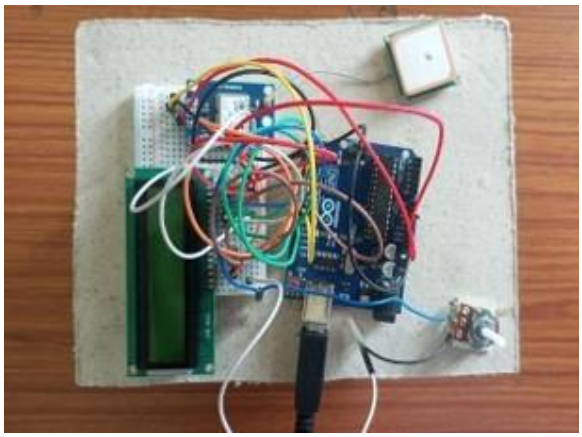

Fig. 9. Final prototype with the hardware connections

VI. CONCLUSION

The proposed Smart GPS-Based Toll Collection System will eliminate the need to have toll booths and allow driver toll zones without frustration of stopping and waiting possible. This technology will ensure a smoother traffic flow, with the ease of payment and reduced emissions. It also promises transparency, safety and reliability without any discrepancies. This system will heavily reduce the operational costs of the transport management system. This system will pave the way for GPS-based toll collection to revolutionize how we pay for road usage, creating a more efficient and potentially more equitable system for drivers and transportation authority's alike.

VII. FUTURE SCOPE

There is immense potential for further advancements and integration with broader transportation and infrastructure management systems. By incorporating a communication module, such as a GSM or GPRS module, the system could transmit the vehicle's GPS coordinates, toll road data, and calculated toll amounts to a centralized server in real-time. This would enable automated toll billing, streamlined record-keeping, and the ability to detect and address any discrepancies or attempts at toll evasion. Additionally, the system could be integrated with traffic management systems, providing valuable data on vehicle movements and traffic patterns within toll road networks to increase safety and reduce vehicular theft. Furthermore, the system could be expanded to include mobile payment options, allowing drivers to conveniently pay tolls directly from their smartphones, reducing the need for manual toll booths and cash transactions.

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