

Blockchain-Based Carpooling and Vehicle Borrowing using Smart Contract

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Abstract - The increasing reliance on centralized ride-sharing and rental systems poses significant risks, including data manipulation, single points of failure, and privacy violations. In addition, high commission fees imposed by such platforms reduce the net earnings of drivers and compromise fairness within the ecosystem. To address these inefficiencies, this project introduces a decentralized vehicle borrowing system and carpooling, based on Ethereum Compatible blockchain and smart contracts. The proposed platform eliminates intermediaries by allowing KYC-verified drivers, passengers, and vehicle owners to interact directly, thereby building trust and operational transparency. All ride postings, bookings, car borrowing transactions, and agreement verifications are recorded immutably through smart contracts. Identity proofs, vehicle documents are cryptographically signed through MetaMask and uploaded via a decentralized file system (IPFS), ensuring authenticity and wallet-to-user binding. For drivers who borrow cars, temporary verification is enabled after signing a smart-contract-based agreement linked to the vehicle's verified owner. To maintain decentralization without depending on an administrator, the system introduces a Global Dispute Center where only users who fulfill certain predefined conditions—having verified their identity—can participate in resolving concerns through a voting process. This decentralized decision-making process enhances fairness and trust. Additionally, a structured post-ride rating system builds mutual accountability and trust among participants, while integrated CO₂ tracking encourages environmentally conscious behavior. Together, these features help minimize traffic load, support conscious travel habits, and build a reliable, user-governed mobility system that is secure, transparent, and environmentally supportive—functioning entirely without any centralized authority or administrative oversight, thereby ensuring long-term sustainability.

Keywords - Blockchain, Smart Contracts, Carpooling, IPFS, Ethereum, Decentralized Application.

I. INTRODUCTION

Traditional ride-sharing platforms rely heavily on centralized intermediaries that control user data, impose high commissions, and limit transparency for passengers and drivers. Such dependency reduces trust, creates unfair pricing

structures, and exposes users to risks such as system failures and privacy breaches.

To address these limitations, this project proposes a blockchain-powered peer-to-peer carpooling and vehicle borrowing system that enables direct interaction between passengers, drivers, and vehicle owners without intermediaries. The platform utilizes smart contracts to automate agreements, MetaMask for secure authentication, and IPFS for decentralized storage of essential records. By shifting operational control to users, the system enhances transparency, fairness, and reliability in transactions.

Conventional mobility services also face issues such as opaque processes, inefficient dispute handling, and limited mechanisms for conflict resolution. Drivers often lose a substantial portion of their income to service fees, while users lack trust in centralized decision-making systems. Furthermore, minimal emphasis is placed on promoting environmentally responsible travel practices.

Motivated by the need for an open and community-driven mobility platform, this research aims to establish a distributed ecosystem that eliminates third-party dominance and ensures tamper-proof record keeping. The system incorporates KYC-based digital identity verification, smart contract-enforced agreements, decentralized dispute resolution through voting, and CO₂ emission tracking to encourage sustainable transportation.

The scope of the project includes enabling secure ride booking, vehicle borrowing under verified ownership, and democratic dispute resolution among verified users. By leveraging distributed networks and digital wallets, the platform presents a scalable and sustainable alternative to centralized ride-sharing models.

II. LITERATURE REVIEW

Blockchain technology has been increasingly explored for decentralized mobility solutions, particularly in ride-sharing and car-sharing systems.

Sharma et al. [1] proposed *Cabverse*, an efficient and secure carpooling system built using blockchain technology. The study focuses on eliminating centralized control by using smart contracts to manage ride coordination and transaction recording. The system enhances transparency and reduces dependency on intermediaries. However, the proposed model does not emphasize structured KYC-based identity verification, QR-based transaction validation, or decentralized dispute handling mechanisms.

The work presented in [2] introduces a blockchain-based car-sharing platform designed to decentralize vehicle rental services. The system enables secure vehicle access and transaction logging using distributed ledger technology. While it ensures data immutability and reduces reliance on central authorities, the study primarily focuses on vehicle ownership validation and does not provide detailed mechanisms for community governance or automated dispute resolution.

In [3], a blockchain-enabled peer-to-peer ride-sharing service is proposed to allow direct interaction between riders and drivers. The system records trip details and payments using smart contracts to ensure transparency and prevent data tampering. Although the architecture removes centralized booking control and secures trip records, it does not extensively address advanced role management, identity verification frameworks, or environmental impact monitoring.

A broader analysis is provided in [4], which presents a comprehensive survey of blockchain applications in vehicular networks. The survey examines how blockchain enhances security, trust, and data integrity in transportation systems. It highlights decentralized communication models and secure transaction frameworks but remains conceptual in nature without detailing a fully integrated carpooling and vehicle borrowing implementation.

The study in [5] explores peer-to-peer ride sharing using blockchain technology, emphasizing secure booking and direct user transactions. The proposed approach enhances transparency and reduces intermediary fees. However, challenges related to scalability, identity validation, and automated governance are not comprehensively addressed.

III. SYSTEM ARCHITECTURE

A. Architectural Overview

The proposed system follows a decentralized architecture designed to enable secure and transparent interaction between passengers, drivers, and vehicle owners. The architecture eliminates centralized control and ensures that all transactions are executed through blockchain-based smart contracts.

The platform consists of four primary layers: the user interface layer, the blockchain layer, the smart contract layer,

and the decentralized storage layer. Each layer works together to maintain transparency, automation, and data integrity across the system.

The architecture ensures transparency through immutable records, security through wallet-based authentication, and automation through smart contract logic.

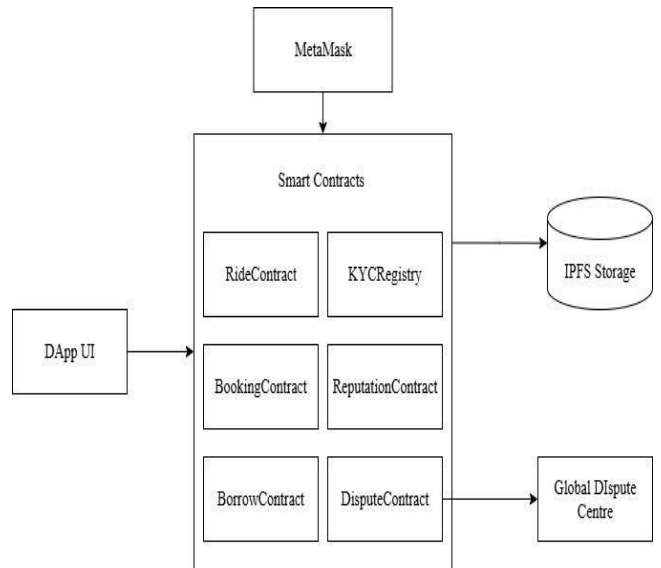


Figure 1: System Architecture

B. System Design and Interaction Flow

The system enables passengers, drivers, and vehicle owners to interact directly through the decentralized

interface. When a user performs an action such as booking a ride or borrowing a vehicle, the request is processed through the and transmitted to the blockchain network.

Smart contracts validate the request, enforce predefined conditions, and record the transaction permanently on the distributed ledger. Payment-related operations are executed through wallet-to-wallet blockchain transactions authenticated via MetaMask.

All agreements and supporting documents are stored on IPFS, this design ensures that all participants operate within a transparent, tamper-resistant, and trustless environment without dependence on centralized administration.

C. Proposed System Structure

The proposed architecture integrates decentralized booking, vehicle lending, and identity verification within a unified blockchain framework. Transaction logs and reputation data are recorded on-chain, ensuring accountability among participants. The decentralized structure supports scalability and allows the platform to operate without third-party

governance.

By combining smart contracts, wallet authentication, and decentralized storage, the system establishes a secure and reliable mobility platform aligned with distributed technology principles.

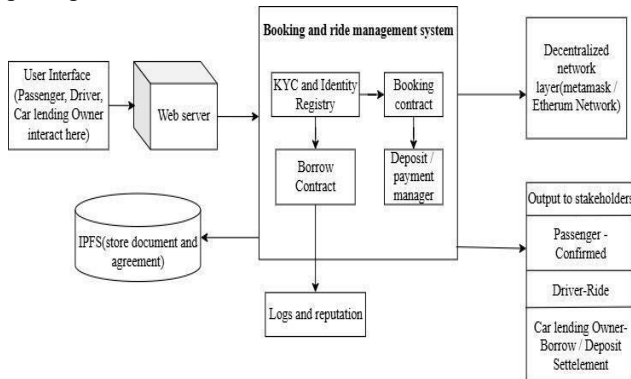


Figure 2: Proposed System

IV. METHODOLOGY

The proposed decentralized carpooling and vehicle borrowing system was developed using a structured blockchain-based development approach. The methodology focuses on smart contract implementation, decentralized storage integration, and wallet-based transaction authentication.

The development process began with defining system requirements and identifying key operational modules, including ride booking, vehicle borrowing, identity verification, and dispute handling. These modules were implemented as independent smart contracts using Solidity programming language.

Smart contracts were developed and tested locally using the Hardhat development framework. Unit testing was performed to verify contract logic, transaction validation, and agreement enforcement mechanisms. Once validated, the contracts were deployed on a Polygon-compatible blockchain network to ensure low transaction cost and scalability.

The frontend decentralized application is developed using React.js and integrated with the blockchain using Ethers.js library. MetaMask wallet integration was implemented to enable secure user authentication and digital signature-based transaction confirmation.

For off-chain storage, the Inter Planetary File System (IPFS) was integrated to store identity documents and agreement records. Only the corresponding hash references were recorded on the blockchain to maintain immutability while optimizing storage efficiency.

System testing included functional validation of ride booking, vehicle borrowing, smart contract execution, wallet authentication, and dispute routing mechanisms. All blockchain transactions were verified through network explorers to ensure correctness and transparency.

This methodology ensures secure deployment, decentralized governance, and automated execution of mobility transactions without reliance on centralized intermediaries.

V. IMPLEMENTATION

The implementation phase involved deploying the developed smart contracts and integrating them with the decentralized application interface. After successful testing using Hardhat, the smart contracts were deployed on a Polygon-compatible blockchain network.

Each contract was assigned a unique blockchain address, which was configured within the frontend application using Ethers.js. The decentralized application was connected to the blockchain network through MetaMask, enabling secure wallet-based authentication and transaction signing.

User registration and identity verification were implemented by linking wallet addresses to verified KYC records. Ride booking and vehicle borrowing requests were executed as blockchain transactions, where smart contracts validated conditions and recorded data immutably.

For document storage, IPFS integration was implemented to upload and retrieve identity and agreement files. The generated content hash from IPFS was stored on the blockchain to ensure tamper-proof verification.

Unit Testing

Unit testing was performed to validate individual smart contract functions independently. The following key checks were conducted:

- Smart contract deployment verification
- Validation of function execution (ride creation, booking, borrowing)
- Access control testing (authorized wallet execution)
- Payment validation and amount verification
- Revert condition testing for invalid transactions

Integration Testing

Integration testing was performed to verify interaction between different system components. The following integrations were validated:

- Frontend connection with deployed smart contracts
- MetaMask wallet authentication and transaction signing

- Blockchain transaction confirmation and hash verification
- IPFS document upload and hash storage on-chain
 - End-to-end workflow validation (booking, borrowing, dispute process)

VI. RESULTS AND ANALYSIS

The proposed decentralized carpooling and vehicle borrowing system was implemented and evaluated on a Polygon-compatible blockchain test network. Smart contracts were successfully deployed to manage ride creation, booking, vehicle borrowing, and payment validation. User authentication and transaction approvals were performed through MetaMask wallet integration, ensuring secure interaction with the decentralized application. All transactions were immutably recorded on the blockchain and verified through generated transaction hashes, providing transparency and traceability. The system also integrated IPFS for decentralized storage of identity documents and agreement files, with content identifiers securely linked to blockchain records. Smart contract logic effectively enforced predefined conditions for ride booking and vehicle borrowing operations. Experimental testing confirmed reliable execution of all system workflows, demonstrating the feasibility of a secure, transparent, and decentralized mobility platform without reliance on centralized intermediaries.

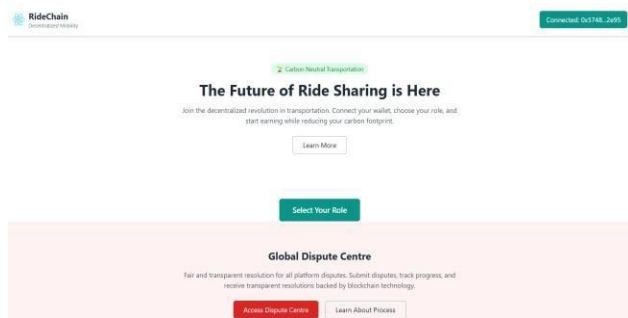


Figure 2.1: Home Page

The RideChain decentralized mobility platform interface provides users with a blockchain-based environment for secure ride sharing and vehicle borrowing. The system allows users to connect their digital wallets and select their roles within the platform through a decentralized application interface. Smart contract integration ensures transparent ride management and automated transaction validation. The platform also includes a Global Dispute Centre that enables fair and transparent dispute resolution backed by blockchain technology. Its interface demonstrates a user-friendly gateway to decentralized transportation services while maintaining security, transparency, and trust.

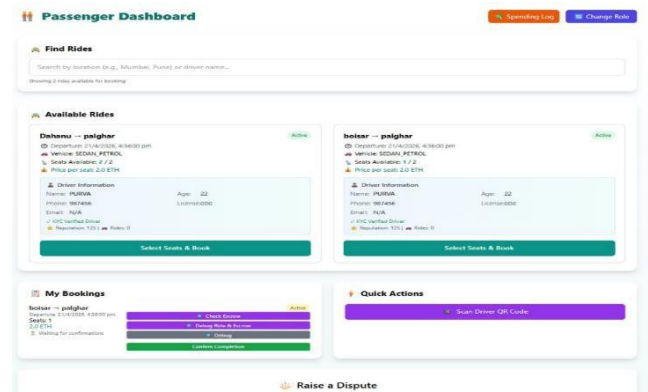


Figure 2.2: Passenger Dashboard

The Passenger Dashboard provides users with an interface to browse available rides and select suitable travel options within the decentralized carpooling platform. Passengers can view ride details such as pickup location, destination, available seats, and fare before confirming a booking. The dashboard also includes additional features such as spending tracking and CO₂ monitoring to promote transparent and environmentally conscious transportation. Furthermore, users can raise disputes through the integrated dispute center for fair resolution of ride or payment-related issues.

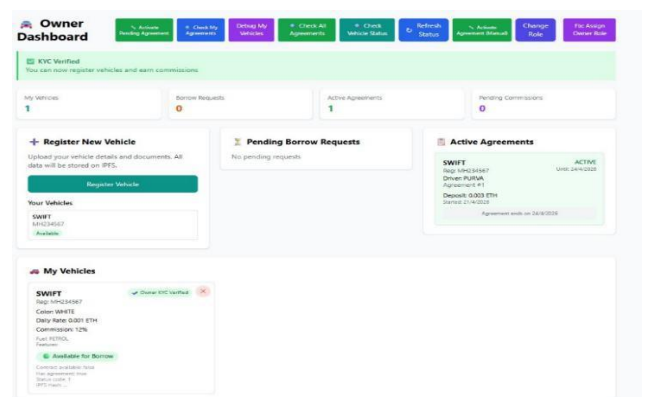


Figure 2.3: Owner Dashboard

The Owner Dashboard allows vehicle owners to register their vehicles and digitally sign lending agreements through smart contract integration. Owners can add vehicle details, upload relevant information, and manage their registered vehicles within the platform. The dashboard also displays the availability status and sharing percentage of listed vehicles. Additionally, owners can access the dispute center to manage and resolve issues related to vehicle lending transactions.

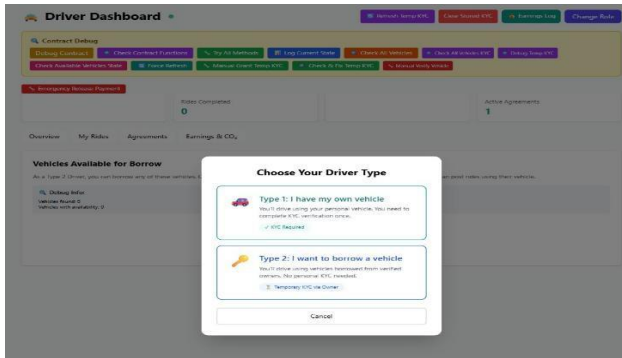


Figure 2.4: Driver Dashboard

The Driver Dashboard enables drivers to borrow available vehicles listed by owners and participate in the decentralized ride-sharing network. Drivers can post rides, manage ride listings, and monitor their earnings from completed trips. The dashboard also includes a CO₂ tracker to measure environmental impact and shared ride statistics.

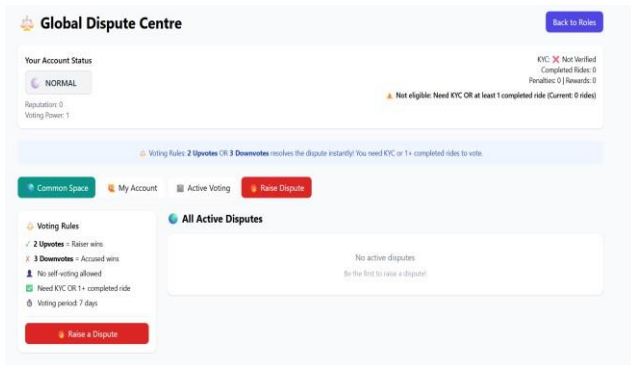


Figure 2.5: Dispute Centre

The Dispute Centre provides a decentralized mechanism for resolving conflicts related to rides, payments, or vehicle borrowing. Users can raise disputes, view existing cases, and participate in voting to determine fair outcomes. Each dispute record includes transaction details and status updates to maintain transparency. The system ensures community-driven and blockchain-backed resolution of issues without relying on centralized authorities.

VII. CONCLUSION

This study presented the design and implementation of a blockchain-based carpooling and vehicle borrowing system that eliminates reliance on centralized intermediaries. The proposed architecture integrates smart contracts, MetaMask wallet authentication, and IPFS-based decentralized storage to ensure secure and transparent execution of ride booking and vehicle lending operations. Smart contracts deployed on a Polygon-compatible network enabled immutable transaction recording, automated agreement enforcement, and decentralized payment validation. The system also

incorporates KYC-based identity verification to enhance trust among participants. Experimental implementation confirmed that the platform successfully supports decentralized ride creation, booking, vehicle borrowing, and dispute management. The results demonstrate the feasibility of using blockchain technology to enable transparent, secure, and automated peer-to-peer mobility services.

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