Decentralized Vehicle Legitimacy Verification for Toll Gate Using Blockchain

A PROJECT REPORT

Submitted by

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ABSTRACT

Vehicle registration number plates are a requirement for vehicles as they help in identifications and confirming the legitimacy of vehicles in the road. Each and every vehicle is supposed to have a distinct number plate which acts as a very important tool for law enforcement, transport authorities and regulatory bodies. Nonetheless, most of today's toll systems are unable to provide an effective means of still verifying the authenticity of these plates. Quite a number of vehicles move through the toll gates with number plates that are most likely to be duplicate, modified or even completely fake. There is absolutely no verification. This verification gap not only diminishes the safety and efficiency of the collection toll processes but also creates an opportunity for many illegal acts including tax avoidance, vehicles theft, and a lot more that can be conducted and remain unsolved. Therefore, to fill in this serious gap, our research paper puts forward a creative idea that detects and confirms with number plates as vehicles cross the toll gates while using block chain as a tool to safeguard and trace the credibility of the vehicle.

We begin with the registration office, wherein the vehicles are first brought into the system. At the time of this initial registration, several codes are assigned to that vehicle, and these codes are said to be the identifiers that cannot be changed and are connected with the owner and his or her vehicle. These codes are embedded in the number plates of vehicles with the aid of radio frequency identification (RFID) making it possible to read at toll gates with ease, while it is also difficult to interfere with the plate. By only embedding this code at the registration stage, we have made it impossible to change, replace, or forge the code, which is why the security of the system is robust.

As a car draws near the toll, there is an RFID reader that scans the code from the number plate, and this code is instantly reconciled with the decentralized blockchain database. If this specific code is in our database, the vehicle is authenticated and the transaction can be completed. An entry for this particular transaction is also recorded on the blockchain, which further adds a block to the chain that contains the proof of the vehicle passing the toll. Otherwise, the scanning reading fails to capture an existing unique code, and the vehicle will be marked as suspicious or fraudulent. This alert is automatically sent to relevant authorities that manage the emerged facilities for appropriate and timely investigation or response.

The fact that the system bears the use of blockchain gives assurance to users of the system that all the activities are done in a secure, transparent, and trustful environment. The blockchain ledger presents an accurate and verifiable record of each unique transaction that took place across its border of that object in history, making it difficult to attain backtracking on time. Once a transaction is placed on the blockchain it is impossible to change or take off and control, ensuring every one of the unmistakable transactions between the vehicle and tolls is completely and securely recorded. Besides, such decentralized databases/delegated ledgers reduce dependence on a central authority. This lowers the possibilities of data breaches and unsolicited modifications.

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ABBREVIATIONS

HTML	Hyper Text Markup Language
CSS	Cascading Style Sheets
JS	Javascript
UI	User Interface
UX	User Experience
POA	Proof of Authority
TS	TypeScript
UID	UniqueID
ZKP	Zero Knowledge Proof
IOT	Internet of Things
OCR	Optical Character Recognition
ANPR	Automatic Number Plate Recogniton
LPR	License Plate Recognition

CHAPTER 1

INTRODUCTION

As we know Vehicle registration number plate plays a key role in verifying the identity of a vehicle, it is mandatory and crucial for every Automobile. On the other hand, the existing toll system does not verify the legitimacy of a car whether the number plate is original or a duplicateone. So, this paper aims to propose an innovative solution for this problem that deals with inspecting a number plate while a vehicle passes through the toll gate. We use blockchain technology which stores the transaction of a vehicle after it is proven as the legal one. Our approach follows that while registering the vehicle at the office we provide a unique code and store that unique along with the owner details and we integrate that code in the number plate as RFID, we only do this once while registering afterward it can't be tampered with. When a vehiclepasses through toll we scan and retrieve the unique code and verify whether it exists in our database. If it exists, the Vehicle is legitimate. If we can't extract the unique code from the number plate, then it is a duplicate one.

If the scanned number plate is verified as legitimate, the toll transaction proceeds seamlessly, and a new transaction block is added to the existing blockchain network, recording the vehicle's verified passage through the toll. This process creates a tamper-proof record that can't be altered, ensuring transparency and traceability at every checkpoint. By embedding a unique, untamperable RFID code in the number plate at registration, this system protects against fraudulent activities, such as the use of duplicate or counterfeit plates, which often contribute to toll revenue losses and broader security issues.

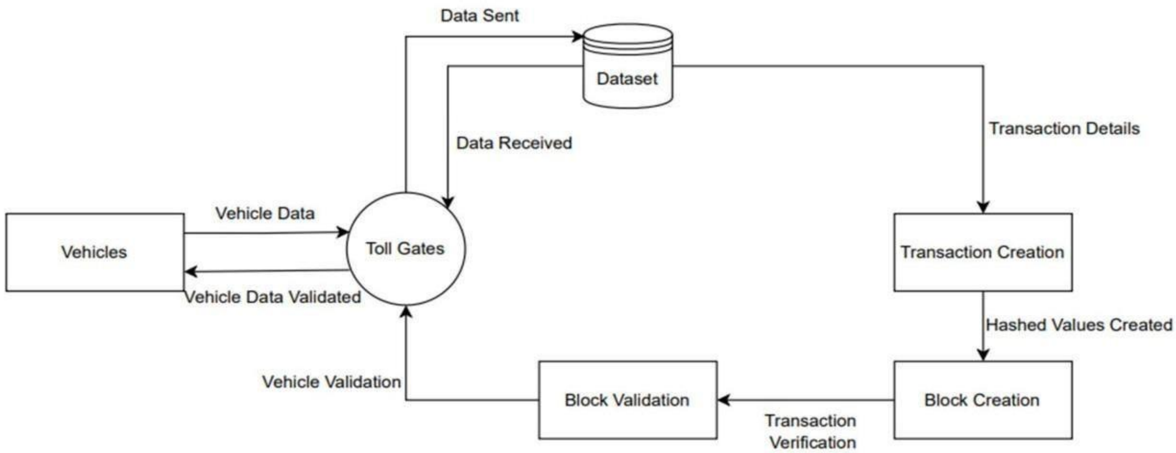

Fig 1.1 Data Flow Diagram

The above figure(1.1) describes that, it proposes a blockchain-based framework for the safe collection of toll data, ensuring integrity and fraud reduction. Vehicle data is collected from the toll gates; preliminary validation is performed at the toll gates. The validated data is then forwarded to a dataset, which acts like a temporary storage device. From the dataset, transaction details are fed to the transaction creation module, which digitally signs each transaction and hashes it for security. These transactions are collected and, in addition, compiled into a block that is then verified for correctness. Once verified, the block is also addedto the blockchain, thereby making the transaction record unalterable. This is done in a decentralized manner that, by its very nature, increases transparency while weakening any attempt at tampering and generally increases the reliability of the toll data stored and its verification. In essence, it shows that blockchain technology is going to revolutionize some important sectors of toll systems by putting more emphasis on data security and operational aspects.

This diagram(1.2) for blockchain-based verification of a toll system. The leading component consists of some of the key elements that are described as follows: VehicleRegistry maintains the list of the registered vehicles. Each of the vehicles has attributes such as vehicleNumber, uniqueID, owner, registrationState, and whether it is valid/legitimate or not.Two central functions in the context of this registry are discussed: registerVehicle and verifyVehicle. The class CSVHandler deals with vehicle datadelineated in a CSV file; these listed vehicles are to be registered on blockchain.

At theToll gates The class BlockchainNetwork communicates with the blockchain network to connect to its nodes and execute any transaction via functions such as connectToNode, sendTransaction and callContractFunction. The architecture ensures validation of the validity of a vehicle at the toll gates in a decentralized manner securely to bring more transparency and integrity into the system.

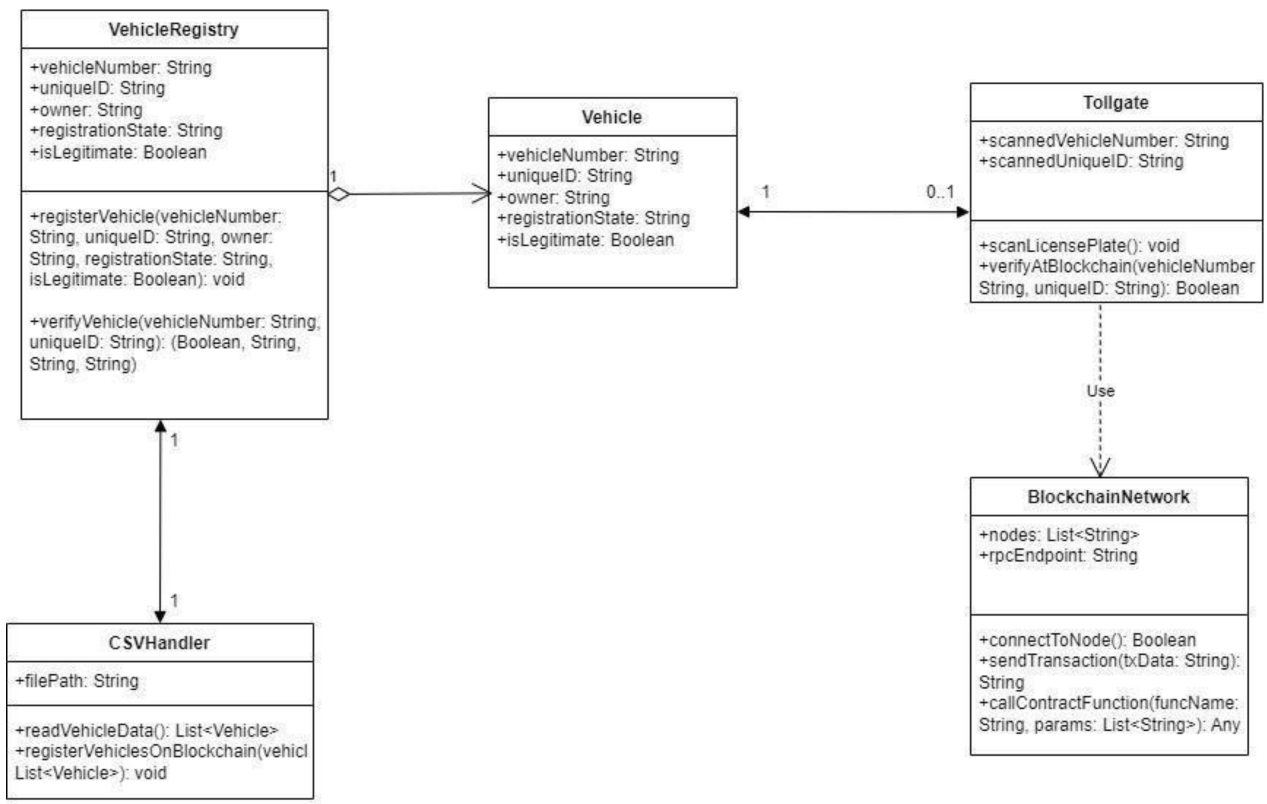

Fig 1.2 Class Diagram

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CHAPTER 2

LITERATURE SURVEY

The author [1] put forward a model whereby Optical Character Recognition (OCR) and Automatic Number Plate Recognition (ANPR) technologies can be deployed to scan and identify the letters and numbers represented on vehicle license plates in a bid to help with toll collection. The system dispenses the needfor the vehicle owner to stop at a booth and instead sends an OTP to the vehicle owner for confirmationof payment. While this method is good for text detection, it has some limitations as it relies heavily on the quality of the image provided and, it is known that recognition of number plates with a large varietyof designs tends to be less accurate.

Another study [2] reported on a project that wished to implement the ethereal blockchain on a toll for secure payment on highways. They concentrated on the security of the data, processing of transactions, and performanceevaluation on Hyperledger Caliper. It has also been noted in the study that due to increased user load there are issues of scalability that need to be addressed alongside better connectivity with other transportmanagement systems.

The [3] has observed that a model such that a fusion between blockchain and IoT technology can be utilized to improve the security of transportation networks in smart cities. The system employs a hierarchical structure made of smart contracts that focus on ensuring secure data transmission. However, the study noted that there are issues that relate to delay and optimization of resources with regard to largescale implementation which need to be addressed.

It has been suggested that [4] researched the introduction of mobile permit trading systems in a transport network through blockchain. Their method was qualitative as it sought to assess the economic effects of adopting thosetechnologies. It was noted that there are difficulties in using blockchain with already existing systemsbut further research on the future effects is still required.

The [5] highlights a proposed blockchain-based trust management system for vehicular networks. Simulations were used to test the system and were found to be better in performance, latency, and efficiency than the current model. However, the authors mentioned that privacy-enhancing and comprehensive trust management mechanisms of the system are areas of future work.

The [6] suggests a developed Toll collection system for autonomous vehicles that is based on blockchain. They implemented an Ethereum blockchain for transactions and used sensors together with smart contracts indata collection and verification. The paper confirmed the expectation of further studying the capabilities of blockchain platforms and scalability methods for decreasing traffic in an optimal way.

They claim that [7] presented an enhanced intelligent transportation system in which the tolls are automated based on thedata related to the speed and identification of a number plate from the ALPR and OCR system using a blockchain. Even though this system has its advantages, the weakness surrounding the safety of the information during transfer is still a struggle, and the time and fuel consumption must be optimized in comparison to the conventional systems.

The [8] integrated Blockchain into vehicle- to-everything communication. Systems were simulated in real-time to assess gas fees and transaction volumes across different blockchains. The authors recognize that for scalability in terms of the number of transactions full integration would have to be carried out between the transport operators.

The [9] suggests a secure blockchain system that incorporates License Plate Recognition (LPR) to improvethe privacy assurance of such systems. Similarly, this solution enables reaching the consensus betweennodes of the network and the vehicle data finds its way into the blocks of the chain for protection. However, no serious attempts were made to consider the legal and ethical implications that come alongwith the implementation of such systems.

The author [10] developed a GPS-based integrated tolling for highways supported by blockchain: “Our system enables secure transactions even at peak hours”. The main challenges posed are ensuring system reliability at peak times and the practicality and economic viability of embedding such technology invehicles.

They [11] explored collection of toll fees with the use of edge computing and blockchain solutions. Their scheme employs smart contracts on Ethereum by opening payment channels and providing services. Thestudy found however that delays in transactions and excessive gas fees were potential hurdles to adoption.

According to [12] created a system for the management of traffic and toll collection ensuring privacy by utilizing Zero- Knowledge Proofs on blockchain. This helps to enhance the privacy of the vehicles by allowing them to authenticate their positions without necessarily disclosing addresses. The study also pinpointedthat the computational overhead required for ZKPs was a serious drawback as it interfered with the requirements for real-time processing.

The author [13] studied how blockchain can be utilized with IoT for electronic toll-collection vehicle data management. Using IoT and blockchain technol-ogies, the movement of a vehicle can be constantly tracked and verified in real-time. These findings suggest the possibility of the use of a blockchain system for the verification of vehicle data in real time, which may also be applied to a system of vehicleregistration.

The [14] proposed an automated tolling system with image processing and blockchain payment which was secure. This method of protecting information against unauthorized alteration is most relevant to the registration of vehicles, where a blockchain can be used as a secure database to prevent the alteration ofvehicle information by unauthorized persons.

The [15] argues at several areas associated with the storage and protection of sensitive data that is securedby blockchain technology. Also, they were able to demonstrate that the weakness of global databases in the financial and healthcare industries can be eliminated by the decentralized architecture of blockchain. Therefore, their findings also support the premise that blockchain can assist in the registration of vehicles as it contains features of a secure system devoid of or with minimal risk of unapproved changes occurring.

CHAPTER 3

PROPOSED METHODOLOGY

1. **System Architecture**: Within the framework figure(3.1), blockchain is designed to be embedded in the verification of vehicles at the toll gates to achieve a secure, decentralized, and transparent system ofverification. These toll gate nodes act as additional nodes in the blockchain. Any node can access and change the blockchain ledger to meet the requirements of real-time verification. This vehicle dataset contains basic details such as vehicle number, encrypted number plateas a unique identifier, and the owner. The data is written on the ledgers of the blockchain but in an immutable form. The verification mechanism is approved on a network of a private blockchain, whichis also not operated by a single person, and all the actions taken on the blockchain are recorded as a block, which means the legitimacy of the transfer data is preserved. This smart contract is for automatized verification of the process through whichthe vehicle is verified without requiring human participation.

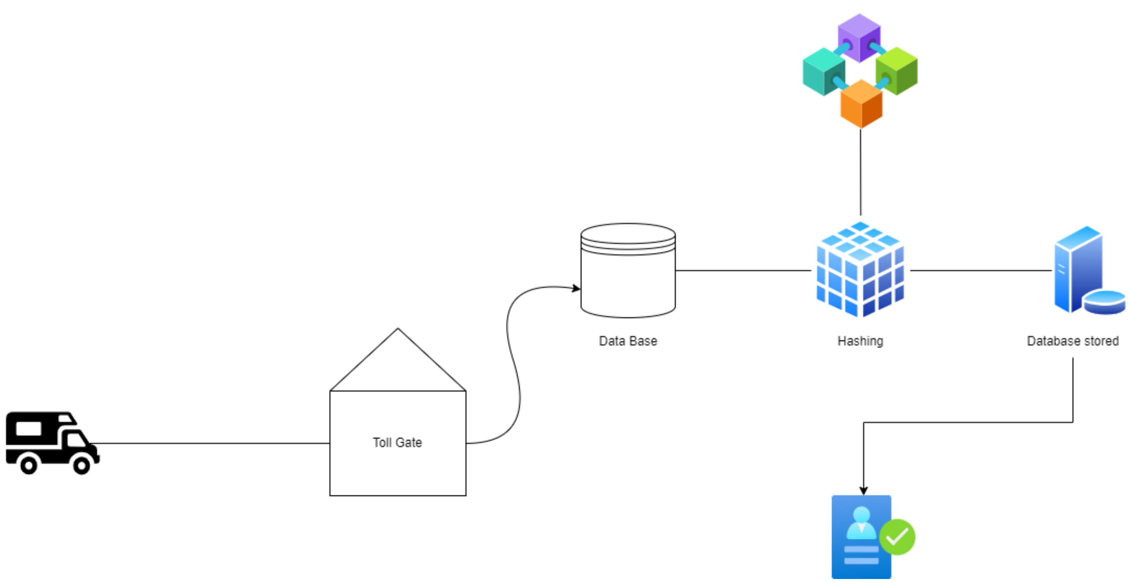

Fig 3.1:System Architecture

2.Data Structure: It should be noted that a vehicle framework data structure figure (3.2) would be needed whichwill incorporate a few fields such as the following. Vehicle Number is the unique identifier for each vehicle and is issued by the authority. Unique ID is the identifier specific to the blockchain, the encrypted identifier is found on the number plate.Owner Information this includes the owner’s name, which helps in the owner’s verification. Registration Details this gives the details of vehicle registration.

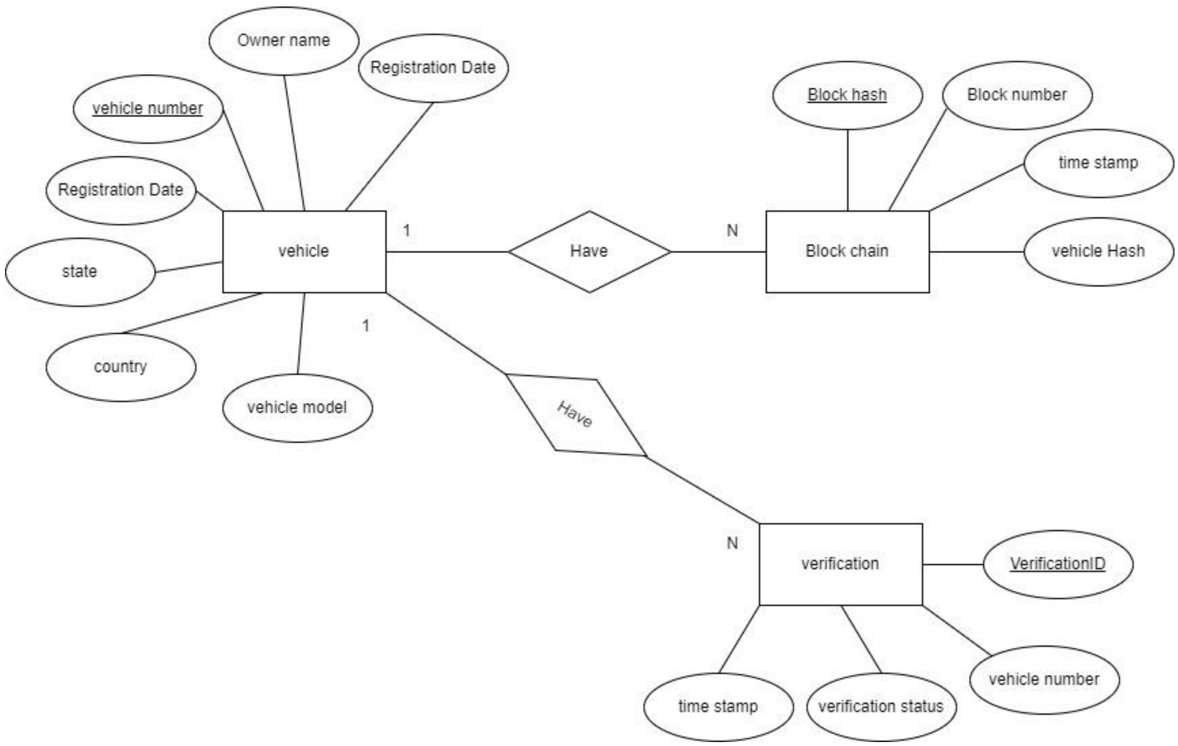

Fig 3.2: Data Structure ER Diagram

3.Blockchain Layer: This layer is central to providing security, transparency, and immutability. Every toll gate is a part of the node in the blockchain network. Each such node executes any transaction and then verifies the given transaction within the dataset system. In case of anydiscrepancy, the node raises an issue flag. The Smart Contracts are made available to them for verification purposes. A smart contract would be able to verify if the vehicle number and unique identifying no on the blockchain have a matching no, then that vehicle is a legitimate vehicle and passes the toll gate. If not, then the systemwill mark that vehicle as potentially an inappropriate vehicle and request a manual inspection of that vehicle. A Consensus algorithm such as proof of authority (PoA) for instance, enables to avoidance of data discrepancies between all the toll gates. This increases computation efficiency while guaranteeing that every node can have one legitimate database record.

4.Verification Process: This process includes the procedures below. The unique ID shown on the number plate of vehicles is read and verified with thedatabase. The nodes of the toll gate assess whether the ID has met the unique vehicle number with a combination of the ID stored. Legitimacy check, in the case of a match between the ID and vehicle number from the database entry, the vehicle gets on the road. Otherwise, it would get flagged off for manual checks. Every verification is recorded like a transaction on a blockchain, and therefore for every vehicle verified via the toll gate, there is a stamped record in time and date that becomes set inhistory. In that way, transparency across all the toll gates is maintained.

5. Mechanism for Security and Fraud Detection:

In the data encryption the unique ID, vehicle number, etc., is sensitive information kept encrypted to avoid breaches. The immutability of the Blockchain ledger makes it very tamper-proof and therebypowerful. Once a record is added, it cannot be changed; hence, verification of old data is secure and trusted. Damaged legally accepts the smart contracts to detect any automobiles containingdata inconsistencies or disparity; then, through the system, it does re-verification, which helps the framework identify fraudulent automobiles in real-time.

Hence this framework offers a comprehensive and safe approach for the toll gate verification with blockchain technology which increases the transparency and security of data. The utilization of decentralized verification at various toll gates reduces the reliance on centralized databases and decreases the instances of fraud.

6. Vehicle Registration and Data Management:

In this paper, we suggest a blockchain based model in understanding how a vehicle's authenticity can be established at the toll gates using various elements for secure and easy verification. The main element of the system is the blockchain network, which can be defined as a distributed ledger keeping records of the vehicle verification at the toll gates. Every record has detailed facts such as the vehicle number plates, its unique identifies (ID), the toll gate number, and the time when the vehicle was verified. One of the most powerful attributes of blockchain technology is that once any type of verification has been recorded on the system, it cannot be changed or erased from the system establishing a trust circle that cannot be broken.

As the centre piece of the system, the registered vehicle dataset is the original source of truth about the legitimacy of the vehicles. It has all of the registered vehicles data including the number of each vehicle and its unique ID. To maintain reliable reference points for legitimacy verification, this dataset is continuously refreshed with new registered vehicles. Furthermore, vehicles are embedded with RFID, or IoT tags, on their number plates. Such tags have unique identification numbers that can be triggered automatically when the vehicle is at the toll gate. These tags are used in RFID technology that makes very fast scans, saving a lot of time and reducing disturbance at the toll gate.

To activate this secure system, the vehicle registration procedures must be implemented as they will create a database of legitimate vehicles and their unique identification Swiss cards for inclusion in the verification process. This procedure has components such as basic data input by car owners or authorities during which the proprietary vehicle numbers and unique IDs are provided. Each combination of a unique ID and several of the vehicle is validated to ensure the validity of the registration and that it has not been already used. Duplicate or modified IDs are flagged by the system automatically and other means. When data is confirmed, it goes through the process of data hashing and uploading it to the blockchain. Hashing is a method that assures an absolute and unique code for each entry, thus increasing the security of the system as it becomes impossible to reverse engineer the original data.

7. Toll Verification Methodology:

The primary element of the methodology is devoted to the toll verification process. An RFID reader or IoT-sensor reads the unique ID printed on the number plate tag when the vehicle approaches the toll-booth. This information is sent to the toll collector’s machine in the same period as the verification of the ownership of the vehicle is being done in the vehicle database. This activity is called data matching, and it involves the checking of images that contain the ID tag and the number plate of the vehicle against images that were registered. There is a special operation called validate Vehicle that performs the validation process. This operation is case insensitive and checks for existence of both unique ID and car number in the system and whether they are in control for standard purposes. Assuming the val idation was unsuccessful, the vehicle will be considered fraudulent, and subsequently, the toll authority will get a report of the instance. A record of every unsuccessful verification is also kept as a form of audit.

When the verification is successful, the event is permanently recorded on the blockchain and can be verified. This stage involves data logging and hashing like vehicle number, a unique ID, the time in UTC format, and a toll gate ID which are hashed and then included as a new block on the blockchain. Cryptographic mining makes it possible to add the block into the blockchain, protecting it from unwanted changes. This step of the mining process also means that the amount of power needed to change data would be vast, providing another level of protection. The block that has been mined integrates itself into the blockchain and further additions will become a permanent and unalterable part of that chain of verification.

The last stage involves reporting the verification results to operators of the toll gates and the owners of the vehicles. Verification results are instantly transferred to toll operators who are informed of any validation failures so that security personnel may step into deal with any violations immediately. Likewise, vehicle owners and other third parties authorized to do so are notified through Socket.io to facilitate the oversight of confirmation processes to enhance compliance among owners of the vehicles. There are also considerations for errors such as incomplete data, arching or odd formatting of data, directing toll operators on required actions.

The transparency in blockchain gives authenticated person an opportunity to access a daughter database of interaction with the vehicle, enhancing the elements of security and auditing. Using the getVehicleHistory function, accusing authorities and workers with appropriate permissions can provide an overview of a vehicle's toll transactions. This function narrows down the blocks fetched to a verification event that is associated with the vehicle of interest and displays them in a timeline format for easy visualization. This history is very important during the auditors' processes and inspections as the characteristics of a distributed ledger technology ensure that details on verifications are forever recorded and can never be changed.

To uphold the security and the trustworthiness of the system, regular competence of the blockchain network is carried out by use of the isChainValid function. By this function, every block's hash is recalculated and, in this way, it is verified that there has been no single block that has been changed. When anomalies are detected, alarms are activated regarding a security breach and the administrators are alerted.

This vehicle legitimacy verification system vastly benefits from various features of Block chain technology. Also, given that no matter what recording is made, verification actions are established, trust with vehicle owners and toll authorities is assured. Further, using decentralization, the technology eliminates dependency on a single authority over control which reduces the levels of risk in fraud. With its mechanisms of cryptography for security, such as proof-of-work and hashing, the system's defence towards hacking attempts is strengthened thereby securing verification events from being altered or modified. This expanded methodology allows the whole framework for the vehicle legitimacy verification system to be clear and precise. Each stage can be well detailed and supported with necessary figures, diagrams of data flow, and illustrations for easy understanding of the readers about the complete procedure.

In a successful test case, the system can properly authenticate a vehicle that is approaching a toll gate. For example, let us say, the vehicle number plate bears the text "TN1234AB" with a corresponding unique ID of "UNQID-9876" and the vehicle is approaching a toll gate referred to as "TollGate-1". When the vehicle reaches the toll Gate, the vehicle's unique ID and number plate are automatically recorded by the RFID reader of the toll gate. The toll gate's system then looks up this information against a vehicle database(figure 3.3) and verifies it against the database with the correct number plate and unique ID.

Vehicle Number	Unique ID (Hex)	Registration Date	Owner Name	Vehicle Type
WB-24-VX-6928	0000621D4D	2020/09/18	Pamela King	Bus
HR-61-JB-2295	00004EADCC	2023/06/08	Robert Scott	Car
RJ-53-NQ-9747	00008C105D	2022/09/09	Bob Brown	Bus
KA-76-AM-4057	0000D903B2	2023/12/20	Grace Martinez	Car
KL-39-YJ-4056	000063CAC7	2020/08/10	Emma Thompson	Bike
RJ-41-JQ-3659	0000580EA1	2020/12/15	Henry Garcia	Truck
HR-50-ZS-3746	00002BF56F	2022/07/24	Bob Brown	Bus
KA-58-CO-7763	0000CCE2AC	2020/06/28	Alice Johnson	Bike

Fig 3.3: Sample Data set

8.Event Logging and Blockchain Storage:

As in this case, the validate Vehicle function makes sure that the captured data and the records have not been compromised, so this match validates the vehicle. Once verification has taken place, the system performs an event logging on blockchain where relevant vehicle number, ID, date and time, and the ID reference of the toll gate is embedded into a secure hash. After embedding this information into the blockchain, a new block that contains these details is created to serve as a record for this successful verification. The vehicle toll gate operator is heavily advised that the vehicle is legitimate in as much as no time would be lost in allowing the vehicle to go through once it has been authenticated.

Moreover, this record of verification is made available to authorized persons, including the vehicle owner, offering transparency and provable history that increases confidence and responsibility. On the other hand, an impaired test case demonstrates how the system detects and portrays an unauthorized vehicle efficiently. For example, a vehicle that has the registration number ‘TN5678XY’ may drive to the toll gate, but the vehicle’s unique ID shows ‘UNQID-5432,’ which is not the one that has been registered. When this vehicle reaches a designated toll gate known as ‘TollGate-2’, an RFID reader gets the vehicle’s number plate and the distinguished ID; following this, the system tries to find similar data. The system finds a record with the combination of the number plate ‘TN5678XY’ but then the system quickly recognizes that there had been a mistake; it was written in the database that the unique ID for this car is as follows ‘UNQID-1234’, hence it cannot be ‘UNQID-5432’. The validate Vehicle function is carried out, which happens to see a difference or discrepancy and so flags the vehicle as illegitimate. The system also records this event in the blockchain even though the verification was unsuccessful because of the need to be accountable. It hashes and metadata – date, time of occurrence, ID of the toll gate that registered the session – for unsuccessful verification, thus a new block is created. This permanent record serves as a complete description of this event in relation to auditing or future use. At the same time, this result gives room for the security officer to be informed on the wrong matching for such operational disparities.

Subsequently, further investigations, are made, particularly approaches that are well suited to the circumstances and the time factor as an additional parameter. The toll gate officials or operators can investigate the matter more deeply, taking appropriate measures as warranted by the failure to verify. Here, it is possible to emphasize the reliability of the system about detecting deviations and the fact that every attempt of verification, no matter how it ended, is recorded in a safe manner.

9. Reporting and Notification:

Apart from dealing with the normal cases of verification, the system is also designed to be able to deal with several edge cases so that there is enough robustness when deployed in real world. For example, an edge case may be a situation when part of the vehicle number plate or unique ID is covered or otherwise the RFID or the camera systems fail to get a clear picture of the data. In such a case, if the RFID reader attached to the toll gate is unable to pull a clear unique ID or number plate, the system automatically creates an error log and marks the verification and its attempt as incomplete. Instead, the system sends out an alert for manual review of the eight scenarios to toll operators who can then examine the vehicle visually to identify it. This edge case illustrates the necessity of dependable data capture hardware, as well as the requirement for automated error processing methods. The collection of blocks of incomplete verifications as well as registration of these attempts on the blockchain was made to have a detailed record of all interactions such that it can assist in tracing the past during audits and quality assurance.

10. Blockchain Transparency and Auditing:

The design of the blockchain is also important to secure the data and provide accountability. When a verification of a vehicle is done, this is then stored in a block containing the vehicle's number plate, a hashed unique ID, the time of the transaction, and the toll gate ID.(figure 3.4) The blockchain applies the proof-of-work algorithm in which every new block must be mined with a specified level of difficulty before being incorporated by the chain to increase security. This method also helps add only the verified blocks into the chain thereby reducing the chances of false or wrong data entry. Apart from ensuring basic security, the design of the blockchain guarantees every malicious attack does not succeed in interfering with the system. Each block of verification is also secured by encryption and all information about the blockchain is localized to the authorized nodes of the toll system. Such limitation allows blockage of any unauthorized manipulation, but enables toll authorities and other relevant parties to check the blockchain whenever they require. Technical issues affecting one toll gate in a blockchain are, however, self-correcting in that the information stored in that chain is still briefed from other nodes still active.

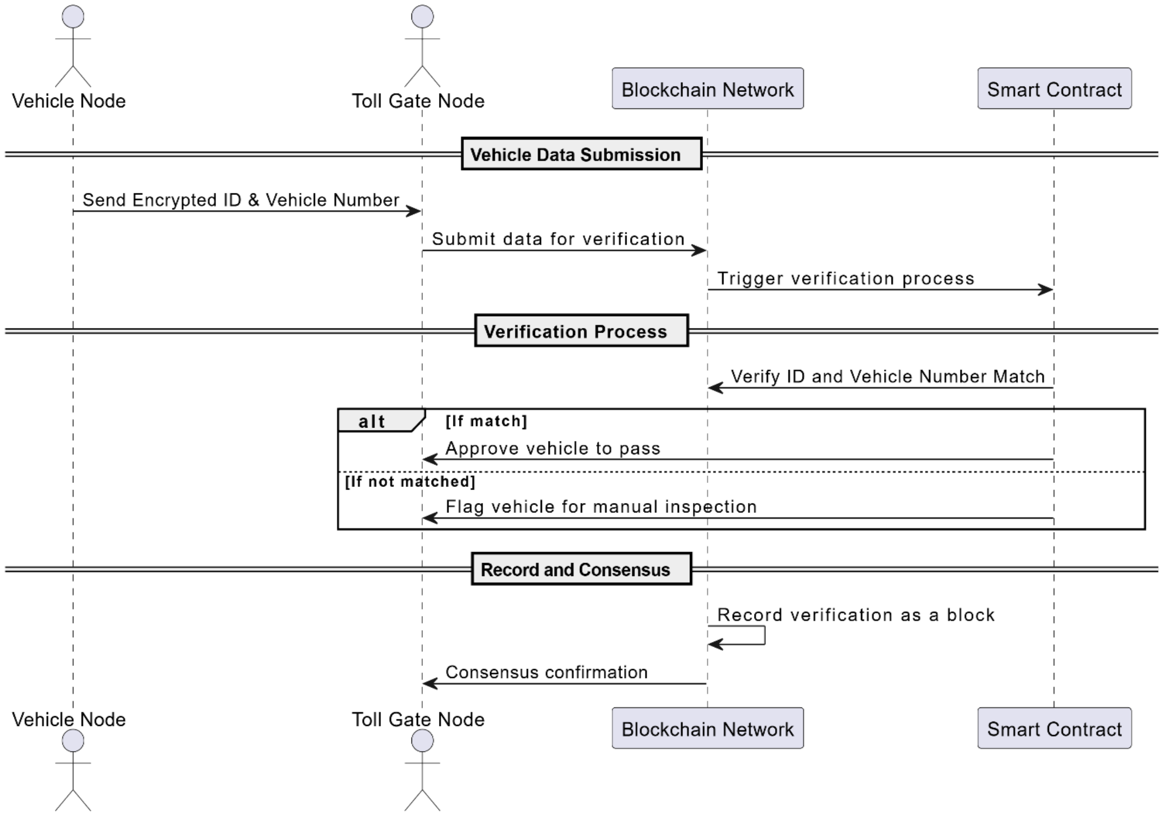

Fig 3.4: Sequence Diagram

Subsystem specification includes performance requirements, which affect the entire design of the system. The main task of this blockchain is to verify and log every vehicle in real time and therefore regardless of high-volume traffic, the blockchain must be efficient. As a response to such an appeal, system uses selective mining strategies which allows for block mining when a certain number of verifications takes place when time runs out. The system improves efficiency by grouping respades without risking loss of information by increasing processing times. Also, the system can adjust its poof of work in terms of the amount of traffic traversing it, during hours of high capacity, a lower rate of proof enables blocks to be generated faster and these guarantees vehicles do not backup at toll gates. Whereas in low traffic hours, the rate may be increased when there is less traffic to the system and speed is traded for security.

11. Network Integrity and Security Verification:

The interface that the application layer consists of also enhances the efficiency. This layer is concerned with the exchange of data between the systems which are the toll gates and the blockchain. It helps in arranging the data in structures so that the toll operators and the auditors can easily retrieve and analyze the information. At the time of making substantiation requests, the application layer knows the relevant records maintained on the blockchain, which allows them to be shown in a simple way to the operator, which displays the most recent verification of the provisioning system and attempts to check why this result was obtained. The application layer performs an additional security function by restricting access, thus only valid registered users can request sensitive data.

The systems busyness is also considered during the designs. With the increase in the number of traffic volumes or the expansion of the number of toll stations, the blockchain architecture depicts the possibility of accommodating an ever-increasing number of toll gates and verification requests. Thanks to the modular design, every toll gate operates as a stand-alone node which connects to the central blockchain which is scattered across all other gates. Such a decentralized structure makes it possible to add more toll gates to the system without making drastic changes to its configuration. For instance, in a national toll network, individual areas could have their nodes that only keep infrequent verification pages but be local within the general blockchain. This organization of data aids in the growth of the system without any degradation of performance via version control.

CHAPTER 4

RESULTS AND DISCUSSION

The vehicle verification system offered can be used at toll gates by obtaining the unique ID of the vehicle and the basin number plate when the vehicle gets to the toll gate. Such information that has been captured will then be used to determine the vehicle's verification status whether the vehicle is registered and allowed to be on the roads. At this moment, a verification check is enabled on the said information against the block to ensure and identify the verification of the vehicle. Two different processes are initiated in the system based on the outcome of the verification of the vehicle; one is for successful verification while the other one is for unsuccessful verification.

Once the verification of the unique identification of the vehicle and its number plate is complete, a new block is created and added to the blockchain history. It is now possible to create a permanent record of the motor vehicle's toll gate entry which can be always accessible and invariable in its log status. The structure of this block contains several important fields, especially the block number, which identifies a unique block on the blockchain, the ID of the toll gate that was used to verify the vehicle and the registration number and unique ID of the vehicle that was registered through the unique id. A block also contains the time corresponding to when the verification occurred, a hash of the previous block which is a pointer to the last block in the chain and the hash of the current block which is given to the current block being filled in. The validation and verification of the transaction is marked as true to signify the successful completion of the verification process. Moreover, the vehicle owner's identity and unique number are also included in the block as the verification was carried out successfully.

This arrangement allows the tracking of not only the vehicles' current condition but also the details that correspond to their condition thereby increasing the verifications efficiency and safety. If the validation outcome is marked as true, it simply means the vehicle in question has undergone all the required inspection checks and is therefore authorized to use the toll roads. This segment of information is now etched into the blockchain(figure 4.1); hence, the system can easily monitor and record every entry, leaving an accurate database of every automobile that has ever existed.

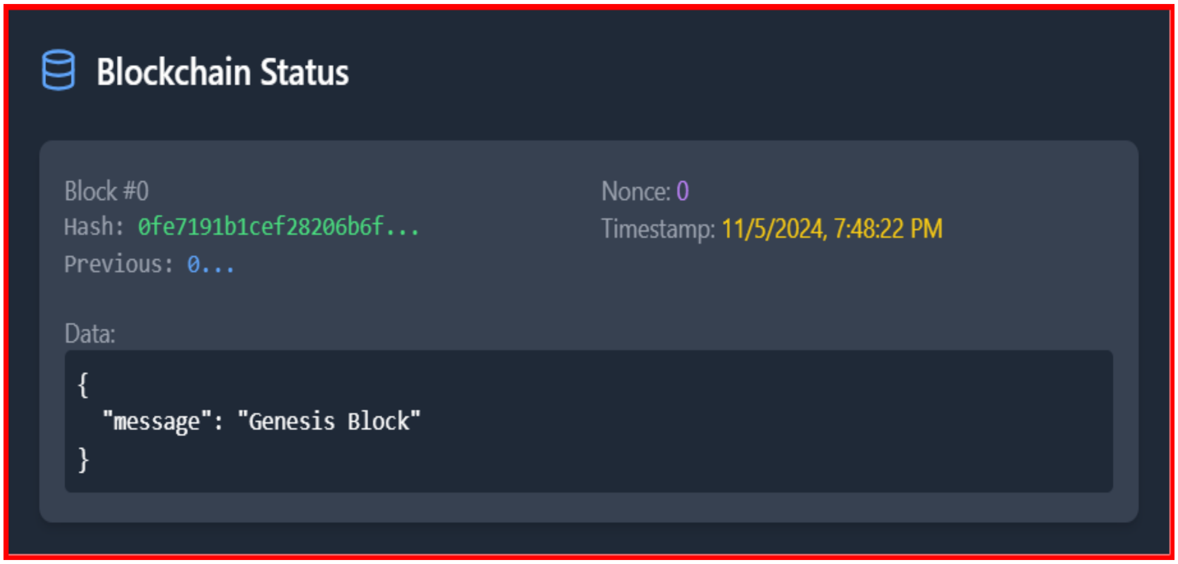

Fig 4.1:block chain status

If there is a failure in the verification process, that is when the registered data has no reference to any vehicle data that is already on the blockchain, the same processes of mining a block will be followed, but certain amendments will be made to indicate the unsuccessful verification of the vehicle on the process. This block will also be integrated into the blockchain with the intention of keeping track of the fact that a verification process has been attempted in the first place but was unsuccessful. This time however, there are some changes in some fields which are present in the case of a successful verification block. The list of fields for a verification block that was not successful includes the owner of the vehicle's number, the block number, the ID of the toll gate, and the number plate of the vehicle as well as its unique ID even if they are incoherent to the system. There is also the time indicating when the verification in question failed in the first place and which is also present in some other blocks known to have the block hash codes which help for verification purposes. The time taken for the vehicle handle is marked nil since it has not been successful with the verification and thus fields such as the owners name and unique id which are usually associated with vehicles are left empty as this information does exist. The integration of the above block for instance in this case, vehicles that do not succeed during the verification process will receive specific codes that have important connotations to the functionality of the system.

It means that even when there is no authorization granted to a vehicle, there exists a combination of a historical trace where that vehicle attempted access into the toll road. In this case, the system raises an indicator for the failed verification as an history (figure 4.2) of the various attempts and all such attempts are recorded into the blockchain. The phrase, “vehicle not found in the registry cannot be deleted” is also embedded within the statement and all rows connected to the vehicle’s registration and particulars are kept blank so that they do not contain any sensitive information but records the incident. The basis of such verification is the fact that a specific vehicle has attempted to access a toll gate and if successful, that history is based on both attempted and successful when the attempt has failed always remains vast. When a specific toll gate is approached by the vehicle by the vehicle at some future time, the history in the blockchain is checked to see if it was successful in getting through and this check could be done faster than before. Such functions would enhance the efficiency of the processes since the records of a vehicle would state whether it has been previously verified as opposed to being verified on every single occasion. Such history records will not only enhance the speed of the entire process but will also allow the toll operatives to detect the frequency of failed verifications and the reasons behind them.

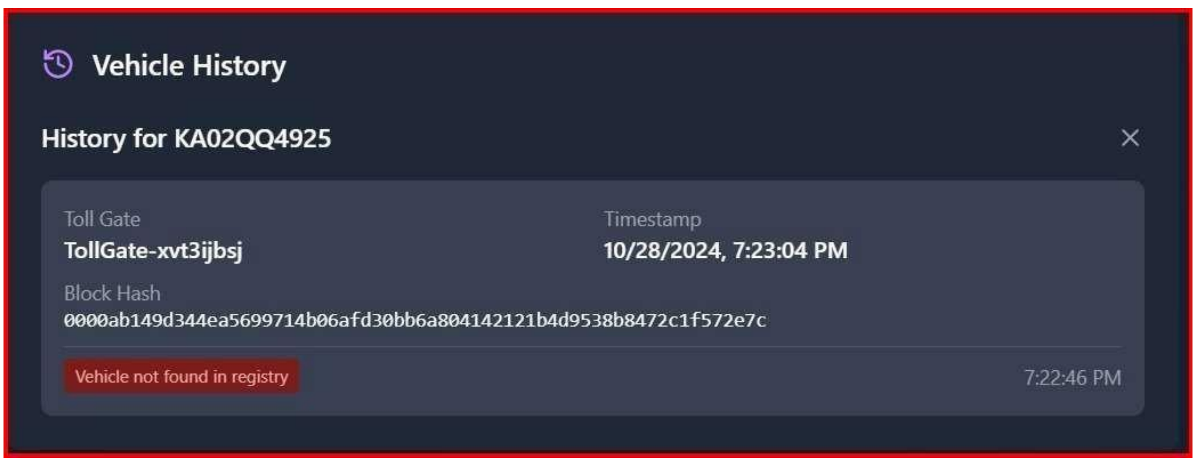

Fig 4.2: Vehicle History

Because of the decentralized structure of the blockchain, this historical information is well-protected, transparent, and unchangeable. Each information block remains on the chain permanently and can be accessed by the pertinent authorities for auditing or investigations, without interfering with the data in any way.

In short, vehicles that use this blockchain-based vehicle verification system find practically no use in having tolls built in at the toll gates, as all records maintained electronically and are irrefutable. Ministries of Finance or TGA vehicles create history for each vehicle by mining a block for both efficient and inefficient verification performed within the system and facilitating accurate, effective, and real-time verification security. Such data enables the toll infrastructure to be more active which shortens the verification cycle for such vehicles that are receptive to return and instead lengthens the verification case for vehicles suspected of having a history of red flags. This system demonstrates how the incorporation of blockchain in public infrastructure improves the whole processes by allowing for timely, efficient, and effective security of data and transparency in the management of toll operations.

This study proposes a decentralized vehicle verification system aimed at authenticating vehicles and preventing any fraudulent action at toll gates. The introduction of the blockchain to capture the vehicles universal identity and recorded history of toll usage ensures traceability and prevention of malicious infringement. This section explains the outcomes and technical details of the system and discusses its role in improving security, efficiency, and transparency of toll management.

System Process and Verification Steps:

As the vehicles get to the toll booth area, a vehicle number plate RFID reader is first situated at the booth and scans the unique embedded code affixed on each vehicle plate number. Its unique code affiliated with the vehicle at registration is embedded securely on the owner and vehicle records placed on the blockchain. Upon scanning the vehicle that the warm getting scanned and the seal is on the was initiated it starts cross checking the warm against the blockchain. This attempt establishes conclusively whether the warm scanned bears the code already registered within the decentralized ledger.

In Successful Verification if the vehicle is regarded illicit if the unique code is sustained in the blockchain. The customers continue with their normal business, and the new block is incorporated in the blockchain. This block gets created with data verification and saves toll gate ID, vehicle license plate, pointer, date and time of the transaction as well as the hash code covering the growing block. Such wordings create irreversible record network which allows having a complete picture of each vehicle user of the toll gate multiplicity.

In Failed Verification if the presented distinguishing feature does not find its unique code in the existing blocks, the responsible bodies receive unequivocal information of possible discrepancies. Appropriate bodies will be able to contain possible breaches since the appropriate bodies have been automatically notified. In such cases, a block is still created to record the verification process so that it provides information on the failure of the outcome in some fields. Information about the toll gate ID, date, time, and virtual images of vehicles which have not been completely verified have been included in this entry to ensure that the verification processes have been recorded but not to infringe on the data catalogued.

Blockchain Block Structure and Security Features

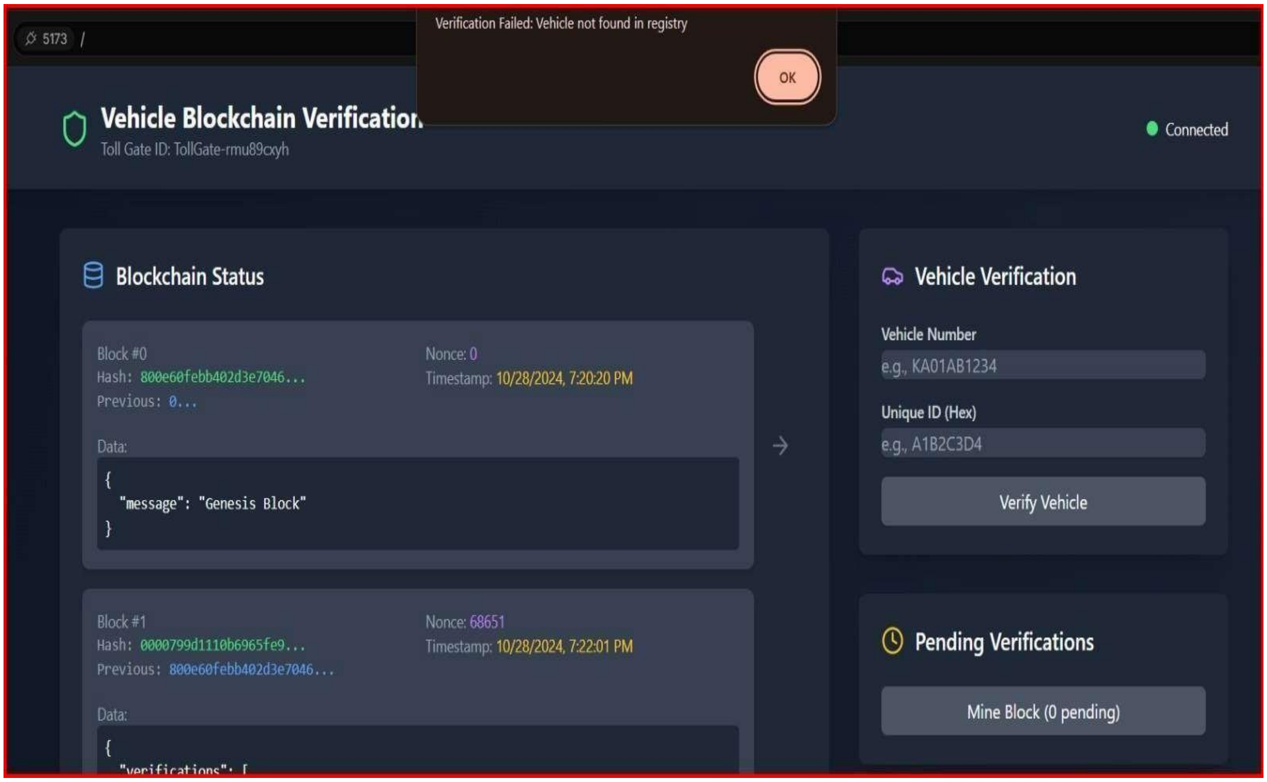

Fig 4.3: Verification success / failure

Every interaction of the vehicle with the verification system creates a block on blockchain technology which serves the function of logging the vehicle in and out of the toll gate system as transparent and traceable within the blockchain. Therefore, in this blockchain based road toll management system, it has been uniquely assigned block numbers whereby each block occupies its specific place in the chain. The precise location of the vehicle at a specific toll gate can be verified from the Toll Gate ID. In addition, entry of the data is accompanied by a Vehicle Registration Number and Unique ID which is linked to a specific vehicle to avoid duplications or forgery. At the time of verification, a Timestamp is also recorded, which chronologically orders the events allowing for tracing and auditing. Each block as a matter of security contains a Previous Block Hash which serves as a pointer to the block in front of it, forming an uninterrupted and unmodifiable sequence. A Current Block Hash comes last which is created based on the content of the particular block which serves to further secure and protect the system. Because of the security inherent in the blockchain, unauthorized changes to it is impossible. If a block is altered, the hash value will change, breaking the links in the chain and sounding the alarm. This unique feature means that all verification activities that are done, whether successful or failed, are not lost and remain visible to all.

Improved toll operation performance and security

In implementing the RFID-based system, it integrates the block chain technology which enhances the operations of the system. First, it almost eliminates toll fraud since the authenticity of a vehicle is verified before charging tolls to that particular vehicle. By limiting or even eliminating duplicate or fraudulent license plates, the system helps prevent tax revenue losses and enhances road safety. Also, the technology provides seamless and extensible verification. Instead of conventional approaches, which may consist of physical checks or dependence on a specific locality's databases, it is possible to verify across several toll points quickly and easily because of the blockchain's centrally-distributed network. This makes it possible to carry out immediate verification swiftly and reliably without the intervention of a central administrator. In addition, the blockchain ledger is chronologically organized and therefore, capable of providing historical traceability of all the verification actions conducted in the past. These features not only make it easier to perform subsequent verifications but also provide fertile ground for assessing traffic and fraud patterns; for instance, cars that are verified multiple times unsuccessfully can easily be follow up on preventive measures. Finally, the system ensures that all cost toll transactions can be verified by authoritative bodies since such records are immutable owing to the blockchain technology employed. Such transparency engenders public confidence that all tolls and verification processes can be observed and have not been interfered with.

Future Enhancements and Broader Applications

The robust design of the proposed system of the claim sees various possible improvements beyond toll gate verification. The addition of blockchain into law enforcement agency databases could increase its scope of use as it would be able to trace vehicles that have criminal records or even those whose fines are outstanding. Furthermore, the distributed nature of the blockchain makes it capable of scaling to different regions which would allow future applications to enhance inter and intra state and international toll interoperability. Different states or countries would allow vehicles to pass through their tolls with verification history on a common blockchain database. Another possible improvement is the use of blockchain ledger to automate billing systems by getting toll fees from the digital wallet linked to the vehicle. Such a system would eliminate the hustle of paying tolls and also ease traffic since there would be no need for toll booths. Additionally, the information of the tolls could be utilized by authorities for traffic and revenue management with an aim of optimizing the operations of the tows during peak traffic periods and assisting planning of infrastructure and revenue forecasting. In addition, stronger privacy features transactional and sensitive details of vehicles and their owners could be encrypted selectively to provide privacy but still ensure traceability. The deployment of RFID technology together with blockchain provides a forthright answer to the problem of verifying a vehicle in a decentralized manner and this improves the safety of tolling activities. This system not only reduces threats of fraudulent activities but also provides an invincible, clear, and verifiable history of every vehicle that pays a toll. The blockchain database leaves a historical trace for every attempt to verify, whether it was successful or not; thus, every activity is easily traceable, which for toll operations brings about greater transparency and accountability.

These problems in the current toll systems we overcome through the vehicle verification approach that is decentralized, thus providing a basis for a more secure and efficient physical infrastructure. This system demonstrates the advantages of utilizing blockchain in the public services, further illustrating its prospects in revolutionizing toll management systems in the future. Scalability is one of the most important benefits offered by a blockchain-based system. If the scope of toll operations increases or an additional number of toll booths are set up, there is no need to worry because new verification nodes can be fitted into the system's network seamlessly. Such scalability is important to the existing system as it aims to incorporate more vehicle checkpoints in future, maybe at border crossings or inspection stations. In addition, the modular nature of blockchain technology implies that more functions could be incorporated to improve functionality further, such as automatic withdrawal of toll fees or the inclusion into law enforcement databases. For example, one of the advances may enable cross-referencing with a vehicle insurance database in order to identify uninsured or registered vehicles in the system.

This research proposes a decentralized vehicle verification system that also addresses key challenges related to toll gate operation by legitimating only registered vehicles access privileges. By recording all activities on the blockchain, there is no doubt that all vehicles authenticated at the toll gate transactions are all stored in a permanent, unchanging and transparent database. While the system definitely presents impressive results, further studies could be directed towards perfecting the system to further enhance scalability, improve transaction speed and reduce costs. Other public integrations may also be investigated in future works.

In closure, the decentralized vehicle verification system presented in this research work has a great potential of transforming the operations of toll gates as it integrates the use of blockchain technology and RFID identification of vehicles. The results suggest that blockchain ledgers can ensure that all toll transactions are recorded and makes the verification of any vehicle more sufficient and easy.This system efficiently addresses the existing challenges of toll operations in which unauthorized or fraudulent vehicles gain access to toll roads thereby preventing loss of toll revenue and promoting public security.

The blockchain's constancy of data and its transparency makes it more secure for all authorized parties to retrieve and assess such sensitive data such as verification records since there is no risk of altering the underlying facts or details. The rapid time for real time verifications as well as the unchangeable and permanently embedded logs of all the transactions depict the ability of the system to withstand high volumes of transactions without compromising on efficiency. Furthermore, the versatility of the blockchain network makes it possible that this approach can be extended to additional checkpoints or combined with other vehicle compliance measures, like insurance and emission checks, increasing its effectiveness.

In conclusion, the implemented verification system based on the blockchain technology does not only eliminate significant security problems which exist in traditional solutions introduction while creating a more robust, transparent, and efficient tolling system as a whole. Future upgrades such as integration with other public databases and improvements aimed at reducing latency, will make it possible to introduce this model across the industry increasing trust and safety within transportation networks and during tolling of legitimate users.

CHAPTER 5

CONCLUSION

The vehicle verification and the tolls in question are both secured by blockchain technology which ensures that the governments or the tolls themselves have access to reliable and accurate data regarding each vehicle on the road at a given time. As the entire country of the United States has a distributed blockchain which increases the verification action need since there are many nodes which contain the vehicle data view, this capability makes it practically impossible to modify any of them and stores the history of all verifications that are performed through the database. It has the capability of keeping all nodal verification records without the nodes being changed and controls a free flow of throughput however preserves quite a number of toll level security for India.

The distinction of the system is also an ability to confirm a distinguishing feature: this feature enables the discrimination of images in real time registration once a Vehicle license plate as well as the vehicles registration mark is printed. It seamlessly interacts with the system by searching for certain keywords within the blockchain which have been entered. Within seconds, toll collectors verify the current status of a vehicle's registration or check whether a vehicle is marked as stolen.

In the event that, for example, the tag has expired status or that vehicle is stolen, then an alarm is sent out without any delay so that toll operators can take the necessary measures. This way, all legal vehicles are stopped from passing the toll which enhances the security of the area by making sure that there are no unnecessary vehicles on the road.

Other commentators think uncompromised transaction privacy is the other strength of this blockchain based solutions. So, the toll operators do not have to worry if every vehicle transaction is recorded in a separate from the other blockchain graphic. This kind of transparency, however, instills confidence not only to the toll operators but also to motorists and the authorities, knowing that every transaction may be traced back to the parties on the chain. This means that cases of fraud and errors commonly connected with centralized databases are minimized and the contact information is secure and well managed. This feature is useful in building confidence in the system since all the players are sure that it will function effectively.

During testing, the system has proven to be very efficient and precise and very scalable. It has been tested with several scenarios of vehicle statuses which include active, expired and stolen registrations and it has provided accurate results.

Such resilience guarantees it can be used at all levels as it can endure the hi frequency needs of the toll gates of the nation. With the interstate traffic at new peaks each day, it has become essential that systems are so scalable that they can easily scale up to accommodate all the increase in volume of data with accuracy so as to enable effective toll systems.

Not only improving the existing ones, this technology has – or is believed to have – the potential to revolutionize tolling processes through enhanced security, transparency, and accountability. Because even when a vehicle is captured by a joint system and numerous agents, everyone is confident that every transaction is open because real time data verification was utilized. All information is contained within the Blockchain system due to its decentralized architecture which makes it daunting for malicious actors to access or change any data.In brief, this time around, the process of toll collection and its related activities in particular has been made much more efficient and effective through the deployment of Blockchain technology. Beyond greatly improving the mechanics of toll operation, it goes to a tremendous length in maximizing public trust and safety, enabling full, real-time verification of every single vehicle on the street.

Innovation is very well visible in this case especially where it goes beyond enabling blockchain transactions but rather enabling secure and very transparent public service systems. This development confirms the future of the tolls with a promise of moving away from the central database model and shortening the distance and the trust of the data and the information. Furthermore, it would assist in fostering enhanced accountable and dependable toll systems throughout the nation.

CHAPTER 6

FUTURE SCOPE

The blockchain-based vehicle registration and verification system has a great scope in the future. A significant room for growth is national integration — facilitating a single, interoperable network for vehicle data across all Indian states. This would enhance coordination between the state transport departments and provide a seamless experience for owners of the vehicle. Further, the cooperation across national borders may result in uniform car registration and observation mechanism provoking more mobility and simultaneously engendering greater regional identities.

From a security point of view, it could also be further enhanced with decentralized systems, algorithms, more advanced cryptographic protocols, and powerful multifactor authentication to avoid fraud and unauthorized access. Another great opportunity comes with Internet of Things (IoT) functionalities, which would provide real-time data from the vehicles regarding emissions, mileage, maintenance, and more. By housing this data on the blockchain it would create a greater level of transparency, assist regulators with compliance of safety and environmental protocols, etc.

Roadside toll collections, through current smart contract architecture, may be automated via smart contract upgrades, acting as a higher layer of toll payment avoiding all physical tolls as a transaction. In addition, by applying AI and ML to fraud-detection systems, we can also identify and prioritize suspicious activity ahead of time, which means that such an approach can also make the system more powerful simultaneously. Privacy springs to mind as potential later updates of the system will be the requirement to safeguard against the spread of protections around user data so that user data (and all of its associated personal information) can be managed as securely and in private as possible.

It becomes advantage and highly accessible to vehicle owners through the mobile app. thus, they will be allowed to view registration status, verification history, and notifications online in real time. Later on, this system can be extended to other automotive services that include insurance verification, financing, as well as resale transactions by opening up more transparent and trustworthy processes from both sides of transactions with the help of blockchain.

Policymakers need real-time analytics to aid in the decision-making process of where to invest in transport infrastructure and development, which dashboards can provide. Heightened public awareness and communal and individual demonstrations of use would help drive adoption of the system and ultimately ensure that it proves effective as intended.

REFERENCES

[1] M. Sindhu, and I. Jeya Sheela, “Toll Plaza Management System Using Text Detection and TextRecognition Techniques,” International Journal of Scientific Research in Computer Science, Engineering and Information Technology, vol. 5, no. 3, pp. 1-7, 2019.

[2] H. Tanveer, N. Javaid, “Using Ethereum Blockchain Technology for Road Toll Collection onHighways,” COMSATS University Islamabad, Pakistan, 2019.

[3] K. Abbas, L. A. Tawalbeh, A. Rafiq, et al., “Convergence of Blockchain and IoT for Secure Transportation Systems in Smart Cities,” Hindawi Security and Communication Networks, vol. 2021, pp. 1-13, 2021.

[4] S. A. Bagloee, M. Tavana, G. Withers, et al., “Tradable Mobility Permit with Bitcoin and Ethereum: A Blockchain Application in Transportation,” Transportation Research Part A: Policyand Practice, vol. 124, pp. 354-372, 2019.

[5] J. Jamshaid, N. Javaid, “A Distributed Blockchain-Based Decentralized Trust Management Vehicular Network in Smart Cities,” COMSATS University Islamabad, Pakistan, 2020.

[6] Z. Ying, L. Yi, and M. Ma, “Blockchain-Based Efficient Highway Toll Paradigm for Opportunistic Autonomous Vehicle Platoon,” Wireless Communications and Mobile Computing,vol. 2020, Article ID 8868656, 2020.

[7] D. Das, S. Banerjee, P. Chatterjee, et al., “Design and Development of an Intelligent Transportation Management System Using Blockchain and Smart Contracts,” Cluster Computing,vol. 25, pp. 1899-1913, 2022.

[8] M. Zrikem, I. Hasnaoui, and R. Elassali, “Vehicle-to- Blockchain (V2B) Communication: Integrating Blockchain into V2X and IoT for Next-Generation Transportation Systems,” Electronics, vol. 12, no. 3377, 2023.

[9] F. Alharbi, M. Zakariah, R. Alshahrani, et al., “Intelligent Transportation Using Wireless Sensor Networks, Blockchain, and License Plate Recognition,” IEEE Transactions on Intelligent

Transportation Systems, 2023.

[10] A. Gupta, R. Agarwal, A. Prabhat, et al., “Toll and Traffic Management System for Express Highways,” International Journal of Innovative Technology and Exploring Engineering (IJITEE),vol. 9, no. 5, pp. 1-10, 2020.

[11] B. Xiao, X. Fan, S. Gao, et al., “Edge Toll: A Blockchain-Based Toll Collection System forPublic Sharing of Heterogeneous Edges,” IEEE INFOCOM 2019 - IEEE Conference on Computer Communications Workshops (INFOCOM WKSHPS), pp. 1-6, 2019.

[12] W. Li, H. Guo, and M. Nejad, “Privacy-Preserving Traffic Management: A Blockchain and Zero-Knowledge Proof Inspired Approach,” IEEE Transactions on Intelligent Transportation Systems, vol. 21, no. 8, pp. 1-14, 2020.

[13] Deng, X., & Gao, T. (2020). "Electronic Payment Schemes Based on Blockchainin VANETs." IEEE Access, 8, 38296-38303.

[14] Sathya, V., Ostwal, R., Bhattacharjee, S., & Karmakar, M. (2019). "Automated Toll Collection Using Image Processing and Blockchain." International Journal of Engineering Science and Computing, 9(10), 23809-23813.

[15] Casino, F., Dasaklis, T. K., & Patsakis, C. (2019). "A systematic literature review of blockchain-based applications: Current status, classification, and open issues." Telecommunications Systems, 69(1), 67-91.

APPENDIX A

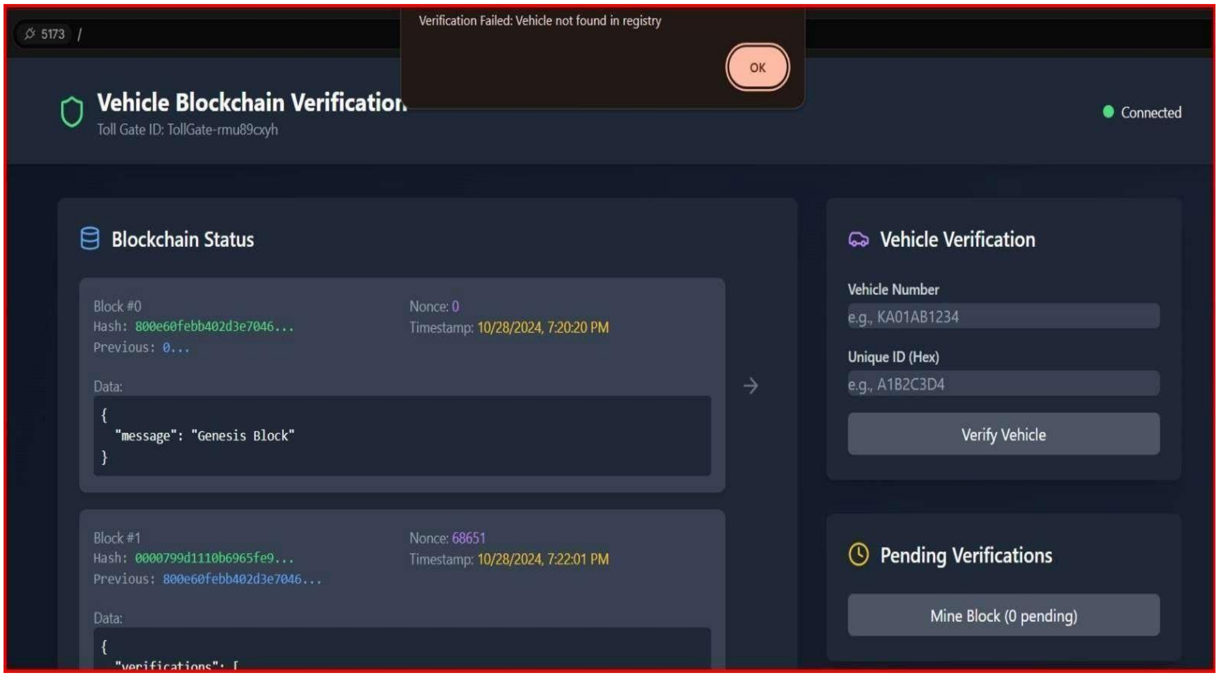

Fig 6:Dashboard

The above includes a blockchain status section with information on blocks, each displaying a unique hash, timestamp, and message data, starting from the genesis block (Block #0). A "Vehicle Verification" section is present on the right, where users can input a vehicle number and unique ID for verification. The error message at the top indicates "Verification Failed: Vehicle not found in registry," suggesting the system couldn't locate the entered vehicle details in its records. The system appears connected, as indicated in the top right.

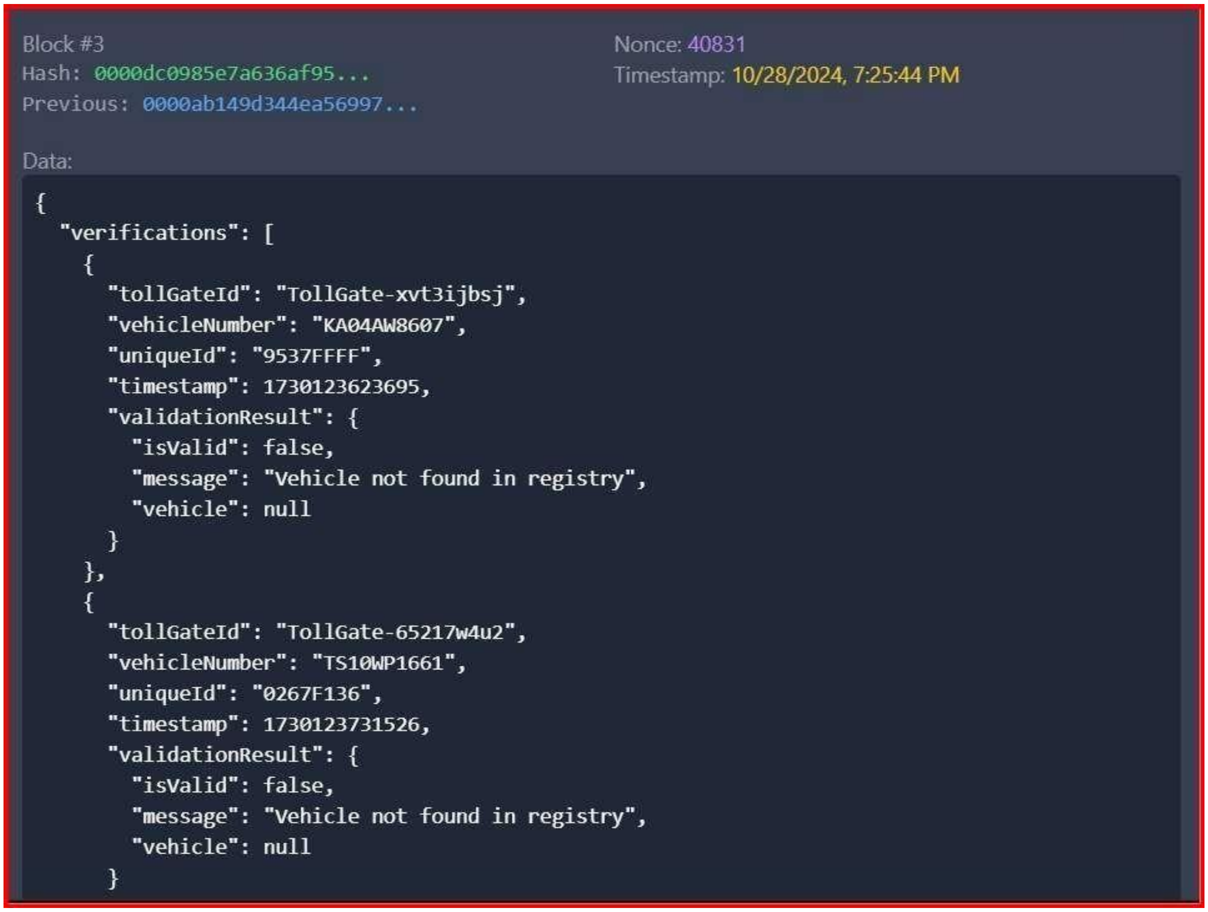

Fig 7:Block Creation

This image shows the data of Block #3 in a blockchain-based vehicle verification system. The block contains multiple vehicle verification records, each associated with a specific toll gate ID, vehicle number, unique ID, and timestamp. The validationResult for each vehicle entry indicates "isValid": false, with a message saying "Vehicle not found in registry," suggesting that these vehicles are not registered in the system's database. This block documents verification attempts for vehicles that were not successfully validated.

Fig 8:Vehicle Registry

Vehicle Registry shows the history of the vehicles which are passed by the tollgates. And vehicleregistry shows the details of the car (Number Plate, Owner Name, State, Country Name, and unique ID of the car).

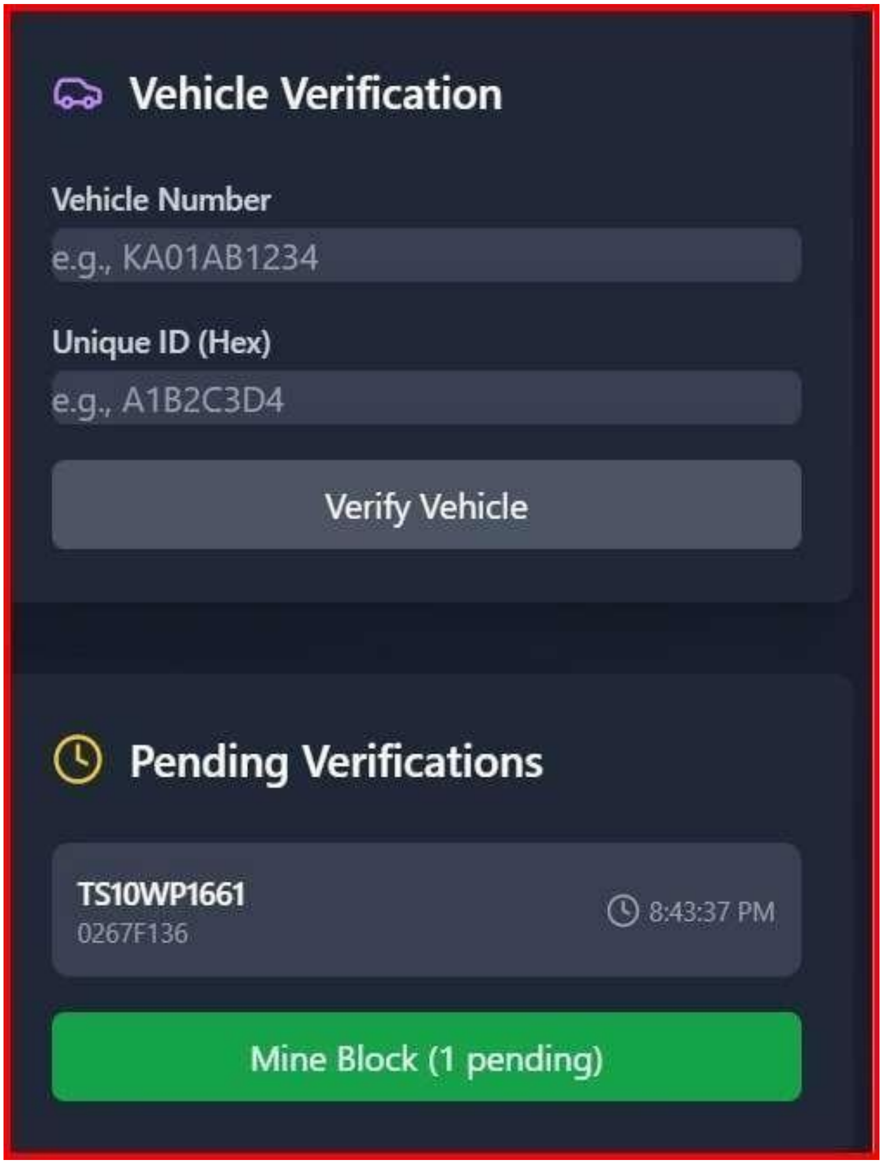

Fig 9:Vehicle Verification

The above image shows a Vehicle Verification interface where users can input a Vehicle Number and a Unique ID (Hex) to verify the vehicle. Below this, there is a Pending Verifications section listing a vehicle with registration number TS10WP1661 and unique ID 0267F136, pending verification at 8:43:37 PM. A button labeled Mine Block (1 pending) is available, indicating that one verification is awaiting processing.

}

BLOCKCHAIN.JS

```
import crypto from 'crypto-js';
import { registeredVehicles } from './models/Vehicle.js';

class Block {
  constructor(timestamp, data, previousHash = '') {
    this.timestamp = timestamp;
    this.data = data;
    this.previousHash = previousHash;
    this.nonce = 0;
    this.hash = this.calculateHash();
  }

  calculateHash()   {
    return crypto.SHA256(
    this.previousHash +
    this.timestamp +
      JSON.stringify(this.data) +
      this.nonce
    ).toString();
  }

  mineBlock(difficulty) {
    while (
      this.hash.substring(0, difficulty) !== Array(difficulty + 1).join('0')
    ) {
      this.nonce++;
      this.hash = this.calculateHash();
    }
  }
}
```

```
class Blockchain {
  constructor() {
    this.chain = [this.createGenesisBlock()];

    this.difficulty = 4;
    this.pendingVerifications = [];
  }

  createGenesisBlock() {
    return new Block(Date.now(), { message: 'Genesis Block' }, '0');
  }

  getLatestBlock() {
    return this.chain[this.chain.length - 1];
  }

  validateVehicle(vehicleNumber, uniqueId) {
    // First check if vehicle exists in registry
    const registeredVehicle = registeredVehicles.find(v => v.vehicleNumber ===
    vehicleNumber);

    if (!registeredVehicle) {
      return {
        isValid: false,
        message: 'Vehicle not found in registry',
        vehicle: null
      };
    }

    // Then check if uniqueId matches
    if (registeredVehicle.uniqueId !== uniqueId) {
      return {
        isValid: false,
```

```
        message: 'Invalid unique ID for vehicle',
        vehicle: null
      };
    }
// Finally check if vehicle data is valid if
(!registeredVehicle.isValid()) { return {
        isValid: false,
        message: 'Vehicle data integrity check failed',
        vehicle: null
      };
    }

    return {
      isValid: true,
      message: 'Vehicle verified successfully',
      vehicle: registeredVehicle
    };
  }

  addVerification(tollGateId, vehicleNumber, uniqueId) {
    const validation = this.validateVehicle(vehicleNumber, uniqueId);
    const verification = {
      tollGateId,
      vehicleNumber,
      uniqueId,
      timestamp: Date.now(),
      validationResult: validation
    };

    this.pendingVerifications.push(verification);
    return validation;
  }
```

```
minePendingVerifications(tollGateId) {
  const block = new Block(
    Date.now(),
    {
      verifications: this.pendingVerifications,
      tollGateId,
      timestamp: Date.now()
    },
    this.getLatestBlock().hash
  );
  block.mineBlock(this.difficulty);
  console.log('Block mined!');
  this.chain.push(block);
  this.pendingVerifications = [];
}

isChainValid() {
  for (let i = 1; i < this.chain.length; i++) {
    const currentBlock = this.chain[i];
    const previousBlock = this.chain[i - 1];

    if (currentBlock.hash !== currentBlock.calculateHash()) {
      return false;
    }

    if (currentBlock.previousHash !== previousBlock.hash) {
      return false;
    }
  }
  return true;
}

getVehicleHistory(vehicleNumber) {
```

```
    const history = [];
    for (const block of this.chain) {
      if (block.data.verifications) {
        const vehicleVerifications = block.data.verifications.filter(
          v => v.vehicleNumber === vehicleNumber
        );
        if (vehicleVerifications.length > 0) {
          history.push({
            blockHash: block.hash,
            timestamp: block.timestamp,
            tollGateId: block.data.tollGateId,
            verifications: vehicleVerifications
          });
        }
      }
    }
    return history;
  }
}

export default Blockchain;
```

INDEX.JS

```
import express from 'express';
import { createServer } from 'http';
import { Server } from 'socket.io';
import cors from 'cors';
import Blockchain from './blockchain.js';
import { registeredVehicles } from './models/Vehicle.js';

const app = express();
```

```
const httpServer = createServer(app);
const io = new Server(httpServer, {
cors: {
   origin: "http://localhost:5173",
   methods: ["GET", "POST"]
  }
});

app.use(cors());
app.use(express.json());

const vehicleChain = new Blockchain();

io.on('connection', (socket) => {
  console.log('Client connected');
  const tollGateId = TollGate-${Math.random().toString(36).substr(2, 9)};
  console.log(Assigned Toll Gate ID: ${tollGateId});
socket.emit('tollGateAssigned', { tollGateId });

  socket.on('requestBlockchain', () => {
    socket.emit('blockchainUpdate', {
    chain: vehicleChain.chain,
      pending: vehicleChain.pendingVerifications,
      registeredVehicles
    });
  });

  socket.on('addVerification', (data) => {
    const validation = vehicleChain.addVerification(
      data.tollGateId,
      data.vehicleNumber,
      data.chassisNumber
    );
```

```
    io.emit('blockchainUpdate', {
      chain: vehicleChain.chain,
      pending: vehicleChain.pendingVerifications,
      registeredVehicles
    });

    socket.emit('verificationResult', validation);
  });

  socket.on('mineBlock', (data) => {
    if (vehicleChain.pendingVerifications.length > 0) {
      vehicleChain.minePendingVerifications(data.tollGateId);
      io.emit('blockchainUpdate', {
        chain: vehicleChain.chain,
        pending: vehicleChain.pendingVerifications,
        registeredVehicles
      });
    }
  });
  socket.on('getVehicleHistory', (data) => {
    const history = vehicleChain.getVehicleHistory(data.vehicleNumber);
    socket.emit('vehicleHistory', history);
  });
});

const PORT = 3000;
httpServer.listen(PORT, () => {
  console.log(Server running on port ${PORT});
});
```

VEHICLEHISTORY.TSX

```
import React from 'react';
import { X } from 'lucide-react';

interface HistoryEntry {
  blockHash: string;
  timestamp: number;
  tollGateId: string;
  verifications: Array<{
  vehicleNumber: string;
  uniqueId: string;
  timestamp: number;
  validationResult: {
      isValid: boolean;
      message: string;
    };
  }>;
}

interface Props  {
  history: HistoryEntry[];
  vehicleNumber: string;
  onClose: () => void;
}
const VehicleHistory: React.FC<Props> = ({ history, vehicleNumber, onClose }) => {
  return (
    <div>
      <div className="flex justify-between items-center mb-4">
        <h3 className="text-lg font-medium">History for {vehicleNumber}</h3>
        <button
          onClick={onClose}
          className="text-gray-400  hover:text-gray-300"
        >
```

```
    <X className="w-5 h-5" />
  </button>
</div>

<div className="space-y-4">
  {history.length === 0 ? (
    <p className="text-gray-400">No history found for this vehicle.</p>
  ) : (
    history.map((entry, index) => (
      <div key={index} className="bg-gray-700 rounded-lg p-4">
        <div className="grid grid-cols-2 gap-4">
          <div>
            <p className="text-sm text-gray-400">Toll Gate</p>
            <p className="font-medium">{entry.tollGateId}</p>
          </div>
          <div>
            <p className="text-sm text-gray-400">Timestamp</p>
            <p className="font-medium">
              {new Date(entry.timestamp).toLocaleString()}
            </p>
          </div>
        </div>
        <div className="mt-2">
          <p className="text-sm text-gray-400">Block Hash</p>
          <p className="font-mono text-sm break-all">{entry.blockHash}</p>
        </div>
        {entry.verifications.map((v, i) => (
          <div key={i} className="mt-2 pt-2 border-t border-gray-600">
            <div className="flex justify-between items-center">
              <span className={`px-2 py-1 rounded text-xs ${
                v.validationResult.isValid
                  ? 'bg-green-900 text-green-300'
                  : 'bg-red-900 text-red-300'
```

```
          }`}>
           {v.validationResult.message}
          </span>
          <span className="text-sm text-gray-400">
           {new Date(v.timestamp).toLocaleTimeString()}
          </span>
         </div>
        </div>
       ))}
      </div>
     ))
    )}
   </div>
  </div>
 );
};

 export default VehicleHistory;
```

VEHICLEREGISTRY.TSX

```
import React, { useState } from 'react';
import { Search, ChevronLeft, ChevronRight } from 'lucide-react';

interface Vehicle {
 vehicleNumber: string;
 uniqueId: string;
 ownerName: string;
 state: string;
 country: string;
}

interface Props {
```

```
  vehicles: Vehicle[];
  onViewHistory: (vehicleNumber: string) => void;
}

const VehicleRegistry: React.FC<Props> = ({ vehicles, onViewHistory }) => {
  const [currentPage, setCurrentPage] = useState(1);
  const vehiclesPerPage = 40;
  const totalPages = Math.ceil(vehicles.length / vehiclesPerPage);

  const indexOfLastVehicle = currentPage * vehiclesPerPage;
  const indexOfFirstVehicle = indexOfLastVehicle - vehiclesPerPage;
  const currentVehicles = vehicles.slice(indexOfFirstVehicle, indexOfLastVehicle);

  return (
    <div className="space-y-4">
      <div className="grid grid-cols-1 md:grid-cols-2 gap-4">
        {currentVehicles.map((vehicle) => (
          <div key={vehicle.vehicleNumber} className="bg-gray-700 rounded-lg p-4">
            <div className="flex justify-between items-start">
              <div>
                <h3 className="text-lg font-medium">{vehicle.vehicleNumber}</h3>
                <p className="text-sm text-gray-400">ID: {vehicle.uniqueId}</p>
                <p className="text-sm text-gray-400">Owner: {vehicle.ownerName}</p>
                <p className="text-sm text-gray-400">
                  {vehicle.state}, {vehicle.country}
                </p>
              </div>
              <button
                onClick={() => onViewHistory(vehicle.vehicleNumber)}
                className="flex items-center space-x-1 text-sm text-blue-400 hover:text-blue-
300"
              >
                <Search className="w-4 h-4" />
```

```
          <span>History</span>
        </button>

      </div>
    </div>
  ))}
</div>

<div className="flex justify-center items-center space-x-4 mt-4">
  <button
    onClick={() => setCurrentPage(prev => Math.max(prev - 1, 1))}
    disabled={currentPage === 1}
    className="p-2 rounded-full hover:bg-gray-700 disabled:opacity-50"
  >
    <ChevronLeft className="w-5 h-5" />
  </button>
  <span className="text-sm">
    Page {currentPage} of {totalPages}
  </span>
  <button
    onClick={() => setCurrentPage(prev => Math.min(prev + 1, totalPages))}
    disabled={currentPage === totalPages}
    className="p-2 rounded-full hover:bg-gray-700 disabled:opacity-50"
  >
    <ChevronRight className="w-5 h-5" />
  </button>
</div>
</div>
);
};

export default VehicleRegistry;
```

APP.TSX

```
import React, { useEffect, useState } from 'react';
import { io } from 'socket.io-client';
import { Shield, Car, Database, Clock, History } from 'lucide-react';
import BlockchainVisualizer from './components/BlockchainVisualizer';
import VerificationForm from './components/VerificationForm';
import PendingVerifications from './components/PendingVerifications';
import VehicleRegistry from './components/VehicleRegistry';
import VehicleHistory from './components/VehicleHistory';

const socket = io('http://localhost:3000');

function App() {
  const [blockchain, setBlockchain] = useState({ chain: [], pending: [], registeredVehicles:
    [] });
  const [isConnected, setIsConnected] = useState(false);
  const [tollGateId, setTollGateId] = useState('');
  const [vehicleHistory, setVehicleHistory] = useState([]);
  const [selectedVehicle, setSelectedVehicle] = useState(null);

  useEffect(() => {
    socket.on('connect', () => setIsConnected(true));
    socket.on('disconnect', () => setIsConnected(false));
    socket.on('blockchainUpdate', (data) => setBlockchain(data));
    socket.on('tollGateAssigned', (data) => setTollGateId(data.tollGateId));
    socket.on('vehicleHistory', (history) => setVehicleHistory(history));
    socket.on('verificationResult', (result) => {
      if (!result.isValid) {
        alert(Verification Failed: ${result.message});
      }
    });
```

```
  socket.emit('requestBlockchain');

  return () => {

    socket.off('connect');
    socket.off('disconnect');
    socket.off('blockchainUpdate');
    socket.off('tollGateAssigned');
    socket.off('vehicleHistory');
    socket.off('verificationResult');
  };
}, []);

const handleAddVerification = (vehicleNumber: string, chassisNumber: string) => {
  socket.emit('addVerification', { tollGateId, vehicleNumber, chassisNumber });
};

const handleMineBlock = () => {
  socket.emit('mineBlock', { tollGateId });
};

const handleViewHistory = (vehicleNumber: string) => {
  setSelectedVehicle(vehicleNumber);
  socket.emit('getVehicleHistory', { vehicleNumber });
};

return (
  <div className="min-h-screen bg-gradient-to-br from-gray-900 to-gray-800 text-
  white">
    <header className="bg-gray-800 shadow-lg">
      <div className="container mx-auto px-4 py-6">
        <div className="flex items-center justify-between">
          <div className="flex items-center space-x-3">
```

```
        <Shield className="w-8 h-8 text-green-400" />
        <div>
          <h1 className="text-2xl font-bold">Vehicle Blockchain Verification</h1>
          <p className="text-sm text-gray-400">Toll Gate ID: {tollGateId}</p>
        </div>
      </div>
      <div className="flex items-center space-x-2">
        <div className={w-3 h-3 rounded-full ${isConnected ? 'bg-green-400' : 'bg-red-

400'}}></div>
        <span className="text-sm">{isConnected ? 'Connected' : 'Disconnected'}</span>
      </div>
    </div>
  </div>
</header>

<main className="container mx-auto px-4 py-8">
  <div className="grid grid-cols-1 lg:grid-cols-3 gap-8">
    <div className="lg:col-span-2 space-y-8">
      <div className="bg-gray-800 rounded-lg shadow-xl p-6">
        <div className="flex items-center space-x-3 mb-6">
          <Database className="w-6 h-6 text-blue-400" />
          <h2 className="text-xl font-semibold">Blockchain Status</h2>
        </div>
        <BlockchainVisualizer blocks={blockchain.chain} />
      </div>

      {selectedVehicle && (
        <div className="bg-gray-800 rounded-lg shadow-xl p-6">
          <div className="flex items-center space-x-3 mb-6">
            <History className="w-6 h-6 text-purple-400" />
            <h2 className="text-xl font-semibold">Vehicle History</h2>
          </div>
```

```
    <VehicleHistory
      history={vehicleHistory}
      vehicleNumber={selectedVehicle}
      onClose={() => setSelectedVehicle(null)}
    />
  </div>
 )}
</div>

<div className="space-y-8">
  <div className="bg-gray-800 rounded-lg shadow-xl p-6">
    <div className="flex items-center space-x-3 mb-6">
      <Car className="w-6 h-6 text-purple-400" />

      <h2 className="text-xl font-semibold">Vehicle Verification</h2>
    </div>
    <VerificationForm onSubmit={handleAddVerification} />
  </div>

  <div className="bg-gray-800 rounded-lg shadow-xl p-6">
    <div className="flex items-center space-x-3 mb-6">
      <Clock className="w-6 h-6 text-yellow-400" />
      <h2 className="text-xl font-semibold">Pending Verifications</h2>
    </div>
    <PendingVerifications
      verifications={blockchain.pending}
      onMine={handleMineBlock}
    />
  </div>

  <div className="bg-gray-800 rounded-lg shadow-xl p-6">
    <div className="flex items-center space-x-3 mb-6">
      <Database className="w-6 h-6 text-green-400" />
```

```
          <h2 className="text-xl font-semibold">Vehicle Registry</h2>
        </div>
        <VehicleRegistry
          vehicles={blockchain.registeredVehicles}
          onViewHistory={handleViewHistory}
        />
      </div>
    </div>
   </div>
  </main>
 </div>
);
}

export default App;
```

APPENDIX B

CONFERENCE PRESENTATION

We have applied for the INCIP 2025 Conference and waiting for the result.

APPENDIX C

PUBLICATION DETAILS

Awaiting for the result.

APPENDIX D

PLAGIARISM REPORT

Dr. Gouthaman P

Report.pdf

Paper24

IOT

SRM Institute of Science & Technology

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