Decentralized Wallet for EV Charging Station using Block chain

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Abstract- This project presents an innovative distributed wallet system leveraging blockchain technology to streamline and standardize electric vehicle (EV) charging payments across multiple charging networks. The system implements a unified payment solution that enables EV users to utilize a single digital wallet for charging their vehicles at any participating charging station within the network, eliminating the need for multiple accounts and payment methods. The blockchain-based architecture ensures secure, transparent, and immutable transaction records while facilitating seamless interoperability between different charging station operators. Smart contracts automate the payment settlement process, handling real-time pricing, authentication, and cross-network reconciliation. The system incorporates features such as automatic wallet top-ups, usage analytics, and dynamic pricing integration. Initial implementation results demonstrate reduced transaction overhead, enhanced user convenience, and improved charging station utilization rates. This solution addresses the current fragmentation in EV charging payment systems and provides a scalable framework for future expansion of the charging network ecosystem. The proposed system has significant implications for advancing EV adoption by simplifying the charging payment experience for end users while offering charging station operators a standardized payment processing platform

Keywords- Machine learning, block chain

1. INTRODUCTION

As the world transitions towards sustainable energy solutions, Electric Vehicles (EVs) have gained significant popularity. However, EV charging infrastructure faces several challenges, including payment security, transaction transparency, interoperability, and trust between users and charging station providers. Traditional payment systems rely on centralized authorities such as banks or third-party payment gateways, leading to high transaction fees, potential security vulnerabilities, and dependency on intermediaries.

To address these issues, the development of a Decentralized Wallet for EV Charging Stations using Blockchain Technology is proposed. By leveraging blockchain, the system ensures secure, transparent, and tamper-proof transactions between EV users and charging stations without the need for intermediaries.

2. RELATED WORK

The transition to electric vehicles (EVs) has gained significant momentum due to the increasing global focus on sustainable energy solutions and reducing carbon emissions. However, the current EV charging infrastructure faces multiple challenges, particularly in payment processing, security, transparency, and interoperability. Traditional payment systems are centralized, leading to high transaction fees, data privacy concerns, and limited cross-network compatibility.

Blockchain technology has emerged as a promising solution to address these challenges by enabling decentralized, secure, and transparent transactions. Through the use of smart contracts, decentralized identity management (DID), and peer-to-peer (P2P) energy trading, blockchain can revolutionize the way EV charging stations handle payments and energy distribution. Various research studies have explored the potential of blockchain in enhancing EV charging infrastructure, focusing on areas such as secure payment mechanisms, automated billing, integration with smart grids, and privacy-preserving transactions.

The recent research papers and academic studies that discuss the application of blockchain technology in EV charging systems, emphasizing its impact on:

- Decentralized payment systems for seamless EV charging transactions.

- Smart contracts for automated billing and trustless energy trading.
- Privacy and security mechanisms, including zero-knowledge proofs (ZKP) and decentralized identity management (DID).
- Interoperability solutions to enable cross-network EV charging.
- Integration with smart grids and renewable energy sources for efficient energy utilization.

"Electric Vehicle Charging Transaction Model Based on Alliance Blockchain", Dongjun Cui, Jinghan He, Xiaochun Cheng, Zhao Liu, *World Electric Vehicle Journal*, July 2023

This paper proposes a consortium blockchain-based trading model to address the complexities in transactions between EV users and charging operators. By establishing interconnected transaction networks and channels among charging operators, the model employs the Practical Byzantine Fault Tolerance (PBFT) consensus algorithm to verify EV charging transactions. Smart contracts automate the transaction process, enhancing trust and efficiency. The feasibility of this approach is validated through an experimental setup using Hyperledger Fabric, reflecting real-world scenarios in Beijing.

"Blockchain-Based Dynamic Pricing Framework for Electric Vehicle Charging" *Lecture Notes in Electrical Engineering*, 2023

This study addresses the challenges of long waiting times and grid instability due to unregulated EV charging demands. It introduces a blockchain-enabled dynamic pricing mechanism inspired by the Stackelberg game model. The proposed system imposes penalties for overcharging during peak times, thereby controlling demand and reducing waiting periods. Smart contracts on the Ethereum blockchain ensure transparent and secure transactions between EVs and charging stations. Numerical analyses demonstrate that this approach effectively balances demand and enhances the charging experience.

"A Payment System for Electric Vehicles Charging and Peer-to-Peer Energy Trading", *IEEE Xplore*, 2023

This paper presents a blockchain-based payment system designed to address issues such as limited public charging stations, high installation costs of private charging stations, and electricity price volatility. The system facilitates peer-to-peer energy trading, allowing users with surplus energy to sell directly to others. By utilizing smart contracts, the platform ensures secure and transparent transactions, reducing reliance on centralized entities and promoting a decentralized energy economy.

"Blockchain-Based Peer-to-Peer Energy Trading and Charging Payment System for Electric Vehicles", *Sustainability*, July 2021

This research proposes a peer-to-peer energy trading and charging payment system leveraging blockchain technology. The system enables users generating electricity (e.g., via solar panels) to sell excess energy to charging stations or other EV users through smart contracts. An automatic payment system for EV charging is developed using Hyperledger Fabric, enhancing trust, transparency, and privacy among participants. Performance evaluations indicate efficient resource utilization and transaction processing, offering valuable insights for smart city policymakers.

"EVchain: An Anonymous Blockchain-Based System for Charging-Connected Electric Vehicles" , *IEEE Transactions on Vehicular Technology*, 2021

Addressing privacy concerns in EV charging, this paper introduces "EVchain," a blockchain-based system that ensures anonymous transactions between EV users and charging service providers. By eliminating reliance on third-party platforms, EVchain leverages cryptographic techniques to protect user identities while maintaining transparent and secure transaction records. The system enhances user trust and promotes wider adoption of EVs by safeguarding sensitive information.

"Blockchain-Based Intelligent Charging Station Management System Platform", *IEEE Xplore*, 2021

This study proposes a smart energy management system for EV charging stations utilizing blockchain technology. Each charging pile operates as a local blockchain distributed ledger node, synchronizing with the blockchain network to protect user privacy and ensure fair power transactions. The decentralized approach facilitates efficient management of charging demands for a large number of EVs, enhancing the scalability and reliability of charging infrastructures.

"Blockchain-Based Secure EV Charging System", *IEEE Xplore*, 2023

Focusing on the security of customer data in EV charging systems, this paper presents a blockchain-based solution to securely store and manage user information. The proposed system prevents unauthorized access and manipulation of data, thereby enhancing the overall security of the EV charging infrastructure. By integrating blockchain technology, the system ensures that only eligible and validated users can access charging services, mitigating potential security threats.

"ESP2CS: Securing Internet of Vehicles through Blockchain-enabled Communications and Payments", Rateb Jabbar, Mohamed Kharbeche, *arXiv preprint*, December 2023

This research introduces the Ethereum-based Secure Payment and Communication Solution (ESP2CS) to address security concerns in Vehicle-to-Everything (V2X) communications and payments within the Internet of Vehicles (IoV). By utilizing Ethereum as middleware, ESP2CS ensures robust and secure interactions among vehicles, including inter-vehicle communication, parking space detection, and transaction management. Preliminary evaluations highlight the solution's cost-effectiveness and enhanced security, offering a promising approach to secure V2X communications.

Existing System

Currently, EV charging stations primarily rely on centralized payment systems that involve banks, payment gateways, and third-party service providers. These systems function through a cloud-based or network-based infrastructure managed by charging station operators, utility companies, or fintech firms.

1. User Registration:
o EV users must register on the charging station's mobile app or website to access services.
o Requires personal details, bank account information, or linked payment methods (credit/debit cards, digital wallets, etc.).
2. Payment Processing:
o Payments are processed via third-party financial intermediaries (Visa, Mastercard, PayPal, Stripe, etc.).
o Some systems support subscription-based models for EV charging.

3. Charging Session & Billing:
o Once the EV is plugged in, charging data (time, energy consumed) is sent to the central server.
o The user is billed accordingly, and the payment is deducted from the linked account.
4. Data Storage & Management:
o Charging stations store transaction records on centralized databases.
o User data, payment details, and charging history are managed by the service provider.

Disadvantages of the Existing System

While the current system is functional, it suffers from several limitations:

Centralized Control & Single-Point Failure
• Charging service providers control the entire network, meaning users and station owners depend on a single entity for transactions.
• If the central server goes down or is hacked, payments and charging services can be disrupted.

High Transaction Fees
• Banks and payment gateways charge processing fees (2-5%) for each transaction.
• Additional costs arise due to cross-border payments, currency conversions, and financial regulations.

Security & Privacy Concerns
• Risk of cyberattacks: Centralized databases are prone to hacking, data leaks, and unauthorized access.
• User privacy is compromised: Charging networks collect sensitive user information (location, energy consumption, financial details).

Lack of Transparency & Trust Issues
• Users cannot verify whether they are correctly billed for the electricity they consume.
• Manipulation of records is possible by charging station operators or third parties.
• Smart charging tariffs often lack transparency, leading to unfair pricing models.

Interoperability Issues
- Different EV charging networks use proprietary payment methods, requiring users to sign up for multiple apps.
- Cross-network charging is difficult since each provider has its own closed ecosystem.

Slow & Inefficient Payment Processing
- Payments can take several hours or days to be processed, especially for interbank transfers.
- Refunds and disputes involve manual intervention, delaying resolution times.

Inaccessibility in Remote Areas
- Internet dependency: Many charging stations rely on cloud-based authentication, which may not be available in rural or remote areas.
- If the payment gateway is offline, users cannot charge their EVs.

3. PROPOSED METHODOLOGY

This project proposes a blockchain-based decentralized wallet for EV charging stations that enables seamless and secure payments using cryptographic tokens or smart contracts. The key components of the proposed system include:

1. Blockchain-Based Transactions
- The system eliminates intermediaries by recording transactions directly on a decentralized blockchain network.
- Each payment transaction is stored as an immutable record, ensuring transparency and security.

2. Smart Contracts for Automated Payments
- Smart contracts facilitate automated and trustless payments once an EV is charged.
- Users deposit funds into their decentralized wallet, and the smart contract releases payment only when the charging session is completed.

3. Tokenized Payment System
- Users can pay using crypto tokens or stable coins linked to real-world currency.
- These tokens can be exchanged between different charging networks, ensuring interoperability.

4. Peer-to-Peer Energy Trading
- EV users with excess stored energy (e.g., from solar panels) can sell it directly to charging stations or other users.
- Blockchain records the transaction and ensures fair pricing without a centralized authority.

5. Decentralized Identity & Access Control
- EV owners and charging stations are identified through decentralized digital identities (DIDs).
- This eliminates the need for multiple logins and registrations across different charging networks.

6. Mobile Wallet & DApp (Decentralized Application)
- Users can manage funds, locate charging stations, and make payments via a mobile wallet integrated with a blockchain-based DApp.

VI. CONCLUSION

The adoption of electric vehicles (EVs) has significantly increased due to the rising demand for sustainable and eco-friendly transportation. However, the current EV charging infrastructure relies on centralized payment systems, which suffer from issues such as high transaction fees, lack of transparency, security vulnerabilities, and interoperability constraints. To overcome these challenges, this project proposes a blockchain-based decentralized wallet for EV charging stations that ensures secure, transparent, cost-efficient, and interoperable payment transactions.

By leveraging blockchain technology, smart contracts, and decentralized identity management (DID), this solution eliminates the need for third-party payment processors, reduces transaction costs, and enhances security through cryptographic encryption. The decentralized ledger ensures immutability, trust, and transparency in billing, while smart contracts automate the charging and payment process without requiring intermediaries. Additionally, peer-to-peer (P2P) energy trading enables users to sell surplus energy, thereby improving energy efficiency and encouraging the use of renewable energy sources.

This system also fosters interoperability, allowing EV users to access multiple charging networks using a single wallet, eliminating the inconvenience of multiple registrations. Furthermore, by integrating zero-knowledge proofs (ZKP) and decentralized identities

(DID), users maintain full control over their personal data, thereby enhancing privacy and security.

In summary, the decentralized wallet for EV charging stations represents a paradigm shift in the way EV payments and energy distribution are managed. It addresses the major limitations of the existing system by providing a secure, efficient, and cost-effective solution that benefits EV users, charging station operators, and energy providers alike. This project lays the foundation for a trustless and decentralized EV ecosystem, paving the way for a smarter, more connected, and sustainable future for electric mobility.

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