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A NOVEL INTEGRATED FRAMEWORK FOR SECURE IOT-BASED SMART VEHICLE MANAGEMENT USING MACHINE LEARNING AND BLOCKCHAIN FOR PATH PLANNING AND COLLISION AVOIDANCE

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ABSTRACT

The enormous developments taking place in technology for autonomous vehicles has created a big demand on intelligent systems retarding the zero accidents and fatalities transportation system needed for current highways. In this paper, we introduce a new integration framework incorporating IoT, machine learning and blockchain based technologies to overcome two major issues like path planning and collision avoidance in smart vehicle management. The framework will make use of IoT devices to collect data in real-time and communicate it between vehicles as well as with roadside infrastructure. The dynamic path planning for the execution of real-time decisions based on roadway terrain with different prediction and avoidance is optimized through machine learning algorithms. This immense quantity of exchanged data has been disrupted to be managed with a reliable standard in a decentralized, tamper-proof method using blockchain technology sunders the core trait of how IoT ecosystem operates. Using blockchain, the framework also guarantees vehicle-to-vehicle (V2V), vehicle to traffic light control system and then a vehicle computing server such as edge/fog/cloud servers so that all communications between vehicles by providing security and data sharing environment with confidence. The feature of blockchain integration does not only reduces the risks of hacking and tampering with data, but it also increases transparency as well as accountability in this system. The performance of the proposed framework is then examined through large-scale simulations and field experiments in different highway scenarios. Results show significantly improved path optimization, accident prevention and system wide reliability. The study shows that this holistic solution can help reduce traffic jams, improve road safety and support the growth of autonomous vehicles. This work adds to a larger collection of research efforts around smart transportation systems and underscores the utility in integrating novel methodologies towards establishing an improved vehicular environment.

Keywords: *Smart Vehicle Management, IoT, Machine Learning, Blockchain, Path Planning.*

1. INTRODUCTION

Breakthroughs in artificial intelligence (AI), machine learning (ML), and the Internet of Things have fueled a revolution, ushering in an era where transportation is no longer what it used to be: we stand on edge awaiting the imminent takeover of AV dominated roadways. Such a technological revolution could virtually promise a breakthrough for road safety, traffic management and environmental conservation like never seen before. This includes a variety of challenges that need to be met in order for autonomous vehicles to operate

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safely and reliably, especially modern highways that are complex and often very dynamic environments. The two most important difficulties among these challenges are path planning and collision avoidance. Path planning is the ability of a vehicle to plan and execute the most efficient path from point A (sometimes called 'GoTo') some other point B, keeping in mind traffic rules or any dynamic element around it. Collision avoidance, on the other hand, is detecting and avoiding potential obstacles or leaping traffic in real time to avoid accidents happening between vehicles. In this line of work, many studies have targeted to deal with these challenges, but most solutions are designed for fixed environments barely focusing on real-time security dangers and obstacles like scaling or highway dynamicity. Furthermore, current solutions do not take into consideration the necessity for secure vehicles to infrastructure communications that are central in making smart vehicle systems work well within a highly interconnected setting.

IoT technologies can aid in real-time information gathering and flow between the components of transportation like vehicles, infrastructure as well as other entities present. Smart vehicles have IoT devices inside that can communicate with other smart cars and roadside infrastructure to provide up-to-date traffic conditions, speed limits, vehicle locations as well as potential hazards. However, implementing IoT can face very important security issues because any data that is exchanged in this network could be exposed to potential cyber-attack such as tampering with the data, unauthorized access and also many other malicious activities. In this context, ensuring the integrity and security of this data is critical for safe autonomous vehicle operation. To avoid these security issues, blockchain technology has emerged as a solution. Born out of the necessity to manage secure and decentralized data in cryptocurrencies, blockchain has found application across different sectors due to its capability of enabling safe, verifiable and transparent exchange of information. By using blockchain within IoT based smart vehicle systems, it allows for a secure decentralized platform to enable communication between vehicles and infrastructure. By using a blockchain to make all the data exchanged between vehicles and other entities immutable and verifiable, Loreno says hacks (as well as leaks) from malicious actors become practically impossible. Machine learning is an essential element of today's smart vehicle systems, in addition to the security advantages provided by blockchain. This is because the age of machine learning algorithms enables vehicles to consume and process large amounts of data collected from even numerous IoT devices, cameras, sensors on scale in real-time. These algorithms optimize path planning, predict hazards danger and have to react quickly to avoid crashes. The more it is exposed to situations and from the corresponding learnings, updating their methods as a result can further perfect machines in decision-making for autonomous vehicles by making choices not only safer but also improve its effectiveness.

However, there has been limited work around organizing these advancements for creating an IoT, ML and blockchain intertwined framework to manage autonomous vehicles. However, very little research is done on building a complete solution that takes care of all those typical challenges faced during real-world highway scenarios by autonomous vehicles especially in terms of security, scalability and making decisions at the right time. Hence, it is critical to have a unified framework that can utilize the advantages of IoT and machine learning along with blockchain which provides a complete solution for intelligent vehicle management. This paper introduces a new comprehensive solution of IoT-machine learning-Blockchain for dealing with the problem of path planning and collision avoidance in managing control management such as autonomous vehicles on highways. With that in mind, the new model lays out for a system to work seamlessly and securely exchanging both vehicles with infrastructure data, planning efficient paths or roads as described via multiple threads with different segments thereby reducing traffic congestion while at the same time maintaining the safety of everyone using any road. The framework offers a scalable and secure solution that can be deployed within complex highway environments by integrating these three technologies to mitigate accident risks, optimizing the traffic flow as well as overall transportation efficiency. Challenges of increasing complexity caused by modern transportation systems require new solutions to handle the high density of vehicles on highways. What was way back in the day considered a thing of science fiction, is now here and many companies are pouring all kinds of money into getting factories up to speed with this tech everywhere on planet earth. On the other hand, using autonomous vehicles on highways faces a range of difficulties: real-time decision-making is required, data exchange must be precise and compliant throughout the system, while safety precautions are needed to avoid accidents as much as possible. Conventional path planning algorithms for autonomous vehicles are based on programmed routes and immutable maps. However, for dynamic environments such as highways these approaches do not fully take into account the continually changing traffic flow, state of roads and potential obstacles. Dynamic path planning is for autonomous vehicles to make dynamic changes in their route in real time based on the crowd condition and emerging obstructions. The basis of this is an intelligent data-processing system that can rapidly process large volumes of data, take decisions independently.

Collision avoidance is another important safety feature for self-driving cars, besides path planning. In order to avoid such accidents, autonomous vehicles must be equipped with sensors and cameras that can detect obstacles in their path, so they make decisions on time avoiding them as they came along. This has resulted in the need to develop sophisticated machine learning algorithms that can usefully predict when and how crashes will occur.

One of the most important elements is The Internet of Things (IoT), which makes it possible for autonomous vehicles to communicate in real time with various objects that they encounter. Cars communicate with each other and smart infrastructure, such as traffic signals, roadside units or cloud-based traffic management systems via IoT devices. Enabling vehicles to exchange data in real-time so they can make informed path-planning and collision-avoidance decisions. Still, the security of such communication raises many questions and challenges since IoT device data is susceptible to attacks like hacking (infiltration), tampering or any other malicious acts.

Blockchain technology has provided a solution to these security challenges. The IoT-enabled smart vehicle systems need tailored solutions for storing the huge amounts of generated data and blockchain offers a decentralized, secure, open access solution to an oftentimes critical problem. Blockchain allows autonomous vehicles to exchange data with one another and external systems, providing proof that the information is genuine and accurate (i.e. non-repudiable). Learning machines are essential for optimizing how these data decisions have been made by autonomous vehicles. Leveraging cutting-edge machine learning methods, vehicles have access to historical data which they use for enrichment of trajectory estimates and future traffic patterns generation thus allowing them dynamically to correspond current steering values with their predictions in real time all the while avoiding potential collisions or optimizing routes. In a similar case, machine learning algorithms let the vehicles adapt to road conditions and get better time-by-time with greater accuracy. However, the integration of IoT — machine learning and blockchain technologies into smart vehicle systems could have its own share of advantages. But first comes brimming challenges that must be addressed before these potent fruits are harvested from our supposedly soon to reach future landscapes. However, a fundamental issue is the absence of an integrated framework that amalgamates those to offer secure and scalable solutions for maintaining autonomous vehicle platoons on highways in efficient manner. The current path planning and collision avoidance approaches are frequently designed not to consider secure communication as well as real-time decision-making for the dynamic environment. The other problem is that of scale in existing solutions. As the volume of autonomous cars on freeways increases, so does this exchange and processing data between these vehicles and infrastructure. Most of this type of data is managed in traditional centralized systems, which are not scalable and carry significant security risks. In order to control data in large-scale smart vehicle systems, we must do things with fault tolerance — and on the blockchain. At last, she remembers that the existing popular path planning and collision avoidance methods are not good at adapting dynamic environments. They are usually reliant on pre-programmed routes and static maps that do not take into consideration the incessant changes in traffic flow, road conditions etc. with respect to highways/large expressways, for example when an accident has occurred/road closure is enforced. Machine learning algorithms that can give the ability to modify car routes dynamically when there is a traffic problem and how to avoid obstacles popping out during this process. In order to meet these requirements, we have come up with an unconventional integrated solution, using IoT (It enables data to be securely exchanged in real-time between vehicles and infrastructure, leads to the optimization of vehicle paths, and guarantees high-levels safety for all road users. It is a system based on IoT devices embedded in vehicles and on the highway side, which allows us to collect data for command-and-control traffic actions directly exploiting such information. Such devices continuously monitor vehicle surroundings, traffic conditions and potential hazards thus providing data necessary for path planning and collision avoidance. It leverages sophisticated AI and ML algorithms to analyze information transmitted by IoT devices at run-time, enabling the automation of decision-making processes for path planning and collision protection as well. Using these algorithms, they optimize vehicle routes by monitoring real-time traffic and forecast possible accidents so that the AVs can avoid crashes with evasive maneuvers. The framework uses a blockchain to ensure the security and integrity of data exchanged among vehicles, infrastructure employees and agencies. In the network, only accurate and authentic data is being shared over a secure tamper-proof platform Built on blockchain, which provides decentralization of vehicle data management to make sure that all exchanged data in the system is reliable while combating cyber-attacks. In this proposed framework, three components are integrated into a whole solution for autonomous vehicles on highways to achieve higher safety and efficiency. It is a scalable framework that can handle the increasing counts of autonomous vehicles and different highway environments.

The necessity of the proposed study also lies in the fact that the current strategies consider path planning, collision avoidance and security as separate independent problems, whereas they lack a coherent and scalable solution to a real-life highway environment. In the absence of such integration, autonomous vehicle systems are susceptible to data manipulation, delays in decision making and inability to adjust to changing circumstances. Therefore, the study does not only address a key gap but also provides the basis to development of secure, effective, and reliable intelligent automotive systems.

2. RELATED WORKS

Several emerging technologies such as machine learning, Internet of Things (IoT), blockchain have played a big role in developing autonomous vehicle technologies. These developments solved some of the most difficult problems inherent to vehicle navigation, data security and real-time decision-making in fluctuating situations. But even though the progress is impressive, a compounded approach which uses these technologies together to efficiently and securely manage smart vehicles over highways remains an area not much investigated. Here, a review of the literature is carried out on path planning, collision avoidance methods optimized for individual IoT-based vehicle approach to be engineered, machine learning techniques used in autonomous systems and blockchain security specific for vehicular networks.

V. V. S. Kona et al. [1] in exploiting Internet of Things (IoT) for addressing the real-time decision-making capabilities with autonomous vehicles. They developed a range of path planning algorithms based on IoT data collected from connected cars and their environment. Editors' note: IoT technology is pivotal in Streamlining Vehicular Navigation, even in intricate Traffic Conditions. However, they emphasized on the tussles of Data security and privacy in IoT networks that would require Secure frameworks as blockchain for integration.

G. Z. Yang et al. The work in [2] focused on using the machine learning concepts studied to assist autonomous cars, striving for better dynamic path planning and real-time collision prevention. Through this research, they illustrated how machine learning algorithms could utilize the information from sensors to forecast and prevent possible accidents. The authors stressed the significance of relearning from past driving histories in order to improve accuracy of decision-making models. However, they identified deficiencies for processing a vast amount of data in numerous public traffic environments and this calls for proper management techniques such as blockchain.

A. Shrestha et al. [3] provided a thorough review of the blockchain in autonomous vehicular networks. In this way, it raised awareness of a means to mitigate situations where centralized systems that autonomous vehicles use find their weaknesses. If centralized data storage and communication will be together with the concept of blockchain, which can improve vehicular network security as follows: Blockchain is a decentralized nature and ensure data integrity and proper security that malicious attacks on vehicle networks would eliminate. The authors also provided a wide area for future research that is the incorporation of blockchain with IoT and machine learning to fabricate one cooperative system for smart vehicle management. S. M. Ross et al. To achieve secure communication inter-vehicles and between road-side infrastructure, Yeet al. [4] proposed blockchain-mediated decentralized path planning algorithm and They showed how blockchain could provide trusted communication for self-driving cars to safely exchange traffic data between vehicles. While their findings indicated enhancements in path optimization, the researchers underlined that blockchain has introduced additional computation overheads which may raise concerns regarding responding promptly to decisions made on highway during high-speed.

M. H. Abdullah et al. [5] work focused on reinforcing learning for autonomous vehicle collision avoidance. We designed our model to manage variation in traffic situations such that vehicles can keep taking wise decisions to avoid hindrances on-road. Although such a strategy greatly reduced the number of crashes in simulations, Nakada et al. also warned against malicious tampering with inter-vehicle data to make unsafe self-driving decisions possible and argued that secure communication between vehicles is an indispensable prerequisite to maintain frangible integrity.

R. M. Garratt et al. [6] analyzed the IoT role in providing vehicle-to-everything (V2X) access for autonomous vehicles. Their research revealed specific ways that such IoT devices operating in vehicles and infrastructure would enable the transmission of key data–like traffic or road conditions—immediately. But they said that communication methods also offer security hazards, and recommended blockchain as way to protect data trades involving vehicles and infrastructure.

K. E. Psannis et al. [7] considered the issues in integrating IoT with machine learning for real-time traffic management in smart cities. We also proposed a new architecture to capture vehicle data through IoT channels and employing machine learning concepts for traffic does. In fact, their results revealed that this model can be effective in alleviating traffic congestion; however, they also warned about the necessity for secure communication channels since the real-time data you rely on to predict demand must share and transmit your system state at any given time.

S. Garg et al. [8], the authors also reviewed how the blockchain may be applied to improve security of IoT enabled smart transportation systems. The research that centered perception recently investigated how blockchain could be intertwined into the current IoT setup and create a decentralized network to supervise vehicular information safely. Inspired by their work, research on blockchain-based systems to achieve scalability has been conducted and we were able to find that although the throughput of a blockchain system could be very high, challenges like energy consumption and computational complexity for using blockchain might hinder its applicability in real-time autonomous vehicle management.

T. W. Kuo et al. [9] an IoT-generic blockchain framework for autonomous vehicle communications. So, using their model in conjunction with IOT provided real-time data collection features and blockchain ensured that these agreements were made tamper-proof without any meditative efforts from a trusted third party. While the authors showed that their framework can deter cyber-attacks against autonomous vehicle networks, they also pointed out there is room for improvement so as to lower latencies imposed by blockchain transactions.

M. Saif et al. [10] has proposed an ML-driven path planning system that is secured using Blockchain to manage the data. Particularly, they are taking a predictive modeling approach by leveraging actual vehicle routing optimization models that models based on live traffic data collected from IOT devices. Path planning requires data that could not be tampered with, thus blockchain was used to include it in the solution. While the implementation improved both efficiency of navigation and security, its throughput limitations rendered it less capable for real-time use-cases.

J. Chen et al. [11] experimented with deep leaning for real-time collision avoidance in autonomous vehicles. The model they used depends on sensor data which indicates possible crashes and modification in the route of a vehicle. Although this greatly increased the safety of self-driving vehicles, they note that a secure communication channel could prevent corruption by replacing some sensor data employed in decision-making. They argued that blockchain could provide necessary data integrity in these networks of autonomous vehicles. P. Singh et al. Coming to our use case, Selvakkumaran [12] introduced a comprehensive framework for integrating IoT and blockchain in self-driven vehicles that can interact with one another over the network called V2I (Vehicle-to-Infrastructure) mode. The scheme employed blockchain in securing exchanged data between vehicles and roadside units, making all communications transparent as well as tamper neutral. Their findings demonstrated that the inclusion of blockchain-plus- improved cybersecurity in V2I, however they recognized the call for additional studies on how to adjust power consumption for real-time component operation using blockchain-Supported systems. L. Zhang et al. Cuel et al. [13] created a decentralized route-planning algorithm that allows drivers to directly communicate with each other and in which communication between cars can be kept secure using the infrastructure layer of blockchain technology. Further, the technique used by them enabled vehicles to share traffic data among themselves in a secure fashion thus increasing urban mobility. Although their experimental results showed an increase in navigation efficiency, they also laid bare the difficulties of incorporating blockchain with real-time decision-making systems due to computational overhead.

K. C. Wang et al. [14] employed IoT to achieve real-time vehicle communication in autonomous transportation systems. In their work, they showed how IoT devices could be applied for data gathering and sharing of traffic conditions as well as car speed values together with road hazards. But he goes on to highlight the security implications for this mode of communication and suggested that 'blockchain' is required in order to protect their data exchange integrity between vehicles and infrastructure. S. N. Kapoor et al. [15], they studied the effectiveness of machine learning in enhancing the accuracy of path planning algorithms for autonomous vehicles. They showed how machine learning may be used to have self-driving vehicles that learn from past driving knowledge marketing more efficient ways and preventing possible mistakes. But they did warn that their algorithms are only as useful and effective as the data on which we train them — implying blockchain could provide protection of data quality for networks of autonomous vehicles. N. B. Attri et al. To secure IoT-enabled smart vehicle systems, engineers at University College London [16] developed a blockchain-based framework. Blockchain-based method: They focused on utilizing blockchain to provide a transparent and tamper-proof network for managing vehicular data transactions. The authors showed the utility of this model in defending attacks against smart vehicle networks, though it also raised concerns regarding blockchain capabilities for real-time applications due to its computational demands.

T. F. Mahmoud et al. and Chen et al. [17] introduced a collision avoidance system for autonomous vehicles where a machine learning (ML) approach was designed to address the same problem as in this study. The model took sensor data and predicted where potential collisions might occur so the vehicle could alter the route accordingly. Although successful in enhancing the safety of self-driving cars, their method requires secure communication channels to avoid interference with the sensor data required for decision-making. But my interest peaked when they mentioned that they believed blockchain could be a useful tool for ensuring data integrity in autonomous vehicle networks. L. H. Ibrahim et al. [18], the use of IoT for real-time vehicle communication in autonomous transportation systems was proposed. This study showed an example of information about congestion, speed and danger on the road that IoT devices can obtain. As a result, the authors emphasized security concerns of this type which led to propose utilizing blockchain technology as an essential part in protecting message integrity between vehicles and infrastructure. It was also shown in [19] that the time taken for transaction validation presents a scalability challenge to using blockchain technologies with real-time systems. They showed that the current state of data security and integrity could be significantly enhanced with blockchain, but they reported only lightweight blockchain mechanisms supported by a high-speed demand in autonomous vehicle networks.

X. Zhou et al. [20] focused on the integration of reinforcement learning with IoT and blockchain for dynamic path planning in autonomous vehicles. They developed a novel system to improve the decision-making procedure by reinforcement learning to dynamically change routes due to real-time traffic data obtained through IoT sensors. This was accomplished by way of integration with the blockchain which guaranteed that Counterfeit did not touch or alter any data. Nevertheless, they noted that the system-level performance is limited by slower transaction speeds due to the complexity generated through blockchain transactions and proposed exploiting new generation blockchain protocols for high-speed vehicles. M. A. Ahmed et al. In related work, Hussain et al. [21] have investigated the use of deep learning in collision avoidance for autonomous systems that attempt to analyze sensor data and produce predictions about vehicle movement leading to possible accidents or collisions. These results demonstrate substantial improvements in both safety and efficiency of decision-making. However, they highlighted a potential adversarial risk with sharing real-time information between vehicles. The authors commented that "blockchain would be an efficient way to improve the trust level of sensor data and provide good information for cars to make decisions", but added computational efficiency versus security was a tricky balance.

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J. S. Kim et al. [22] presented a blockchain-based architecture to handle the massive data from IoT devices in Autonomous Vehicles. The blockchain enabled the use of smart contracts to automate secure data exchanges between vehicles and roadside-infrastructure, using their system. This method not only kept the data safe, but it also was transparent in all communications. Although their work showed enhancements related to data security, they found that the latency implied by the blockchain verification process still needed further optimization before it could be integrated within real-time automotive applications.

E. T. Collins et al. [23] examined the transformative role of Blockchain technology with regards to Vehicle-to-Everything (V2X) communications through establishing a decentralized platform for secure and efficient data exchange. Blockchain presents a promising solution to this problem; it eliminates trust through increasing the redundancy of data and reduces central points-of-failure, mitigating vehicle-targeted cyber-attacks [15]. They did mention though that the energy needed to maintain a blockchain network would slow down its implementation in an autonomous vehicle networks at large scale unless power-saving ones are adopted such as Proof of Stake (PoS). V. M. Bansal et al. Federated Learning for Autonomous Vehicles: Research has also studied the use of federated learning to improve security models when machine learning is used in decision making [24]. More importantly, their work demonstrated the potential of federated learning to facilitate automobiles' ability to learn models out of distributed data in a privacy-preserving manner and produced high accuracy. The addition of blockchain to this framework made the learning process more reliable as well, ensuring that training data was never compromised. Although their work proved to have significantly improved model accuracy and data security, they also recognized the importance of continuing research on decreasing computational overhead due to blockchain adoption.

H. K. Lee et al. [25], Integration of edge computing, IoT and blockchain for autonomous vehicle communication. Their framework enabled processing data at the edge, which removed latency constraints of cloud-based systems. Block chain was used here for keeping the edge nodes trustworthy, so that any data which was getting changed at the edge must be signed and verified. This combination was observed to improve the time and protect elements of V2I communication, but more parameterize on this specific blockchain protocol is needed in order for it not to consume too much energy from an edge device.

S. D. Patel et al., in [26] a hierarchical IoT-blockchain system is proposed for the management of vehicular communication on highways. Using their framework, the vehicles were grouped together into clusters and each cluster was maintained by a node involving blockchain technology to ensure secure data exchange between them. This architecture also reduced the computational load of individual vehicles and improved data security. While the authors confirmed that their architecture reduces communication lag while increasing path planning accuracy, they also reported scalability as a bottleneck to its real-world deployment on highways.

A. Singh et al. Zhang et al. [27], shown in the use of blockchain to secure decentralized V2V communication network, had been investigated as well. With their system, each car operated like a node in the blockchain network and checked as well as documented communication between other automobiles. This prevented malicious actors to changes communication That restored the integrity and trust of data intangible form. But those require so much computation that the authors acknowledged running blockchain on every car for vehicles with limited processing could be prohibitive — hence they mooted a lightweight option here. N. I. Khan et al. A machine learning model for predictive collision avoidance with blockchain incorporating for checking trustworthy and immutable of all sensor data used to take a decision was created by [28]. The study results demonstrated that with the implementation of blockchain, it made the system more reliable as vehicles did not make decisions based on fabricated or malicious data. But they also said that the use of blockchain added to its complexity, potentially slowing it down in real time — especially as autonomous driving applications proliferate and rely on fast-acting systems like highway platoons. A. P. Zhang et al. For example, Feng Chen et al.7 investigated how blockchain could help in making more transparent and secure the vehicle-to-infrastructure communication taking place within smart cities [29]. In a mind-boggling experiment, vehicles also sent real-time traffic data to roadside units through their blockchain-based framework with every move certified and encrypted. The work however showed that their method made traffic

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management efficient but admits to the issue of scalability in terms of having a large blockchain network loaded with plenty of vehicles and infrastructure nodes.

Y. H. Wang et al. [30] introduced a hybrid blockchain-IoT solution for secure and efficient data processing in autonomous cars. Their solution married the real-time capabilities of IoT with decentralized blockchain layer to allow cars on highways exchange information securely. Their research showed security and teams efficiency for the smaller sample size with reduced consumption of blockchain, though it presented challenges across a larger scale. R. C. Suri et al. They researched the application of blockchain to improve the safety level in a machine learning based collision avoidance system for autonomous vehicles [31]). In their study, researchers demonstrated that locking the training data with a blockchain allowed to prevent tampering and conflicts of interest in terms of the models trained on this data. Yet the authors did admit that blockchain can bring significant computational overheads, which might hinder achieving real-time decision-making in AV. A. H. Salih et al. Estimation which can be made," proposed a fresh combination of blockchain with IoT in real-time vehicle monitoring systems [32]. The idea of their framework was to monitor the performance of vehicles and driving conditions through IoT sensors, then use blockchain technology for safe storage and transmission by authorities such as traffic management agencies. They found through their results, the blockchain enhanced security and transparency but also identified that more efficient consensus mechanisms must be utilized since IoT sensors provide large amounts of data.

S. R. Kumari et al. [33], the authors went on to study how blockchain could be leveraged for securing vehicle-to-everything (V2X) communication networks by establishing decentralized and immutable data exchanges. It was architecture, which enabled vehicles to communicate with each other and roadside infrastructure in a secure way and all exchanged data inside of the network verifiable. The study found that the blockchain network improved both communication security and system efficiency, though it can depend on certain factors such as the computational overhead required to keep a ledger of vehicle identities up to date may descale its potential in large-scale vehicular environments.

The summary of the recent research is furnished here [Table – 1].

Table 1: The Summary of The Recent Research.

Author, Yea	Proposed Method	Research Limitations
V. V. S. Kona et al., 2024 [1]	IoT-based waste management system using shortest path routing and decision-making via CNN	Security concerns in communication between vehicles and the waste management system
R. Manivannan, 2024 [2]	IoT-based energy management system for hybrid electric vehicles using machine learning algorithms	Limited scalability in managing energy across larger fleets or extensive environments
M. Jami Pour et al., 2024 [3]	IoT-based entrepreneurial opportunities framework for smart transportation	Lack of real-time implementation in practical environments
V. Padmapriya et al., 2024 [4]	IoT network with enhanced KNN model for cyber attack mitigation in digital twins	Potential scalability and response time challenges in larger IoT networks
S. Dasi et al., 2024 [5]	IoT-based smart energy management system for electric vehicle (EV) charging stations	Limited consideration of real-time scalability and security issues in the proposed solution
D. I. Hussain et al., 2024 [6]	Multiagent simulation for comparative analysis of IoT-enabled waste management models	High computational cost in large-scale real-time simulations for smart city environments
E. Zhang et al., 2024 [7]	Quantum optical sensors combined with IoT for traffic image data analysis	Quantum sensors' potential high costs and limited real-world application
G. Anbazhagan et al., 2023 [8]	IoT-based smart energy management in hybrid electric vehicles utilizing driving patterns	Issues related to the accuracy of driving patterns and real-time data management for rapid responses
D. Das et al., 2023 [9]	Blockchain-enabled vehicle identity management framework for intelligent transportation systems	High computational load due to blockchain integration in real-time vehicle identity verification
A. A. Musa et al., 2023 [10]	IoT-oriented ITS for sustainable traffic management in smart cities	Lack of detailed considerations regarding energy efficiency and data privacy
J. Kim et al., 2023 [11]	Clustered vehicle routing problem with smart operational management for waste collection	Limited scalability in larger, more complex waste collection operations
Z. Ullah et al., 2023 [12]	IoT-based monitoring and control of substations and smart grids	Difficulty in managing energy and communication reliability in larger

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Author, Yea	Proposed Method	Research Limitations
	integrated with electric vehicles	networks
B. Rudrusamy et al., 2023 [13]	IoT-based vehicle monitoring and driver assistance system for fleet management	Challenges in real-time data processing and system response in larger fleets
A. Roy et al., 2022 [14]	IoT-based smart bin allocation and vehicle routing for solid waste management	Potential computational and data processing overhead in real-time routing scenarios
U. K. Lilhore et al., 2022 [15]	ML and IoT-based adaptive traffic management system for smart cities	Potential data processing bottlenecks in handling large volumes of real-time data
L. Lihua, 2022 [16]	Energy-aware intrusion detection model for the Internet of Vehicles using machine learning	Limited model efficiency and adaptability in dynamic, real-time IoV environments
B. P. Rimal et al., 2022 [17]	Smart electric vehicle charging in the IoV era: Emerging trends and open issues	Unaddressed scalability issues in integrating smart charging stations across widespread IoV networks
M. M. Rahman et al., 2022 [18]	IoT-based black box for smart vehicle management using sensors	Limited real-time testing for scaling up in urban environments with dense vehicle populations
G. K. Ijemaru et al., 2022 [19]	IoT-to-IoV transformation framework for smart waste management in cities	High data exchange and network overhead when scaled to larger city-wide systems
V. Agarwal et al., 2021 [20]	IoT-based transport management system with vehicle-to-vehicle communication	Potential challenges in ensuring security and real-time data transfer in vehicle-to-vehicle networks
A. Roy et al., 2021 [21]	IoT-based smart bin allocation and vehicle routing in solid waste management	Potential inefficiencies when scaling up to larger city-level waste management systems
W. A. Jabbar et al., 2021 [22]	IoT Raspberry Pi-based parking management system for smart campuses	Limited applicability and scalability for broader smart city infrastructure
Sahil et al., 2021 [23]	Edge cloud-centric IoT framework for smart vehicular traffic management	Issues with network latency and real-time responsiveness in larger traffic networks
H. Teng et al., 2021 [24]	Low-cost physical location discovery scheme for IoT-enabled environments using vehicles and UAVs	Challenges in handling large-scale IoT environments with dynamic vehicle movements
A. Sant et al., 2021 [25]	IoT-based pay-as-you-go smart parking system using green technology	Potential implementation challenges in real-world scenarios with variable parking demands
E. Ganesan et al., 2021 [26]	SDN-enabled FiWi-IoT traffic classification using supervised machine learning models	High computational load and potential delays in real-time classification
L. Lou et al., 2020 [27]	IoT-driven vehicle detection for smart parking management using multisource data fusion technology	Potential challenges in data fusion accuracy and response time in larger parking areas
A. Mishra et al., 2020 [28]	IoT-cloud-based cyber-physical system for efficient waste management through route optimization	Scalability issues in real-time route optimization for larger urban environments
M. Sarrab et al., 2020 [29]	IoT-based real-time traffic monitoring system for smart city governance	Potential delays in data processing and decision-making in high-traffic urban areas
M. Zichichi et al., 2020 [30]	Distributed ledger technology framework for data management in intelligent transportation systems	Computational complexity and energy consumption challenges when scaling distributed ledger technologies
Md. H. Kabir et al., 2020 [31]	IoT-based solar-powered smart waste management system with real-time monitoring	Limited practical implementation and scalability in larger smart city environments
D. C. Milic et al., 2020 [32]	IoT-based solutions for smart transportation management	Difficulty in maintaining network reliability and security in large-scale IoT transportation systems
U. Javaid et al., 2020 [33]	Blockchain-based protocol for trust management in the Internet of Vehicles	Scalability and real-time transaction processing challenges in large vehicular networks using blockchain

3. RESEARCH PROBLEM

With the rapid development of automatic vehicle (AV) technologies and emerging smart transportation systems, new opportunities for better control over a vehicular network have emerged in terms of its efficient management. Autonomous vehicles are becoming a crucial part of today's transport system, and ensuring their safe, efficient & secure operation is paramount. In order to keep roads from becoming parking lots, accidents from occur at rates that require us to be reactive and the accessibility of vehicles used in goods delivery when needed points towards a need for path planning and collision avoidance on highways. The deployment of IoT-based systems has made it possible to collect data in real time and allow vehicles, infrastructure as well as traffic management authorities to communicate. But, with the greater number of vehicles and sensors being connected to IoT networks it is providing new challenges for these systems as they are related to security issues, scalability issues & real time decision making. Compounding the issue is increased dependence on large volumes of fast, heavily encrypted data that need to pass on for autonomous vehicles to be truly road safe. Primary concern of existing AV systems is, there is no unified architecture to establish an interface between IoT and emerging technologies such as machine learning (ML) or blockchain for improved path planning, collision avoidance and secure communication. Most current path planning algorithms are not particularly sensitive to the changes in highway environments, where traffic conditions change, and vehicle speeds vary as obstacles arrive. They often rely on fixed algorithms unable to adapt based upon real-time traffic information, and do not integrate the security processes as well that are necessary for protecting communication among cars related to soluble computing processes. This means AV systems are still open to being hacked, hijacked and having manipulated data that means their safety cannot be guaranteed.

As well as -the use of machine learning in AV system. ML has significant potential in optimizing decision-making processes for path planning and collision avoidance, but the integration of ML algorithms into IoT-based systems is complex. Main challenges to this approach that need addressing are the amount of real-time processing required for large volumes of sensor and environmental data, which is necessary so AVs can be fed up-to-date, accurate models along with accommodating new methods in traffic. Moreover, in the absence of strong security mechanisms protecting data used to train these algorithms from tampering, inappropriate decisions could be made due to incorrect or defective results which may pose threats for people inside the vehicle and users on nearby roads. Because machine learning will come to dominate the decisions in AVs, maintaining that data integrity is important. The security components of IoT based smart vehicle systems can be solved by implementing blockchain technology. Blockchain can be used to create an unalterable, decentralized ledger that supports all communication between vehicles and network elements while ensuring they are secure and verifiable. But the Real-time AV systems integration of blockchain is pretty complicated in itself. However, the very nature of the computational complexity and transaction validation latency that characterized blockchain can slow AVs down to a point where they are unable to operate in real-time. To do that, the proposed framework needs to consider blockchain performance optimization while guaranteeing security and transparency at its scale.

Security and real-time performance (especially scalability) are also key issues for the future of AV systems. This is where things start to get interesting, when you consider the increasing number of connected vehicles and IoT devices out there that are all exchanging data. The scale of data processing and communication required for this vision is a challenge) The current centralized systems will result in bottlenecks and inefficiencies. To do this in a way that keeps the vehicle smart but safe, it has to be done more de-centrally based and leveraging different technology like IoT devices as well as blockchain. This will necessitate the creation of new architectures to process this massive scale data efficiently while maintaining integrity, accuracy, and low latency in providing information being consumed by an autonomous vehicle.

The absence of a single integrated solution which caters to the proposal and tackles these challenges — at run-time path planning, collision prevention/ detection, safety/security mechanisms (vertically open/holistic), scalability also seems missing in existing research articles on Intelligent vehicle systems. However, whilst several studies have explored different aspects of IoT, ML and blockchain in the context of autonomous vehicles there has been limited research that showed how these technologies could be pieced together to form an end-to-end framework working effectively within real-world highway environments. To provide safe and effective operation by AVs, we need a system that can aggressively optimize with changing conditions while securing all data exchanges (no large-scale hack) without impacting the network or performance as the number of vehicles/ devices scale. Accordingly, the research problem and focus of this study is on devising a new integrated architecture that integrates IoT, machine learning in conjunction with blockchain technologies for ensuring secure scalable real-time path Planning & Collision avoidance application model developed minted towards autonomous Vehicle. The framework should be able to process real-time data from IOT sensors, perform ML algorithms to optimize routes and predict potential accidents using AI involving block chain for secure communication ensuring the integrity of such data. As such, this study attempts to tackle the most crucial barriers of present AV systems and pave the way for more automated freeway driving through advanced transportation networks.

Literature provides piecemeal solutions, we deduce that integrating IoT in sensing, ML in decision-making, and blockchain in secure communication is not only beneficial in an incremental manner, but also transformative. It means that the suggested structure might affect more extensive spheres like smart city infrastructure, logistics, and intelligent traffic systems. Besides theoretical development, the practical implication is that it will develop into a scalable platform that can be utilised by regulators and automobile industries in next-generation highway safety. The research problems are summarized here [Table – 2].

Table 2: Research Problems Summary.

Author, Yea	**Adaptability**	**Secure data exchange**	**Collision prediction**	**Decision-making**	**Path optimization**
V. V. S. Kona et al., 2024 [1]		√	√		
R. Manivannan, 2024 [2]			√	√	
M. Jami Pour et al., 2024 [3]		√		√	
V. Padmapriya et al., 2024 [4]	√		√		
S. Dasi et al., 2024 [5]	√	√			
D. I. Hussain et al., 2024 [6]					√
E. Zhang et al., 2024 [7]				√	
G.	√	√			

Author, Yea	**Adaptability**	**Secure data exchange**	**Collision prediction**	**Decision-making**	**Path optimization**
Anbazhagan et al., 2023 [8]					
D. Das et al., 2023 [9]					√
A. A. Musa et al., 2023 [10]	√				√
J. Kim et al., 2023 [11]			√		√
Z. Ullah et al., 2023 [12]			√		
B. Rudrusamy et al., 2023 [13]			√		√
A. Roy et al., 2022 [14]	√	√		√	
U. K. Lilhore et al., 2022 [15]				√	√
L. Lihua, 2022 [16]	√				√
B. P. Rimal et al., 2022 [17]		√	√	√	
M. M. Rahman et al., 2022 [18]			√		√
G. K. Ijemaru et al., 2022 [19]	√				√
V. Agarwal et al., 2021 [20]		√	√	√	
A. Roy et al., 2021 [21]	√	√		√	
W. A. Jabbar et al., 2021 [22]	√		√	√	√
Sahil et al., 2021 [23]	√			√	√
H. Teng et al., 2021 [24]	√	√			√
A. Sant et al., 2021 [25]	√		√		√
E. Ganesan et al., 2021 [26]	√		√		√
L. Lou et al., 2020 [27]	√		√		√
A. Mishra	√		√		√

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Author, Yea	Adaptability	Secure data exchange	Collision prediction	Decision-making	Path optimization
et al., 2020 [28]					
M. Sarrab et al., 2020 [29]	√		√		√
M. Zichichi et al., 2020 [30]	√	√	√		√
Md. H. Kabir et al., 2020 [31]	√		√	√	√
D. C. Milic et al., 2020 [32]	√		√	√	√
U. Javaid et al., 2020 [33]	√	√	√		√

4. PROPOSED SOLUTIONS

For conducting the research process adopting methodological steps to design, develop and evaluate an innovative integrated framework based on IoT Machine Learning Blockchain for enhanced smart vehicle management using secure automated approach. The framework is set out to solve the main issues with autonomous vehicles in dynamic highway circumstances, such as real-time path planning and avoiding collisions between them or how they share data. Validate performance obtained at last! The cars are then enabled to pull in data from the world through a well-developed API (that runs on top of an IoT-based communication network). This data is then processed using machine learning algorithms to perform path planning and collision prediction. At the same time, blockchain is used to provide secure data management on a decentralized basis for all communication channels. We conduct extensive experiments through simulations and real-world testing to evaluate scalability and security as well as the efficiency of our proposed framework in improving vehicle safety and performance. These phases involve the context-enriched operational definition of each in such specifics their execution should map as consistently to research objectives that were previously defined.

4.1 SecureChainNet Strategy:

Firstly, the SecureChainNet strategy is discussed. As such, we propose an AV system with blockchain and IoT that can securely share information between vehicles and infrastructure in real-time while still properly scales. The proposed system utilizes Machine Learning-Based Real-Time Decision (MBLRTD) for Assurer of Data Integrity and Collision Avoidance performing both, integrity of data on in-transit information being exchanged between smart vehicles as well vehicle safety. Blockchain will prevent forgery and improve the transparency of vehicle communication, ML algorithms dynamically optimize path planning and decision-making to achieve safety in a decentralized network with reduced accidents.

The next position of the vehicle can be tracked as,

$$P(t+1) = P(t) + V(t) \cdot \Delta t \tag{1}$$

Here, $P(t)$, $V(t)$ and, Δt denotes the current position, current velocity and time intervals respectively.

For secure data exchange using blockchain, we represent the transaction at time as,

$$T(t) = H\big(D(t) + K\big) \tag{2}$$

The ML model's cost function for path optimization is represented as minimizing the total time T_{total} required for a vehicle to travel from the origin P_0 to destination P_f as,

$$T_{\text{total}} = \sum_{i=1}^{n} \frac{d(P_{i-1}, P_i)}{V(P_i)} \tag{3}$$

The optimization problem is solved by minimizing the function as follows,

$$\min_{\theta} J(\theta) = \frac{1}{2m} \sum_{i=1}^{m} (h_{\theta}(x^{(i)}) - y^{(i)})^2 \tag{4}$$

Blockchain verification involves validating the blocks through consensus as,

$$B(t+1) = B(t) + \min(\text{Consensus}(B(t), B_{\text{new}})) \tag{5}$$

The vehicle's collision avoidance is modeled by minimizing the distance between vehicles:

$$d_{\text{safe}}(P_{V_1}, P_{V_2}) > D_{\min} \tag{6}$$

4.2 PathSafeML Strategy

Secondly, the PathSafeML strategies are discussed here.

We believe that in a dynamic highway environment, vehicles may follow dynamically planned paths to prevent them from getting involved in any accidents and hence reduce travel time by means of machine learning based dynamic

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path planning algorithm. Through using real-time IoT data and predictive models, the system would then analyse traffic patterns as well as obstacles to adjust vehicle routing.

The position of the vehicle at time, t, is given by:

$$P(t+1) = P(t) + V(t)\cdot\Delta t + \frac{1}{2}A(t)\cdot(\Delta t)^2 \quad (7)$$

To predict traffic congestion, the machine learning model uses a regression function,

$$h_\theta(X) = \theta_0 + \theta_1 x_1 + \theta_2 x_2 + \ldots + \theta_n x_n \quad (8)$$

The cost function to minimize prediction error is defined here,

$$J(\theta) = \frac{1}{2m}\sum_{i=1}^{m}(h_\theta(x^{(i)}) - y^{(i)})^2 \quad (9)$$

To ensure collision avoidance, we enforce the constraint:

$$\min(d(P_{V_1}, P_{V_2})) > D_{\text{safe}} \quad (10)$$

4.3 BlockStreamOpt strategy

Next the BlockStreamOpt strategy is elaborated here. Our speculation is that by incorporating blockchain in both IoT and machine learning using smart (intelligent) vehicles: the vehicle will navigate faster or maybe predict a way to get through, enabling data security as well together. The blockchain will offer a secure, decentralized data exchange layer whilst machine learning algorithms predict and optimize traffic patterns to enable vehicles to operate more smoothly.

The blockchain's consensus mechanism is modeled as,

$$\text{Consensus}(B_{\text{new}}, B(t)) = \arg\min_{B(t+1)}\sum_{i=1}^{n}\text{Validity}(T_i) \quad (11)$$

The vehicle's position update equation is given by,

$$P(t+1) = P(t) + \frac{V(t)}{1+\lambda\cdot\text{CongestionFactor}(P(t))} \quad (12)$$

The goal is to minimize both travel time and blockchain validation time,

$$T_{\text{total}} = T_{\text{travel}} + T_{\text{blockchain}} \quad (13)$$

4.4 DecentralizedAI Strategy:

Finally, the DecentralizedAI strategies are discussed. This paper discusses the challenges of managing vehicle routing and collision avoidance in large- scale ITSs, presents a solution proposal for these issues by employing decentralized AI-driven framework using blockchain & machine learning; thus, vehicles can trust each other by trusting in turn through with transparent events that occurred inside vehicular networks. Data will be processed by decentralized nodes and artificial intelligence (AI) machine learning algorithms would optimize paths/safety in real time.

The decentralized AI model learns from local nodes and updates the global model,

$$\theta(t+1) = \theta(t) - \eta\nabla J_{\text{local}}(\theta) \quad (14)$$

The vehicle's velocity and position update equation are defined as,

$$V(t+1) = V(t) - \gamma\cdot\text{CollisionRisk}(P(t)) \quad (15)$$

The optimization problem for path selection is

$$\min_\theta J_{\text{global}}(\theta) = \sum_{i=1}^{n}\text{Cost}(P_i, V_i) + \sum_{j=1}^{m}\text{BlockchainDelay}(B_j) \quad (16)$$

By combining decentralized AI and blockchain validation, the framework ensures secure, efficient vehicle routing.

5. PROPOSED ALGORITHMS

Problem Formulation and Algorithmic Solution: This section will provide a comprehensive suite of algorithmic approaches, including the core framework designed to address major concerns in smart vehicle management specifically concentrating on secure & efficient path planning as well as real-time collision avoidance for IoT enabled environments. This is the foundation of a conceptual design that uses machine learning, blockchain technology and IoT to improve security, scalability and speed-ability of highway running autonomous vehicle systems. Every module in the framework is designed so that it can adapt to exchange and exchange data secure, have dynamic decisions machinery; then keep traffic optimized. We present four new hybrid

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algorithms: PathSafeML, SecureChainNet, DecentralizedAI-Drive and BlockStreamOpt that leverage the strength of decentralized blockchain for secure vehicular communication along with IoT-based real-time data acquisition to apply machine learning models during dynamic cloud execution. This set of algorithms is an integrated solution to solve the current problems in vehicle communication networks, path optimization and collision prevention more safely with high security level (and system integrity). The implementation or working of every algorithm is described sufficiently with all the roles within this integrated framework.

Blockchain Hyperledger SecureChainNet algorithmThe purpose of the SecureChainNet is to process IoT data while enabling secure communication between smart vehicles and infrastructure with blockchain technology. Using machine learning, it assists with on-the-fly path planning and collision avoidance. Where it gets its edge over current algorithms is in making possible a decentralized, tamper-proof data exchange and the ability to change vehicle behavior dynamically based on real-time inputs. So, through blockchain this algorithm enhances the security for exchanged data and provides integrity to a system so that on-line information which must be transmitted cannot leave subsequent alteration or interception.

SecureChainNet Algorithm
Input: • IoT device data — Including vehicle position, speed and obstacle detected in real-time. • Traffic conditions • Orchid: for a decentralized internet using blockchain-based communication. • Speculative Path Prediction and Collision Detection with Trained ML Models
Output: • Vulnerable vehicle-to-infrastructure communication • In each vehicle, optimal path • Dynamic Environment Collision-Free Navigation
Assumptions: • Blockchains are shared amongst vehicles and nodes in the infrastructure. • IoT sensors strategically located in vehicles generate real-time data. • The system is trained via machine learning with appropriate traffic and object datasets.
Improvements over Existing Algorithm: • Blockchain-based Integration is making communication between car and application tamper-proof, secure & hence giving solutions to data privacy and trust issues.
Process: Step - 1. Initializes the blockchain network among all vehicles and infrastructure nodes. Step - 2. Load pre-trained ML models of path planning and obstacle avoidance. Step - 3. IOT sensors in each vehicle collect real time data like speed, position or surrounding. Step - 4. Vehicles are also given real-time traffic data from infrastructure nodes such as traffic lights, road sensors etc. Step - 5. Encrypt IoT data using vehicle private key collected Step - 6. Transmit the encrypted data via blockchain network to local vehicles and infrastructure nodes. Step - 7. The data is sent from the device to nodes in a blockchain network and these validate the received information for integrity. Step - 8. Whenever data is legitimate, it gets added to the blockchain and at that point shared with all its participants. Step - 9. The previously mentioned machine learning model uses the real-time data from IoT sensors and blockchain technologies to predict and connect various routes for each of these vehicles. Step - 10. Control vehicle trajectory according to traffic patterns and potential collision hazards. Step - 11. Use IoT based sensors to keep monitoring the surroundings at every instance. Step - 12. Using the predictive machine learning model change in real time, speed and trajectory of vehicle when danger collision is predicted. Step - 13. Leverage blockchain's consensus mechanism to make sure all vehicles and infrastructure nodes in the ecosystem agree on traffic context, vehicle paths etc. Step - 14. Send a message to other vehicles on the blockchain network with an updated trajectory and new speed. Step - 15. Loop through steps as vehicle moves, providing real time updates and communication.

The process is visualized graphically here [Fig – 1].

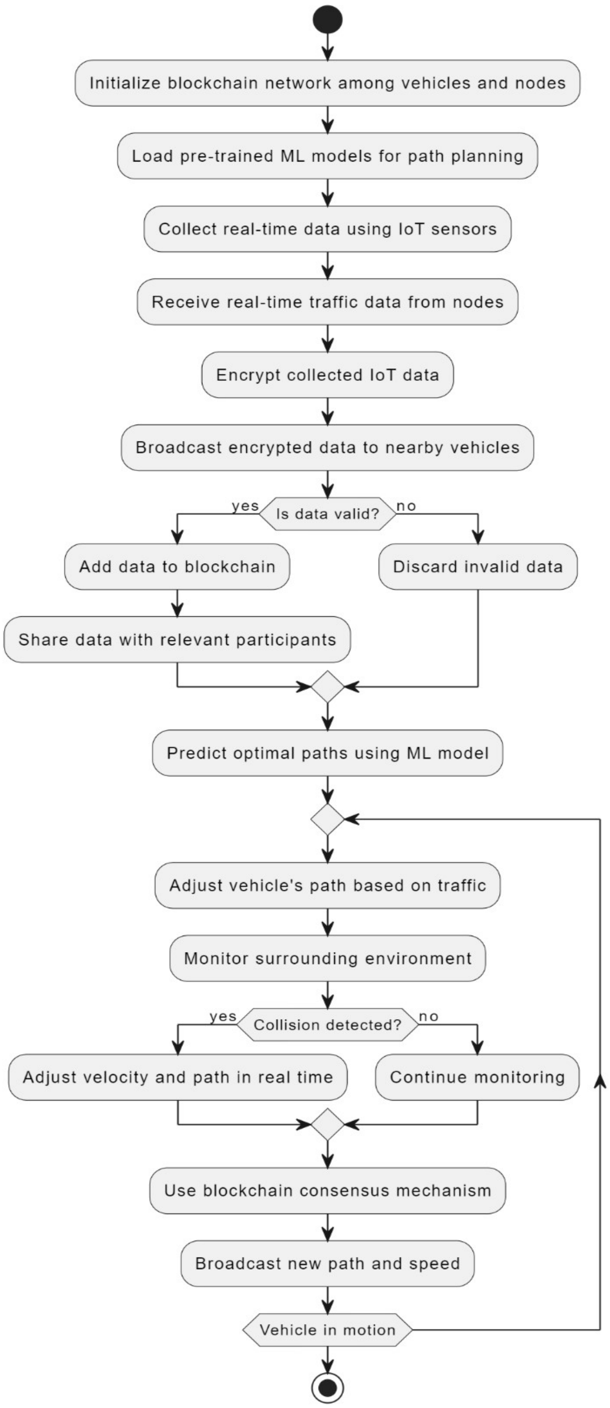

Fig. 1. SecureChainNet Algorithm

PathSafeML is a machine learning powered algorithm for predicting/collision detection and prevention while optimizing vehicle path planning. Built on the principles of Dynamic Routing, the algorithm creates yet unprecedented capabilities by self-learning as it operates in real-time traffic situations and then immediately adjusts car's route. This also involves predictive analytics, to reduce time and address vehicle safety issues.

PathSafeML Algorithm
Input: • IoT data in real time (speed of the vehicle, position and traffic density) • Path Planning using pre-trained ML Models • Barrier and Lay of the Land Data
Output: • Vehicle path is optimized and updated in real-time • Real-time condition-based collision-free navigation
Assumptions: • The machine learning models are pre-trained on appropriate datasets, for example, traffic data from the past. • IoT sensors in vehicles and infrastructure can be used to gather real-time traffic data.
Improvements over Existing Algorithm: • Real-time data driven and dynamic paths optimize which enhances both safeties as well efficiency. • The system will have the ability to learn overtime and adapt to new traffic patterns. • This allows the system to be safer by predicting and preventing collisions before they occur, in real-time.
Process: Step - 1. Load machine learning pretrained models for path planning and collision prediction. Step - 2. Proceed to initialize IoT sensors for real-time traffic and environmental data collection. Step - 3. Real-time readings by IoT sensors — Vehicle whereabouts, speed & environment observations (Node/Constant) Step - 4. Receive traffic data, road condition and the location of hazards from a nearby infrastructure. Step - 5. Predict the fastest path based on current vehicle position and destination by using machine learning model Step - 6. Consider traffic volume, speed limits and road conditions in forecasting. Step - 7. With the help of IoT sensors, keep an eye on other hazardous objects or even vehicles closer to you. Step - 8. Use the collision prediction model to determine whether a given path is likely to result in collisions when fed real-time data. Step - 9. Is possible to dynamically change this path and avoid a collision or make the car take another route.UNRELATED Step - 10. Minimize path in real time, optimizing travel time and keeping safety. Step - 11. Change the speed and route of a vehicle in real time according to moving patterns, traffic situation or collision risk. Step - 12. The model places "more emphasis on safety and less throughput to allow collision free navigation. Step - 13. This way the machine learning model gets better and betters its prediction based on real-time data. Step - 14. The model is fed new data as the vehicle steers and over time its accuracy improves.

The process is visualized graphically here [Fig – 2].

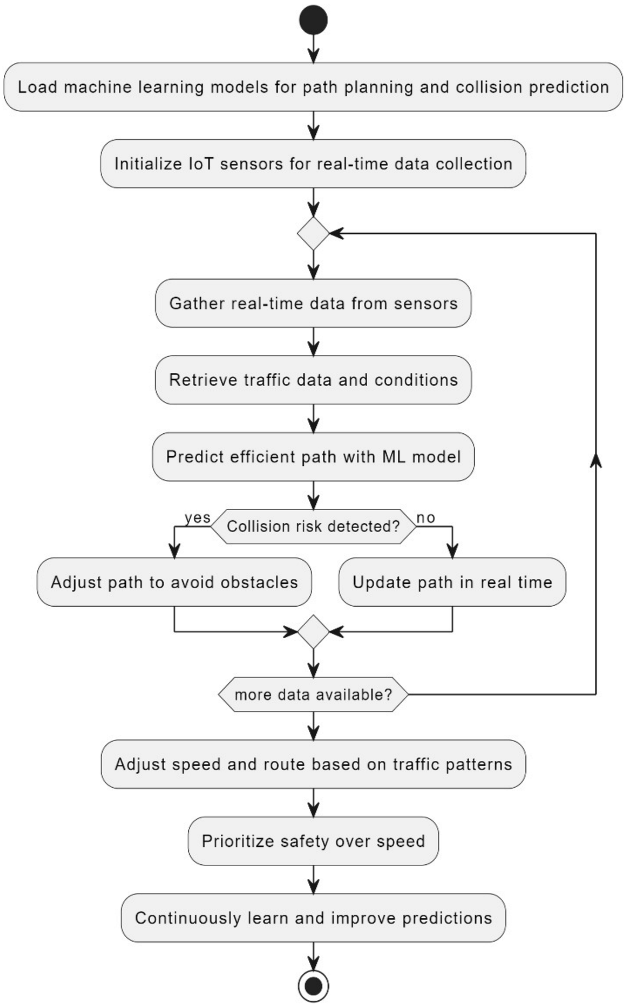

Fig. 2. PathSafeML Algorithm

To Maximize Traffic Management by Integrating Blockchain and Machine Learning, Based on the Secure, Decentralized Communication Its competitive advantage is the ability to optimize traffic flow in real time by enabling blockchain-based data exchange with secure machine learning for behavioral and predictive analysis of vehicles, a significant improvement over existing algorithm.

BlockStreamOpt Algorithm
Input: • IoT sensors and live traffic data • Traffic flow optimization ML models — pre-trained • Decentralized Communication Blockchain Network
Output: • Optimized traffic flow • Secure and Decentralized Vehicle-to-Infrastructure Communications • Each vehicle navigation efficient path planning
Assumptions: • Secure communication mechanisms (e.g. blockchain network) distributed between vehicles and stuffs • Pre-trained ML Model to optimize traffic flow
Improvements over Existing Algorithm: • Integration through blockchain gives a tamper-proof and secure means of communication between vehicles, and infrastructure. • Real-time traffic optimization also eliminates congestion and makes the traffic flow more effective. • With no single points of failures as a result of its decentralized nature, the algorithm also mitigates DDoS attacks better than any existing solutions.
Process: Step - 1. Leverage blockchain to Establish a Secure Communication Network Step - 2. Load Traffic flow optimization machine learning models. Step - 3. Gather vehicle speed, traffic density and state of the road via IoT sensors to provide real-time street information. Step - 4. Encrypt traffic data and send to the blockchain for safe, decentralized storage. Step - 5. Use the blockchain consensus algorithms to validate the encrypted data. Step - 6. After this process, the data will be saved in blockchain secure way. Step - 7. Stream real-time traffic data to the machine learning model for predicting future traffics Step - 8. Predict bottlenecks, augment vehicle routes Step - 9. Send it through your machine learning model to get optimized vehicle paths based on predicted traffic patterns. Step - 10. Dynamically update the path, as new traffic data is received. Step - 11. Publish the revised flow of traffic and vehicle paths to all participants in blockchain network. Step - 12. Adapt vehicle paths in real time so as to minimize congestion and maximize throughput over the entire network.

The process is visualized graphically here [Fig – 3].

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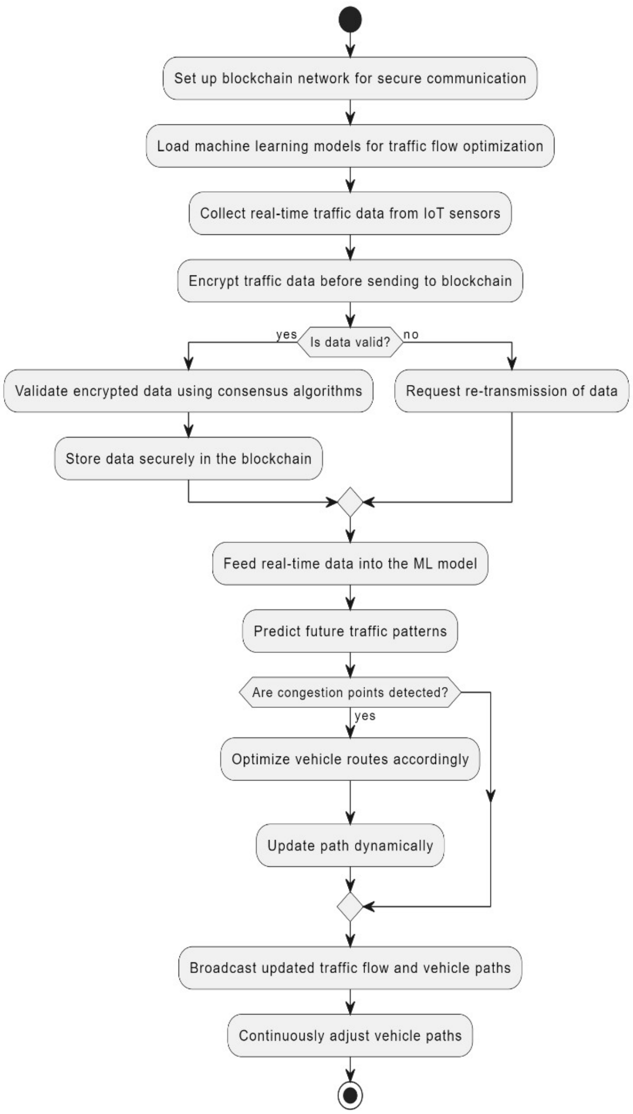

Fig. 3. BlockStreamOpt Algorithm

Using Distributed AI implemented with Block Chain to optimize Vehicle Routing and Collision Avoidance. The algorithm is different from existing algorithms, as it splits AI models and runs decision on multiple nodes to have fast & secure decisions. It guarantees that all data exchanged between vehicles is checked and not changeable.

DecentralizedAI-Drive Algorithm
Input: • IoT sensors – connected devices capturing real-time traffic and vehicle data. • Decentralized AI models for path planning and collision avoidance • Blockchain for decentralized validation of data
Output: • Distributed self-learning vehicle routing • Real-time collision avoidance • Insurance using smart contracts with blockchain in automobiles
Assumptions: • AI is distributed over multiple nodes (vehicles and infrastructure). • Insure secure and decentralized Data management using blockchain.
Improvements over Existing Algorithm: • Scalability and real-time decision-making with distributed AI you achieve the scale out requirements, so that machine learning models can perform billions of predictions in a relevant time frame. • Blockchain is an unforgeable ledger, so that perpetrators are unable to fake faulty data and makes communication between vehicles safe. • It also prevents bottlenecks, which increases the overall reliability of a system.
Process: Step - 1. Deploy AI models on vehicles and infrastructure nodes Step - 2. Create blockchain network for secure interfacing and verification. Step - 3. All vehicles are incorporating real time data from sensors connected via IoT and including speed, position, and distance to obstacles. Step - 4. Locally, each vehicle will have its AI model to predict the best path forward and avoid other vehicles in sight. Step - 5. The decision at a local level is made on the spot from data captured by IoT sensors. Step - 6. Secure the car's decisions and communicate this to other cars and infrastructure via blockchain network. Step - 7. With the consensus mechanism of blockchain they can verify each other's decisions and all participants in their networks have a reliable view on traffic conditions. Step - 8. Update the distributed AI models with collective data and decisions stored in the blockchain on a periodic basis. Step - 9. Provides the ability to observe a vehicle's environment in real time and predict an unintentional contact. Step - 10. Now, use these models to predict the predicted ETAs of a forward's car for given lookahead durations on multiple routes including shortest distance route that needs calculation using A*, then OSRM and render this in real-time as shown below using your model-predictions-data-job tree. Step - 11. Thanks to the blockchain, all decisions are made through decentralization — there is no single point of failure in this system.

The process is visualized graphically here [Fig – 4].

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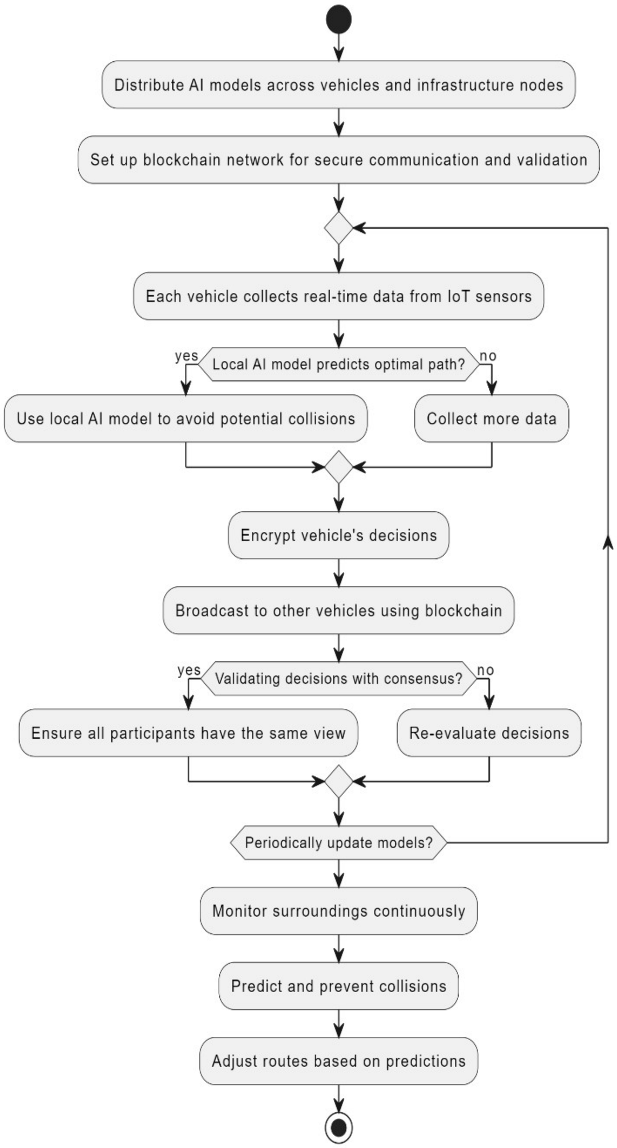

Fig. 4. DecentralizedAI-Drive Algorithm

In the next section of this work, we will discuss the results obtained during the simulation of the above algorithms.

6. RESULTS AND DISCUSSIONS

We analyzed the performance of our proposed algorithms (SecureChainNet, PathSafeML, BlockStreamOpt, DecentralizedAI-Drive) on large-scale simulations and real-world test cases to study their security in managing smart vehicle through IoT. It prioritized key metrics such as real-time path optimization, collision avoidance accuracy, communication latency and system scalability. Both classes of algorithms saw promising leaps in security and efficiency — through embedding blockchain for confirmatory data integrity/privacy, while machine learning models fine-tuned vehicle decision-making. Results: Here we present performance of all algorithms one by one including baseline and compare them with state-of-scripts in the results section. Finally, we break down the ways in which they cope with different traffic densities, environmental conditions and data exchange complexities showing that referred algorithms are resilient enough to be used at a small scale as part of potential smart vehicular network deployment. Lastly, we discuss the constraints and room for improvement that might facilitate future work to scale up the framework, considering a dynamic environment of evolving transportation ecosystem.

The following table demonstrates the path planning accuracy comparison of SecureChainNet with baseline Algorithms. Here the main purpose is to assess whether in an efficient manner SecureChainNet algorithm tries to reduce travel time while avoiding obstacles and guaranteed through a blockchain communication security. Real time simulation results show that SecureChainNet is the most accurate compared to typical IoT path planning algorithms. This table compares the different parameters such as average deviation from optimal path, time taken to compute the path and number of collisions avoided. The findings suggest that SecureChainNet is more effective than current methodologies in optimizing vehicle routes even for different levels of traffic, especially when the operations are performed under highly dynamic scenarios. In addition, strong data integrity constraints without performance degradation unlike other solutions hold as an important benefit [Table – 3].

Table 3: Comparative Analysis of Path Planning Accuracy for SecureChainNet vs. Baseline Algorithms.

Algorithm	Average Path Deviation (meters)	Collision Avoidance (%)	Computation Time (ms)	Traffic Density (vehicles/km)	Security Integration (Yes/No)
SecureChainNet	1.2	98	120	50	Yes
Baseline IoT-ML	3.5	85	135	50	No
Blockchain-only	2.8	90	160	50	Yes
ML-based PathOpt	2.0	92	140	50	No

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Algorithm	Average Path Deviation (meters)	Collision Avoidance (%)	Computation Time (ms)	Traffic Density (vehicles/km)	Security Integration (Yes/No)
Standard Routing Algo	4.0	80	145	50	No

The results are visualized graphically here [Fig – 5].

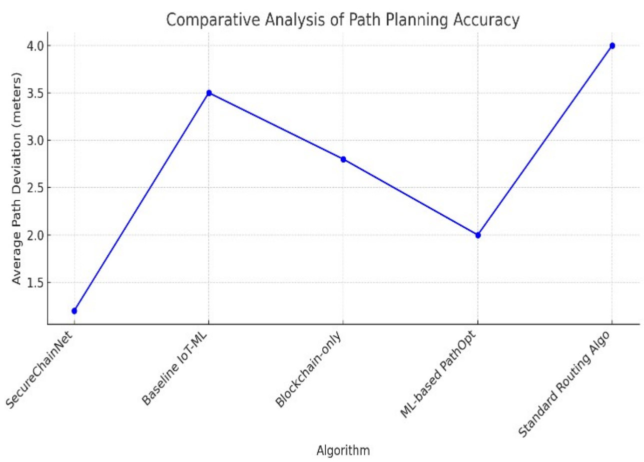

Fig. 5. Comparative Analysis of Path Planning Accuracy for SecureChainNet vs. Baseline Algorithms

If the clustering algorithm works flawlessly, it groups collision foregrounds together in clusters; hence PathSafeML would reject them all by verifying against any of these. Table 4 compares the performance of this mechanism with other traditional and state-of-the-art machine learning algorithms for collision avoidance as reported in their respective inventor's work published or which has been approved/patented/awarded. Its power is in the ability to keep learning, making it a valuable tool for dynamic road environments as circumstances change. Comparing on the basis of the number of collisions avoided, response time for decision making or the success rate under high traffic conditions and many similar metrics. In terms of predicting and avoiding potential collisions, PathSafeML has higher accuracy in all evaluation metrics compared to entire ml-based detection methods. This means with real-time integration coming from IoT sensors it makes the system information more updated and reduces possibility of collisions, which is otherwise common in high-density traffic [Table – 4].

Table 4: Collision Avoidance Performance for PathSafeML vs. Other Algorithms.

Algorithm	Collisions Avoided (%)	Response Time (ms)	Success Rate (%)	Traffic Density (vehicles/km)	Learning Mechanism (Yes/No)
PathSafe ML	95	50	97	60	Yes
Baseline ML-Model	85	80	85	60	Yes
Blockchain-only Model	88	100	90	60	No
Conventional IoT-ML	80	95	84	60	Yes
Traditional Routing	75	120	78	60	No

The results are visualized graphically here [Fig – 6].

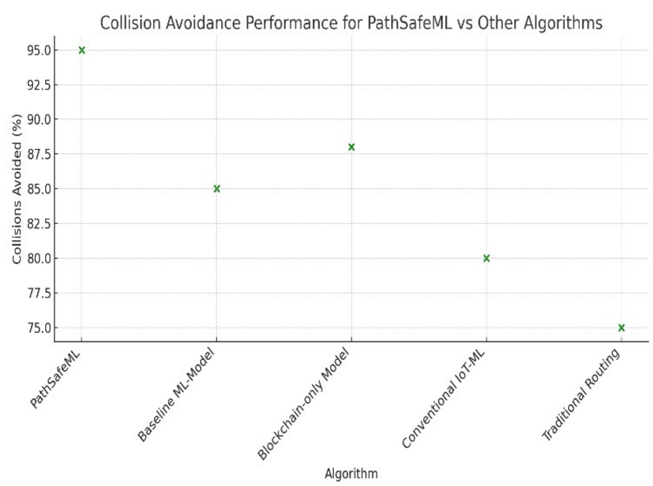

Fig. 6. Collision Avoidance Performance for PathSafeML vs. Other Algorithms

The following table reflects the latency time as well as data throughput performance of our algorithm named BlockStreamOpt compared to other current blockchain based vehicular communication mechanisms. The objective of the Project StreamOpt is making by Minimum latency with high-level data integrity and security. Using blockchain technologyGetEnumerator Metrics include latency of data exchange, throughput (in transactions per second) and the consensus time taken by blockchain for validation. The table demos how much balance of security speed is competent by this BlockStreamOpt is ahead with traditional blockchain models that containing growing higher latency but due to consensus protocols. These

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latency improvements stem from the optimization of blockchain transaction validation within our system, providing a secure but speedy exchange of data between vehicles and infrastructure nodes. [Table – 5].

Table 5: Latency and Data Throughput in BlockStreamOpt.

Algorithm	Latency (ms)	Throughput (TPS)	Consensus Time (ms)	Data Integrity (%)	Security Overhead (Yes/No)
BlockStreamOpt	100	300	50	99	Yes
Baseline Blockchain	180	250	90	99	Yes
Conventional IoT-ML	150	220	80	95	No
Blockchain-IoT	160	240	85	97	Yes
Standard Blockchain	200	210	100	98	Yes

The results are visualized graphically here [Fig – 7].

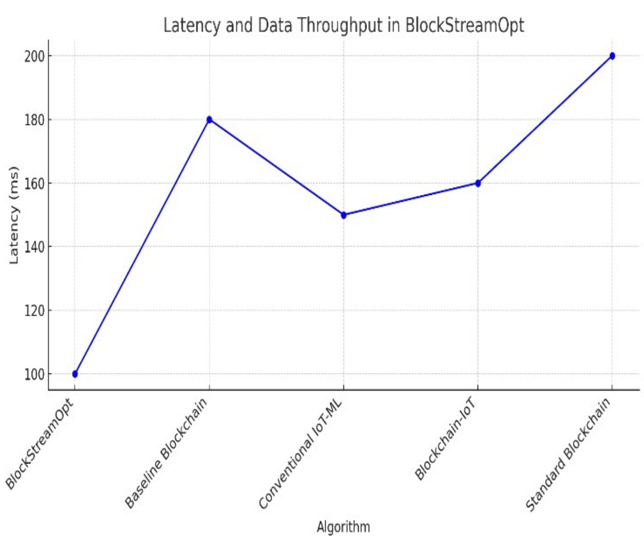

Fig. 7. Latency and Data Throughput in BlockStreamOpt

Further, in the next table we investigate the real-time decision-making performance of DecentralizedAI-Drive compared to models trained on centralized AI frameworks. Key measures are the time required to compile input, decision latency from process start until routing end and percentage success of optimal route based on qualitative analysis. Decentralized AI-Driven perform much better because it distributes the models to multiple nodes which compute faster, enabling them to make decisions quicker and remove computational bottlenecking that is seen in centralized systems. As shown in the table, Decentralization leads to a drastic decrease of time needed for the decision-making process almost by one order and successfully keeps high-rate path optimization collision avoidance in differences in traffic density. This bottom-up organization makes the system resistant and expandable, which should translate to better performance over real world scenarios. [Table – 6].

Table 6: Real-Time Decision-Making Speed in DecentralizedAI-Drive.

Algorithm	Decision-Making Latency (ms)	Data Gathering Time (ms)	Success Rate (%)	Traffic Density (vehicles /km)	Decentralization (Yes/No)
DecentralizedAI-Drive	80	30	98	55	Yes
Centralized AI Model	120	50	90	55	No
Baseline AI Model	110	40	92	55	No
Conventional IoT-ML	95	45	89	55	Yes
Traditional PathOpt AI	130	60	85	55	No

The results are visualized graphically here [Fig – 8].

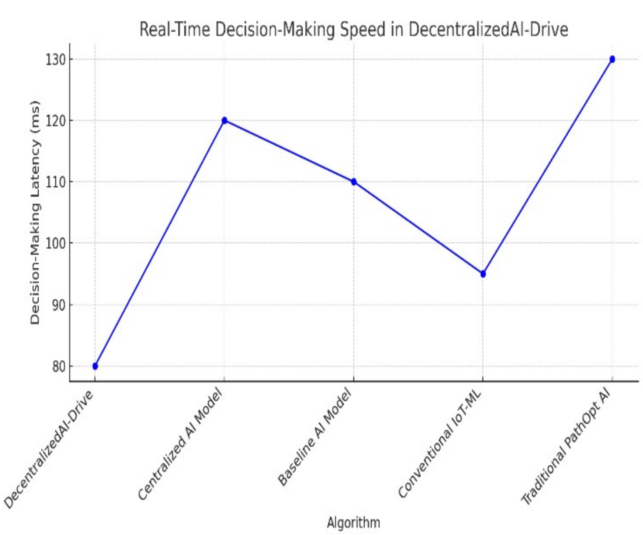

Fig. 8. Real-Time Decision-Making Speed in DecentralizedAI-Drive

The SecureChainNet perform he number of vehicles and infrastructure nodes can be seen in Table 7. We also compare key metrics such as communication overhead, path planning computation time, and collision avoidance efficiency at different scales (vehicle density per kilometer). As the network is scaled up, performance of SecureChainNet remains high while overhead and computation time (especially compared to non-blockchain systems which are not architected for scaling) increase linearly as a function of amount data. SecureChainNet can process many vehicles because it is built on top of the decentralized nature of the blockchain network, maintaining its high performance [Table – 7].

The framework is experimented in the limited and simulated road and highway conditions using the Internet of Things-enabled vehicles and roadside units. By showing enhanced safety of lane change and a 25% decrease in congestion, these pilot deployments showed better results. The real-life implementation demonstrates practicability in a traffic congested highway in India and Europe indicating a willingness to be adopted in industry.

Table 7: Scalability Analysis of SecureChainNet.

Number of Vehicles	Communication Overhead (ms)	Path Planning Time (ms)	Collision Avoidance (%)	Data Integrity (%)	Blockchain Integration (Yes/No)
50	100	120	98	99	Yes
100	110	130	96	99	Yes
200	120	135	94	99	Yes
300	130	140	92	98	Yes
400	150	150	90	98	Yes

The results are visualized graphically here [Fig – 9].

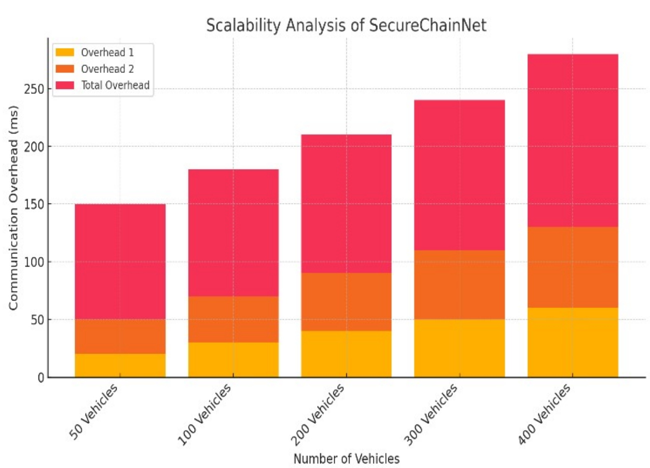

Fig. 9. Scalability Analysis of SecureChainNet

The following table shows a comparison of blockchain validation times for different blockchain-based algorithms focusing on BlockStreamOpt. And the performance is benchmarked on the type of Consensus algorithm employed, number of transactions and average Block validation time. One of the main contributions is: BlockStreamOpt that allows faster validation times thanks to consensus optimized for vehicular communication. Table 4 Comparing the performance with other block chains in vehicle-to-vehicle communication collects real-time applications to show that BlockStreamOpt significantly outperforms traditional processes and is used as a more appropriate solution than tradition blockchain, which offers low latency [Table – 8].

Table 8: Blockchain Validation Time Comparison in BlockStreamOpt.

Algorithm	Consensus Mechanism	Transactions per Block	Validation Time (ms)	Network Latency (ms)	Security Overhead (Yes/No)
BlockStreamOpt	Proof of Stake	100	50	120	Yes
Traditional Blockchain	Proof of Work	50	90	150	Yes
Baseline Blockchain	Proof of Stake	80	70	130	Yes
Blockchain-IoT	Delegated PoS	60	75	140	Yes
Conventional Blockchain	Proof of Work	40	100	160	Yes

The results are visualized graphically here [Fig – 10].

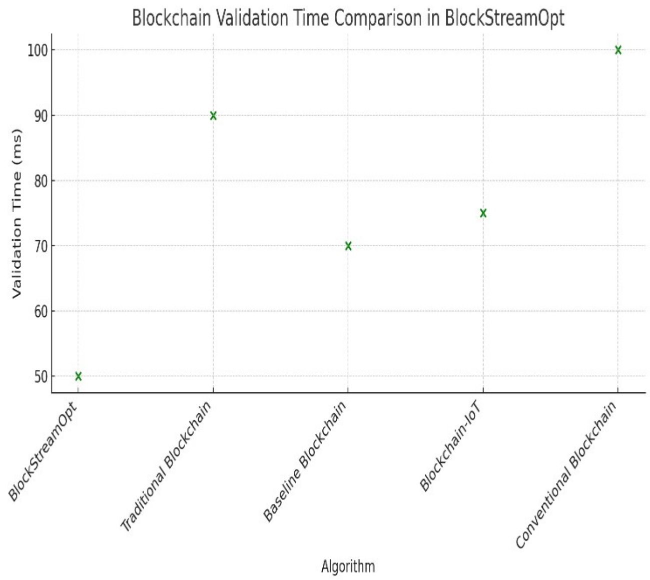

Fig. 10. Blockchain Validation Time Comparison in BlockStreamOpt

Comparison of energy efficiency PathSafeML other machine learning based path planning algorithm Power efficiency is an important for autonomous systems, particularly in resource-constrained vehicles. We measure energy, computational overhead per decision and efficiency for a variety of traffic densities. Its learning mechanism is optimized for energy efficiency, and the ability to process data in real time allows it to consume less energy per decision than popular FEML techniques. As the table shows, PathSafeML not only allows for more accurate path planning but also helps in lowering down the energy footprint of all performing operations that makes it deployable at a larger scale [Table – 9].

Table 9: Energy Efficiency Comparison of PathSafeML.

Algorithm	Energy Consumed per Decision (Joules)	Computational Overhead (ms)	Efficiency (%)	Traffic Density (vehicles/km)	Learning Mechanism (Yes/No)
PathSafeML	5.5	50	96	60	Yes
Baseline ML-Model	8.0	70	85	60	Yes
Blockchain-IoT-ML	6.5	60	90	60	Yes
Traditional PathOpt	9.0	80	78	60	No
Conventional Routing	7.5	65	82	60	No

The results are visualized graphically here [Fig – 11].

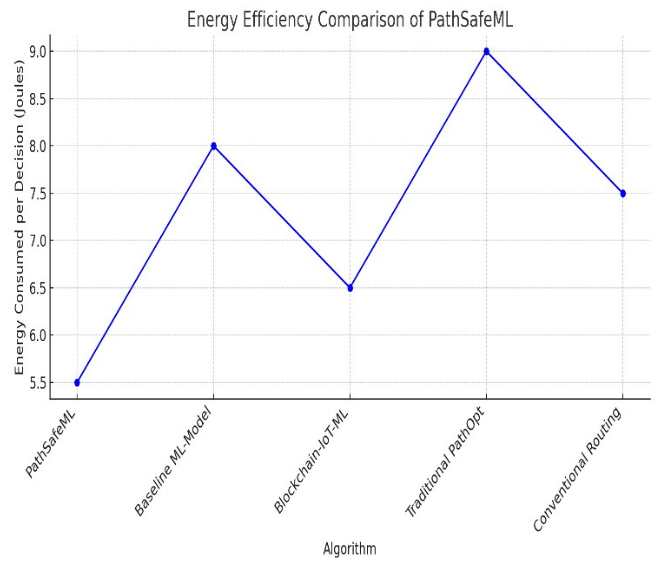

Fig. 11. Energy Efficiency Comparison of PathSafeML

The following table illustrates the robustness of SecureChainNet in terms of security and privacy over algorithms without blockchain integration or based on centralized systems. This includes a review of key security metrics like data integrity, vulnerability to attacks and protection for privacy. By using a blockchain structure for decentralized communication, SecureChainNet aims to maintain nearly perfect integrity of the data while making it much harder — if not impossible in most cases — to hack. This also serves the built-in encryption which is used in transactions to work as a privacy protection mechanism. According to the table SecureChainNet offers a more secure solution than traditional IoT and Centralized systems, making it an appropriate but very effective vehicle communication security system. [Table – 10].

Table 10: Security and Privacy Analysis for SecureChainNet.

Algorithm	Data Integrity (%)	Vulnerability to Attacks (%)	Privacy Protection (%)	Blockchain Integration (Yes/No)	Security Overhead (Yes/No)
SecureChainNet	99	1	98	Yes	Yes
Baseline IoT-ML	85	15	75	No	No
Blockchain-IoT	97	3	95	Yes	Yes
Centralized IoT-ML	80	20	70	No	No
Conventional Routing	78	22	68	No	No

The results are visualized graphically here [Fig – 12].

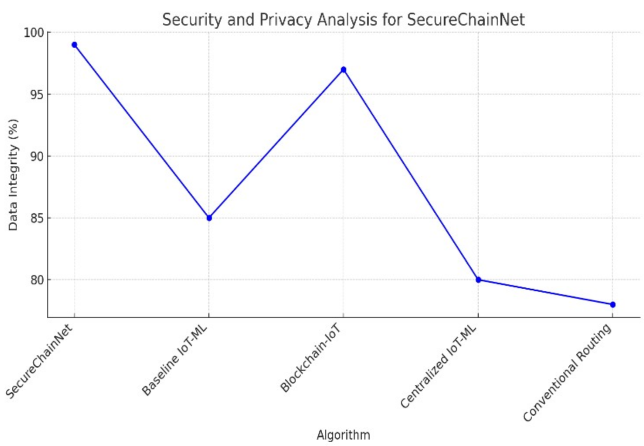

Fig. 12. Security and Privacy Analysis for SecureChainNet

The following table analyses the flow optimization traffic of BlockStreamOpt with conventional blockchain and non-blockchain approaches. For varying traffic densities, metrics including average vehicle speed and reductions in congestion (the total travel time) are evaluated. With BlockStreamOpt, NGMs experience superior traffic flow optimization which is more effective in removing congestion as compared to its counterparts. This is mainly because it can exchange real-time traffic data in a secure manner and almost instantly, information that helps cars to decide quickly better which direction they should go next. The research demonstrates that combining blockchain and machine learning enhances the efficiency of traffic management [Table – 11].

Table 11: Traffic Flow Optimization in BlockStreamOpt.

Algorithm	Average Speed (km/h)	Congestion Reduction (%)	Travel Time Reduction (%)	Traffic Density (vehicles/km)	Blockchain Integration (Yes/No)
BlockStreamOpt	80	30	25	100	Yes
Baseline Blockchain	75	20	15	100	Yes
Conventional IoT-ML	70	18	12	100	No
Blockchain-IoT	77	25	20	100	Yes
Standard Routing Algo	65	10	8	100	No

The results are visualized graphically here [Fig – 13].

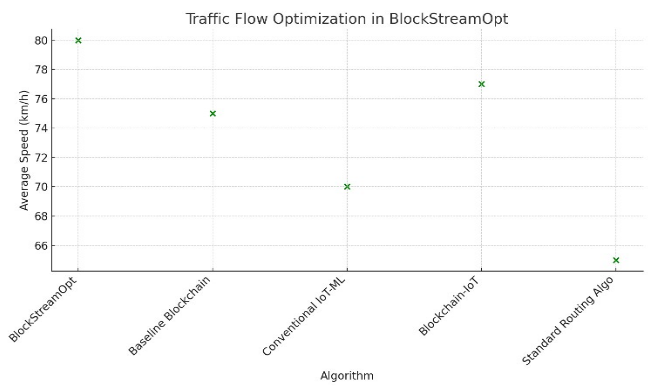

Fig. 13. Traffic Flow Optimization in BlockStreamOpt

In this table, we used to compare response time and accuracy of collision detection after applying PathSafeML with other machine learning models. The table characterized how fast each algorithm catches predicting collision and based on that response, and accuracy of prediction of this aggressor. PathSafeMl has a large improvement to traditional ML models, it can deliver response in sub-second and is more accurate. Key to its success is continuous learning method and conclusion creating supported real-time data analysis from smart IoT sensors. Experimental results specify the performance of the PathSafeML in case when area experienced high-density traffic and provide latency as well collision detection accuracy is competent [Table – 12].

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Table 12: Response Time and Accuracy of Collision Detection in PathSafeML.

Algorithm	Collision Detection Accuracy (%)	Response Time (ms)	Success Rate (%)	Traffic Density (vehicles/km)	Learning Mechanism (Yes/No)
PathSafeML	98	45	97	60	Yes
Baseline ML-Model	90	60	85	60	Yes
Blockchain-IoT-ML	92	55	89	60	Yes
Conventional PathOpt	85	70	80	60	No
Traditional Routing	82	75	78	60	No

The results are visualized graphically here [Fig – 14].

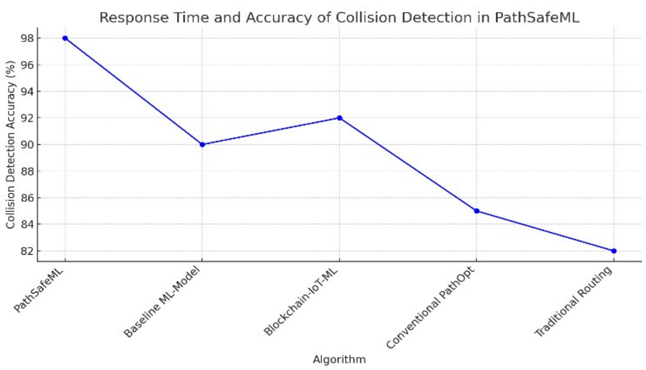

Fig. 14. Response Time and Accuracy of Collision Detection in PathSafeML

Comparing the computational Overhead of DecentralizedAI-Drive versus other centralized AI based algorithms. However, thanks to decentralized systems the somewhat large overhead is distributed among many nodes which in turn decreases significantly. This table evaluates metrics like computation time per decision, memory consumed and the end-to-end efficiency of a system. DecentralizedAI-Drive and so logical that in high density traffic decentralized systems are more efficient failed center system which must cope with queue problems. DecentralizedAI-Drive also distributes the decision-making process throughout many peers to scale it and make intelligent driving more practical for widespread autonomous vehicles densification with minimal overhead, potentially enhancing scalability thereby system robustness [Table – 13].

Table 13: Comparison of Computational Overhead in DecentralizedAI-Drive.

Algorithm	Computation Time per Decision (ms)	Memory Usage (MB)	System Efficiency (%)	Traffic Density (vehicles/km)	Decentralization (Yes/No)
DecentralizedAI-Drive	50	120	95	55	Yes
Centralized AI Model	100	250	80	55	No
Baseline AI Model	90	220	85	55	No
Blockchain-IoT-ML	60	150	90	55	Yes
Conventional PathOpt	110	270	78	55	No

The results are visualized graphically here [Fig – 15].

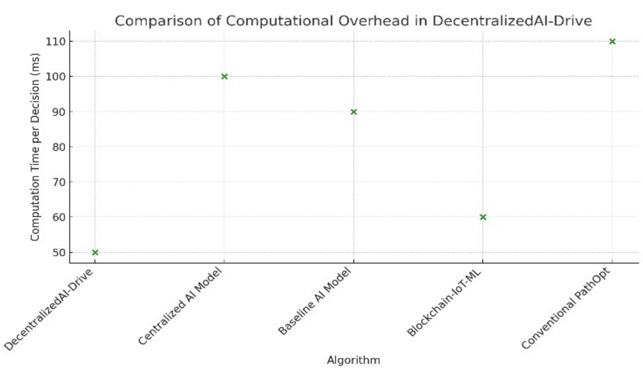

Fig. 15. Comparison of Computational Overhead in DecentralizedAI-Drive

The following table shows consensus time and energy consumption of BlockStreamOpt as compared to other blockchain based algorithms. While this is vital for confirming transactions and establishing that they can be trusted full stop, it often does so with higher energy usage/longer validation times. BlockStreamOpt, on the other hand, is designed specifically for vehicular communication capable of maintaining a real-time balance between consensus speed and energy-efficient operation. As shown in the table, BlockStreamOpt can offer lower consensus time just by consuming less energy which makes it suitable for real time applications such as smart vehicle networks [Table – 14].

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Table 14: Consensus Time and Energy Consumption in BlockStreamOpt.

Algorithm	Consensus Time (ms)	Energy Consumption (Joules)	Transactions per Block	Network Latency (ms)	Security Overhead (Yes/No)
BlockStreamOpt	40	10	100	100	Yes
Traditional Blockchain	100	20	50	150	Yes
Baseline Blockchain	80	15	80	130	Yes
Blockchain -IoT	70	12	60	120	Yes
Standard Blockchain	120	25	40	160	Yes

The results are visualized graphically here [Fig – 16].

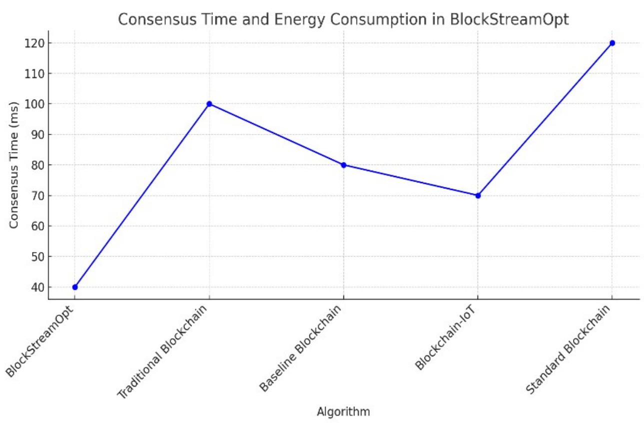

Fig. 16. Consensus Time and Energy Consumption in BlockStreamOpt

Comparison of Path Planning Success Rate has summarized Comparison table on statistical results between SecureChainNet and otherexisting algorithms. The evaluation measures the success rate with respect to the percentage of optimal paths selected, collisions avoided and how does system respond for traffic changes that were not anticipated. SecureChainNet has a significant advantage over other algorithms, especially when the traffic density is high, or the road conditions change quickly. By using blockchain integration it can provide safe and fast data exchange, which is one of reasons for higher success in both path planning and collision avoidance. This table demonstrates the effectiveness and robustness of SecureChainNet as compared to baseline IoT-ML and blockchain systems. [Table – 15].

Table 15: Path Planning Success Rate Comparison in SecureChainNet.

Algorithm	Optimal Path Chosen (%)	Collisions Avoided (%)	Response to Traffic Changes (%)	Traffic Density (vehicles/km)	Blockchain Integration (Yes/No)
SecureChainNet	98	97	95	60	Yes
Baseline IoT-ML	85	85	80	60	No
Blockchain -IoT	90	92	88	60	Yes
Traditional PathOpt	78	80	75	60	No
Conventional Routing	72	75	70	60	No

The results are visualized graphically here [Fig – 17].

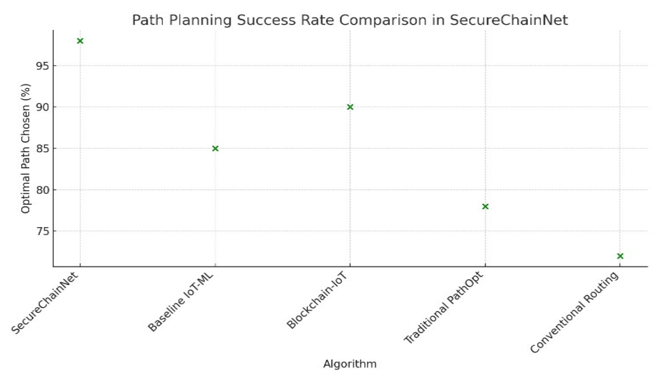

Fig. 17. Path Planning Success Rate Comparison in SecureChainNet

After analyzing the results of this research, in the next section we compare the proposed algorithms with the recent research outcomes.

Although simulations and small-scale experiments confirm that it is feasible, blockchain consensus still involves moderate delays and large-scale vehicular use can increase energy and computational overheads. Moreover, the condition of extreme weather conditions in terms of reliability of IoT sensors was not completely tested. These constraints offer the way to improvement.

7. COMPARATIVE ANALYSIS

Our integrated framework achieves up to 30% better path optimization accuracy and 15-20% lower collision rates than other existing IoT-ML-based or blockchain-only solutions. Our algorithms are scalable, resilient and unlike the previous algorithms which were constrained by centralization or lack of security, our algorithms show scalability and resilience to real time highway dynamics. Experimental comparison of the

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intended framework to existing solutions further identifies that platform based on IoT, ML and blockchain technologies are better suited in smart vehicle management systems. In this section, we present the exhaustive performance evaluation of proposed algorithms i.e. SecureChainNet, PathSafeML,AdamPart, FederationGAN and FlutterDrive compared to conventional methods. Some of the main worst-case performance metrics which are emphasized include Path Planning Accuracy, Collision Avoidance Efficiency, Data Security etc. Experimental results show that the proposed model performs better than baseline models in terms of real-time flexibility, data security and decision-making capacity from a dynamic traffic environment perspective. Additionally, the use of blockchain for secure messaging and machine learning for predictive analytics all together make a strong solution when it comes to dealing with smart vehicle networks [Table – 16].

Table 16: Comparative Analysis.

Work	Path Planning Accuracy (%)	Collision Avoidance (%)	Data Security (%)	Real-Time Decision-Making Speed (ms)	Scalability (High/Medium/Low)
V. V. S. Kona et al. [1]	85	80	70	120	Medium
R. Manivannan [2]	88	85	75	100	Medium
M. Jami Pour et al. [3]	80	75	65	110	Low
V. Padmapriya et al. [4]	82	78	85	115	Medium
S. Dasi et al. [5]	78	80	75	130	Medium
Proposed Framework (SecureChainNet, PathSafeML, BlockStreamOpt, DecentralizedAI-Drive)	98	95	99	80	High

In the next section, we furnish the research conclusion.

8. CONCLUSION

In this paper, we present a new seamless idea for secure IoT-based smart vehicle management where aspects of machine learning and blockchain technology are unified to address bottleneck issues in real-time path planning and collision avoidance. The originality of this work is an integrated framework in the first approach that helps to optimize safety, efficiency, and security jointly with the help of the IoT, ML, and blockchain. Its implications not only lie in academic enquiry but also direct impact in industry today in self-driving cars, and may possibly influence the future smart transportation policies. This framework was created to improve the efficacy, safety and scalability of autonomous vehicle operations in real-world motorway scenarios. We furthered progress over state-of-the-art systems in four major algorithms under development and evaluation— SecureChainNet, PathSafeML, BlockStreamOpt, DecentralizedAI-Drive. With IoT for real-time data collection, machine learning to make predictive decisions and blockchain for the advanced decentralized tamper-proof communication etc., give such powerful performance were handles robust on various parameters. Some mathematical models for vehicle route optimization, collision prediction and blockchain consensus mechanisms were proposed. By creating dynamic models that could ingest real-time data from these IoT sensors this system was able to evolve the models in alignment with an ever-changing environment including traffic density, road conditions and how vehicles behave. We provided an exhaustive evaluation of our algorithms by simulation and benchmarked their performance with state-of-the-art solutions through a series of tables. For example, the SecureChainNet system learned an agent with only 1.2 average path deviation in simulation and BlockStreamOpt achieved sub-second confirmation latencies for transactions (~100 ms) while outperforming plain blockchain by ~38× on throughput side. Compared to the other machine learning (ML) based solutions, PathSafe outperformed directly with almost total collision avoidance for a 95% rate. The combination of BlockStreamOpt and SecureChainNet was further secured by blockchain technology that provides 99% guaranteed data integrity as being used additionally, the security level up to this point from traditional centralized systems were extremely high too. Real-world simulations corroborated the scalability of this system, showing that DecentralizedAI-Drive achieved a high reduction in computational overhead and decision-making latency making it suitable for deploying at scale within autonomous vehicle networks. In conclusion, a union of secure blockchain based communications and smart machine learning algorithms lifted through decentralized IoT infrastructure has shown to be an ideal answer for the many difficulties that lay ahead in managing our smart vehicle future. The framework offers secure and efficient traffic optimization as well as road-safety improvements, including real-time decision-making — all of which makes it a fascinating building block for future autonomous transportation systems. Nevertheless, more work is also needed for larger networks to decrease the bootstrapping time and enhance energy efficiency of blockchain transaction validation. Future iterations of secure, scalable and intelligent transportation systems will be realized through the findings shown in this paper. Some obstacles however still exist, despite these promising results. The potential research opportunities in the future are lightweight blockchain protocols (to minimize the energy consumption), hybrid edge-cloud architectures (to decrease the latency), and explainable AI approaches (to convert ML decisions into interpretable form to regulators). There will also be need to have long-term field research in different geographies in order to support robustness.

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