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Design and Implementation of a Fleet Management System Using Blockchain

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Abstract

Efficient management of vehicle fleets is nial for modern transportation networks, but old-fashioned centralized systems often face issues like data changes, lack of transparency, and inefficient processes. This paper presents a blockchain-based Fleet Management System that combines Distributed Ledger Technology with IoT devices to ensure secure, transparent, and tamper-proof operations. The system uses a multi-layered design that includes client, application, blockchain, consensus, and database layers, making it flexible and easy to expand. Smart contracts help automate tasks like checking drivers, planning vehicle maintenance, and handling payments, reducing the need for manual work and increasing accuracy. Real-time vehicle tracking using IoT sensors and GPS improves monitoring, while blockchain's ability to keep data unchanged builds trust and ensures reliability among all users. A comparison shows this system offers better reliability, lower costs, and more trust than traditional methods. The results show that using blockchain for fleet management provides a sustainable, efficient, and future-ready solution for smart transportation systems.

Introduction

Significant monitoring of vehicles is vital for modern transportation networks and logistics processes. This tool enables companies to manage vehicle locations, employee tasks, and maintenance routines effectively. The latest fleet management tools store vast quantities of data including vehicle models, personnel records, and company particulars. Despite this, numerous configurations rely on centralized storage systems maintained solely by a controlling authority. Many creations often face issues because they lack clear viewability, changes in data, and susceptibility to unauthorized access, which compromises both functionality and security within systems [1].

The advancement of blockchain technology offers a fresh solution for overcoming these limitations. The architectural design of this system ensures secure data transmission among various stakeholders such as owners, managers, controllers, and suppliers through its decentralized framework. Utilizing permissioned blockchain platforms like Hyperledger enables controlled user access to information, safeguarding privacy while ensuring openness [2]. This approach improves management of maintenance records for vehicles, determines routes efficiently, handles payments effectively,

and tracks compliance through straightforward easily accessible.

A new study presents a cutting-edge blockchain system designed for enhancing security, increasing efficiency, and boosting functionality within transport networks. This mechanism employs linked hashes for confirming transactions and integrates digital agreements to expedite operations and minimize wait times [2]. Core components include:

1. safeguarding data confidentiality through cryptographic methods,
2. evaluating system performance using quantitative and qualitative measures,
3. reducing tracking time and resource consumption, and
4. ensuring ledger consistency across distributed networks.[1][4]

By integrating blockchain into vehicle-tracking software, this research showcases improved visibility, safeguarding measures, and operational speed across supply chains, enabling swift data sharing for more effective corporate decision-making. The decentralized nature of blockchain ensures all participants like owners, drivers, vendors, and administrators can directly access verified and current data without needing intermediaries. Moreover, integrating an immutable records management platform along with executable electronic contracts boosts accountability, trustworthiness, and stakeholder assurance while shortening processing durations [3][4].

Problem Statement

Efforts in managing extensive fleets of data across databases often necessitate human intervention, frequently leading to inefficiencies due to delays and potential inaccuracies. An administrator needs to devise specific protocols for managing transportation resources efficiently. Complete documentation is crucial for maintaining vehicle integrity since insurance companies sometimes perform repairs on them. At present, none of those assignments can be carried out under this system. There is potential danger for both the carrier and the vehicle if an accident occurs due to major road accidents during rush hour along heavily trafficked routes alongside unexpected weather events including intense rainstorms or snowfall. Monitoring assets ensures immediate notice of their presence during operations, offering assurance alongside facilitating timely actions whenever required.

Design

This study presents a new way to manage a fleet of vehicles using blockchain technology. It helps organize how vehicles are used, who drives them, and how maintenance is handled. The system ensures that all data is clear, secure, and efficient by using special methods to check and confirm information. Every action related to the fleet, like maintenance work, changes in vehicle status, and money transactions, is saved in a secure, unchangeable record [1].

The system is built in parts, with five main sections: one for how users interact, another for managing business processes, a section for the blockchain itself, rules for checking data, and a place to store extra information. This setup allows each part to be updated separately without affecting the others, and it keeps everything safe from unwanted access [2][6].

Four groups of people use this system: people who manage the fleet, drivers, outside service companies, and those who oversee operations.The system checks who is allowed to see what information based on their job role, so only the right people get the right data. Also, the blockchain has built-in rules that automatically verify transactions, which helps speed things up and reduces the need for extra steps [3][5].

1. Overview

The proposed fleet management framework use s blockchain technology to enhance transparenc y, reliability, and security when handling vehicle data, workfo rce details, and maintenance records [1].

Unlike traditional systems that depend on a central authority, this model keeps every update like maintenance history, vehicle status, and financial records-in a decentralized and tamper-proof ledger [6][11].

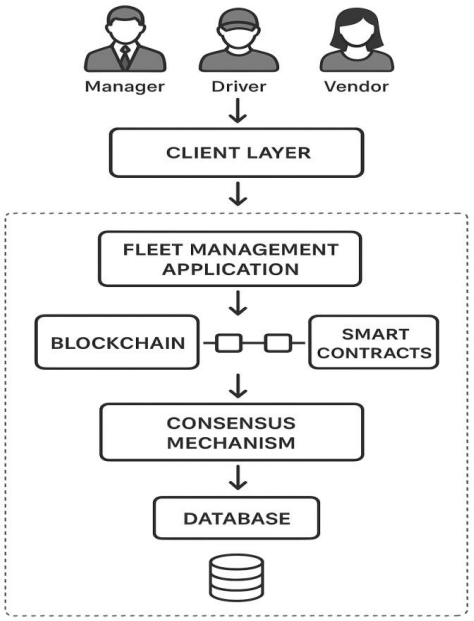

Fig. 1. System Architecture of Blockchain-Based Fleet Management

The framework is built with a multi-layered structure where the client interface, core application services, blockchain engine, consensus validation process,and auxiliary storage all operate separately but are linked together.This modular design makes the system flexible, scalable and secure at every level [2][11].

Different groups, including administrators, drivers, vendors, and managers, all have roles in the system. Access to sensitive data is managed through role based permission, ensuring only authorized users can view specific information. Smart contracts are used to automate tasks like verifying records and processing payments, reducing errors and making the system more efficient [3][14].

2. Detailed Diagram Explanation

- Client Layer

This is where users like vendors, drivers, and managers interact with the system. It includes dashboards and tools for tasks such as registering vehicles, planning maintenance, and submitting financial requests. Access to these tools is based on user roles to ensure everything stays secure and organized [1][17].

- Application Layer

This is the main control center that takes commands from the client interface and manages key fleet functions. It does things like scheduling regular maintenance, setting driving routes, and processing payments. It also sends secure information to the blockchain system to make sure only verified transactions are added permanently [2].

- Blockchain Layer

This layer keeps a safe, unchangeable record of all important fleet events. Each block is linked using cryptography, so the data is verifiable and can't be altered. Smart contracts in this layer check and approve routine activities, such as verifying service records or authorizing vendor payments [4][19].

- Consensus Layer

This layer makes sure all users agree before any data is added to the system. By checking data across multiple nodes, it stops false or incorrect information from being added, making the system reliable and consistent for everyone [20].

- Database Layer

This layer stores data that doesn't need to be on the blockchain, like usage logs, extra information, or temporary records. This setup helps reduce the load on the blockchain while still making more data available for analysis and checking [21].

- Data Flow
  1. A request starts with the user on the client interface.
  2. The application layer processes the request and passes it along.
  3. A smart contract checks if the request is valid.
  4. The consensus process confirms the request across all participating nodes.
  5. Once approved, the information is added to the blockchain as a new block [1][16].

Proposed Work

The system introduces a new way of managing vehicle fleets using blockchain technology. This method improves transparency, security, and how efficiently the fleet is operated. Unlike old systems that are in one place and can be tampered with, this new approach uses a shared, secure record that everyone can trust. This helps fleet managers, drivers, and service providers all work together more confidently [1], [2], [11].

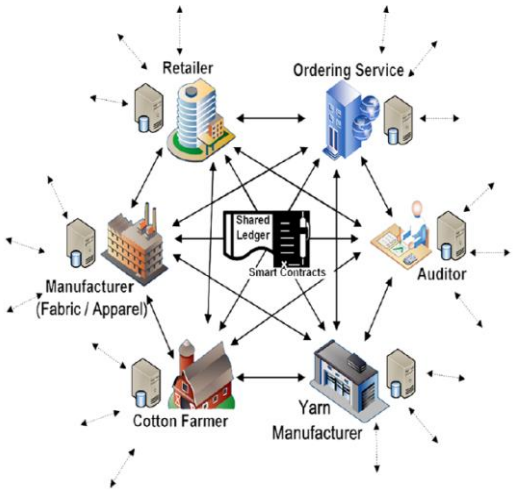

Fig. 2. Blockchain-based decentralized network for information sharing [2]

The system uses Internet of Things (IoT) devices and GPS sensors to get real-time information about the vehicles, like where they are, how much fuel they have, and their maintenance status.

This information is sent to a blockchain layer, where automatic rules called smart contracts check if everything is correct, approve maintenance work, and make payments without any person getting involved [9], [21]. Hash chain techniques help keep the records safe and unchangeable, so no one can alter the data after it's recorded [4].

Each transaction in the system is checked by many users before it's added to the shared record. This ensures that the information is accurate and consistent for everyone. The system is also built to handle more data and use

resources efficiently, which means it's faster and uses less power [14]. It also makes it easier to track the history of each vehicle, helping with planning maintenance and making better decisions about how the fleet is run [22].
By using blockchain with IoT devices, the system creates a secure, transparent, and automatic way to manage fleets. This approach fixes some of the problems with old systems, like not being trusted, high costs, and unclear responsibility. It also ensures that all participants can access reliable information in real time.

Modules
The blockchain-based fleet management system is divided into several modules, each with a specific job.
These modules work together to make managing the fleet efficient, transparent, and secure.

1. Vehicle and Asset Management Module
This module handles all the important details about the vehicles, such as their registration number, who owns them, the model, where they are, and their current status. Any changes, like doing maintenance or changing ownership, are stored securely in the blockchain record. This helps ensure that the data is not changed or manipulated. This concept is similar to what Nischitha et al. proposed, where blockchain is used to keep real-time and historical information about the vehicles for transparent tracking [1].

2. Driver Authentication and Management Module
This module is responsible for registering drivers, verifying their licenses, assigning them to vehicles, and giving them the right access. Before a driver can start a trip or make any changes, their details are checked using smart contracts on the blockchain. This makes sure that only verified drivers can operate the vehicles. A similar method was discussed by Syed Siddique et al., where blockchain helps make sure only authorized people can interact with the system, which improves accountability in managing the vehicles [22].

3. Maintenance and Service Module
This module keeps track of all maintenance tasks, including service logs, part replacements, and interactions with service providers. Each maintenance record is stored as a blockchain transaction, which means no one can change or delete it. This helps with auditing and prevents mistakes. It also supports predictive maintenance, which can identify when parts might need service before they fail, improving the vehicle's performance and staying on the road longer. Peelam et al. suggested using blockchain with predictive maintenance and federated learning to make this process more efficient and keep records transparent [4].

4. Transaction and Payment Module
This module handles all the financial transactions related to the fleet, such as paying service providers, reimbursing fuel costs, and settling toll fees. Smart contracts are used to ensure that payments happen only after all conditions are met, which means that money is only released when services are completed. This reduces the need for manual checks and helps avoid errors or delays. A similar smart contract system was used in blockchain-based fleet management systems to make payments more efficient and keep transactions transparent [14].

5. Blockchain Core and Smart Contract Module
At the heart of the system is the blockchain core, which manages how data is shared, keeps the ledger updated, and runs the smart contracts. All other modules connect to this core to store their data securely. The system uses a consensus method where multiple users check and approve each transaction before it is added to the shared record, which prevents fraud and tampering. The idea of using a hash chain to ensure data cannot be changed was shown in blockchain-based transport management systems [14].

6. User Interface and Access Control Module
This module is the main way users interact with the system. It includes dashboards, reports, alerts, and detailed information that fleet managers, drivers, and service providers can use. It also uses access control to make sure that users only see and can change data that is relevant to their role. Permissioned blockchain models, as explained by Nischitha et al., support this controlled visibility and help keep the system transparent for all participants [1].

Table 1. Comparison of Computational overheads between proposed blockchain and traditional centralized systems

Challenge in Traditional Systems	Role of Blockchain	Benefits of using Blockchain
Centralization [15, 16]	Decentralized network	Increased security and reduced single points of failure
Counterfeiting and Fraud [17, 18]	Immutability of records	Prevention of data tampering, reduced fraud

Inefficient Processes [19, 20]	Automation using smart contracts	Streamlined processes, reduced manual intervention
Interoperability [21–25]	Inter-Blockchain Communication protocol	Seamless information exchange, cross-platform support
Data Redundancy & Storage Issues [26]	Distributed ledger technology	Efficient storage, reduced redundancy
Environmental Impact [27–29]	Eco-friendly consensus mechanisms (Proof of Stake)	Lower energy consumption, reduced environmentalimpact
Real-time Data Availability & Accuracy [30–32]	Real-time updates and data verification	Accurate, up-to-date information
Data Security and Privacy [33, 34]	Cryptographic techniques	Enhanced privacy, protection against unauthorized access

Table 2. Comparitive Study of Blockchain-Based Vehicle and Logistics Management Systems

Ref.	**Application Domain**	**Blockchain Platform**	**Structure**	**Consensus Algorithm**	**Data Security**	**Performance Evaluation**	**Tracking Usability**
Syed (2020) [VLC]	Vehicle life-cycle & ownership tracking	Hyperledger Fabric (permissioned)	On–Off Chain (ledger + external apps)	Not specified (Fabric ordering service)	Considered (access control, auditability)	Considered (prototype + measurements)	Considered (end-to-end lifecycle tracking)
Jiang (2021)	Vehicle condition/maintenance record	Ethereum (private)	On Chain (smart contracts)	Not specified (private Ethereum, typically PoA)	Considered (tamper-resistant records)	Limited/Not explicitly reported	Considered (condition history for vehicles)
Salimi (2022)	Distributed robotic/vehicle ops (ROS2 ↔ HLF)	Hyperledger Fabric	On–Off Chain (Fabric + ROS2 data plane)	Not specified	Considered (identity, channels)	Considered (latency & scalability tests)	Considered (framework usable for fleets/robots)
Balfaqih et al. (2023)	Logistics tracking of high-value shipments	Ethereum	On–Off Chain (IoT + chain)	Proof of Stake (Ethereum, fees reported)	Considered (privacy, smart-contract gating)	Considered (fee/cost analysis, scenarios)	Considered (traceability & condition monitoring)
Peelam et al. (2024/25)	Vehicle lifecycle mgmt + predictive maintenance	Hyperledger Fabric (+ FL)	On–Off Chain (HLF + analytics)	Not specified (Fabric; commonly Raft)	Considered (permissioned PKI, audit)	Considered (framework & design evaluation)	Considered (state tracking across stakeholders)
Ahmed et al. (2025)	Automotive lifecycle (VUCA mitigation)	Permissioned chain + IPFS	On–Off Chain (IPFS for data, chain for proofs)	Delegated Proof of Stake (DPoS)	Considered (IPFS + on-chain integrity)	Conceptual/ Method evaluation	Considered (process-level tracking focus)

O'Brien et al. (2025)	Vehicle emissions monitoring (fleet context)	Hyperledger Fabric	On–Off Chain (sensors + Fabric)	Not specified (Fabric)	Considered (integrity, authenticity)	Considered (scalability/ privacy discussion)	Considered (continuous emissions tracking)

Conclusion

The proposed blockchain-based Fleet Management System offers security, transparency, and efficiency in modern transportation. By adding IoT sensors and GPS tracking along with smart contracts, the system ensures secure data storage and real-time monitoring, and allows for automatic handling of important tasks like driver verification, maintenance checks, and payment processing. The system's modular design makes it easier to scale and helps prevent data tampering and system failures.

This research offers a real-world approach for using blockchain in fleet operations and highlights how it improves upon traditional, centralized systems.

Future work could look into actual implementations, understand specific industry needs, and explore combining the system with AI, predictive analytics, and cloud technologies to boost fleet performance and reliability.

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