DECENTRALISED TRACKING AND BILLING FOR ON-ROAD WIRELESS CHARGING

M.Raja[1],S.Oviyapriya[2],R.Nivetha[3],M.Keronisha[4],J.Harinath[5]

[1,2] Assistant Professor, Department of Electrical and Electronics Engineering, Paavai Engineering College, Namakkal, Tamilnadu, India.

[3,4,5]UG Students Department of Electrical and Electronics Engineering, Paavai Engineering College, Namakkal, Tamilnadu, India.

ABSTRACT:

The project titled “Decentralized Tracking and Billing for On-Road Wireless Charging” aims to develop an advanced system for efficient energy transfer, monitoring, and billing of electric vehicles (EVs) while they are in motion. With the increasing demand for sustainable transportation, wireless power transfer technology has emerged as a promising solution to eliminate the limitations of conventional plug-in charging systems. In this project, an on-road wireless charging infrastructure is considered, where electric vehicles receive power dynamically through electromagnetic induction while traveling on specially equipped roads. To ensure accurate energy usage tracking and billing, a decentralized approach is implemented, eliminating the need for a central authority and thereby improving system reliability, transparency, and security. Blockchain is used to securely record all transactions, preventing data tampering and ensuring trust among users, service providers, and stakeholders. Smart contracts automate the billing process based on energy consumption, eliminating the need for intermediaries and reducing operational costs. This system enhances security, scalability, and efficiency while supporting seamless and contactless charging for EVs. Overall, the project aims to provide a reliable, transparent, and automated solution for future smart transportation and energy management systems.

KEY WORDS: Electric Vehicles (EVs), Wireless Charging, On-Road Charging, Blockchain Technology, Smart Contracts, Decentralized System, Energy Billing, Real-Time Monitoring, Secure Transactions.

1. INTRODUCTION:

With the rapid proliferation of electric vehicles (EVs) in recent years, the need for advanced charging solutions that are efficient, automated, and user-friendly. On-road wireless charging is an emerging technology that allows EVs to charge while moving or during short stops, eliminating the need for manual plug-in systems and reducing range anxiety. However, implementing such systems requires accurate vehicle identification, real-time tracking, and a secure billing mechanism.

This project proposes a decentralized tracking and billing system for on-road wireless charging using blockchain technology and smart contracts. In this system, RFID modules are used to authenticate and verify vehicles, while infrared sensors detect the entry and exit of EVs at the charging station. The energy consumption data is continuously monitored and recorded.

Blockchain technology is used to securely store all transaction data in a decentralized manner, ensuring transparency and preventing data tampering. Smart contracts are implemented to automatically calculate and process billing based on the energy consumed by each vehicle, eliminating the need for manual intervention. This integrated approach improves efficiency, enhances security, and ensures accurate and transparent billing for EV users.

Overall, the project aims to develop a reliable, automated, and secure solution for next-generation EV charging infrastructure, supporting the advancement of smart transportation systems.

2. METHODOLOGY:

The proposed system is designed to implement a decentralized tracking and billing mechanism for on-road wireless electric vehicle (EV) charging by integrating RFID technology, infrared sensors, IoT communication, blockchain, and smart contracts. The methodology is structured into multiple stages, including vehicle authentication, entry/exit detection, energy monitoring, data transmission, secure storage, and automated billing.

Initially, each electric vehicle is equipped with an RFID tag that contains a unique identification number. When the vehicle approaches the charging station, an RFID reader scans the tag to verify the vehicle's identity. This authentication process ensures that only authorized vehicles are allowed to access the wireless charging facility. Once verified, the system activates the charging process.

Infrared (IR) sensors are strategically placed at the entry and exit points of the charging zone to detect vehicle movement. When a vehicle enters the charging area, the IR sensor triggers the system to start tracking the charging session. Similarly, when the vehicle exits the zone, the IR sensor records the exit time, thereby determining the total duration of charging.

Wireless power transfer technology is used to deliver energy from the charging infrastructure to the vehicle without physical contact. During the charging process, parameters such as charging duration or energy consumption are continuously monitored. The NodeMCU microcontroller acts as the central control unit, collecting data from the RFID module and IR sensors, and managing the overall system operations efficiently.

The collected data, including vehicle ID, entry time, exit time, and energy usage, is transmitted to a cloud or blockchain network using Wi-Fi communication. Blockchain technology is employed to store this data in a decentralized and tamper-proof manner, ensuring transparency and data security. Each transaction is recorded as a block, which cannot be altered, thereby maintaining the integrity of the system.

Smart contracts are implemented on the blockchain to automate the billing process. Based on predefined conditions such as charging time or energy consumed, the smart contract calculates the total cost and generates the bill automatically. The transaction is securely recorded on the blockchain, eliminating the need for manual intervention and reducing the chances of errors or fraud.

Overall, this methodology ensures efficient vehicle tracking, secure data management, and accurate automated billing. The integration of wireless charging with blockchain and IoT technologies provides a reliable and scalable solution for future EV charging infrastructure, supporting the development of smart and sustainable transportation systems.

3. RESEARCH AIM:

The primary aim of this project is to design and develop a decentralized tracking and billing system for on-road wireless electric vehicle (EV) charging using advanced technologies such as blockchain, smart contracts, RFID, and IoT-based sensing. The project seeks to address the limitations of conventional EV charging systems, which often rely on centralized control, manual billing processes, and lack transparency and security in data handling.

A key objective of this research is to enable seamless and contactless charging through wireless power transfer, thereby improving user convenience and reducing dependency on traditional plug-in charging methods. At the same time, the system aims to ensure accurate tracking of vehicles during the charging process by integrating RFID technology for vehicle authentication and infrared (IR) sensors for detecting vehicle entry and exit within the charging zone. This combination allows precise monitoring of charging duration and usage.

Another important aim is to implement a secure and transparent data management system using blockchain technology. By storing all transaction-related data, such as vehicle identity, charging time, and energy consumption, in a decentralized ledger, the system eliminates the risks associated with data manipulation and unauthorized access. This ensures trust among users, service providers, and other stakeholders involved in the EV ecosystem.

Furthermore, the project focuses on automating the billing process through smart contracts. These self-executing programs are designed to calculate the cost of charging based on predefined parameters, such as energy usage or time duration, and generate bills automatically without human intervention. This reduces operational complexity, minimizes errors, and enhances overall system efficiency.

In addition, the research aims to develop a scalable and reliable system architecture that can be integrated into future smart city infrastructure. By combining wireless charging, IoT communication, and blockchain technology, the project contributes to the advancement of intelligent transportation systems and sustainable energy management.

Overall, the aim of this project is to create an innovative, secure, and efficient solution for EV charging that improves user experience, ensures transparency in billing, and supports the growing demand for electric mobility in a sustainable manner.

4. DECENTRALISED TRACKING AND BILLING FOR ON-ROAD WIRELESS CHARGING:

At the charging station, a wireless power transmitter is used to transfer energy to the electric vehicle without physical contact. The entry and exit of the vehicle are detected using infrared (IR) sensors, which help in tracking the charging duration. An RFID module is integrated into the system to uniquely identify and verify each vehicle before allowing access to the charging station.

The core control unit of the system is the NodeMCU microcontroller, which processes data from the RFID reader and IR sensors. It manages the overall operation, including vehicle authentication, tracking, and communication. A display unit (LCD) is used to show real-time information such as vehicle ID, charging status, and billing details.

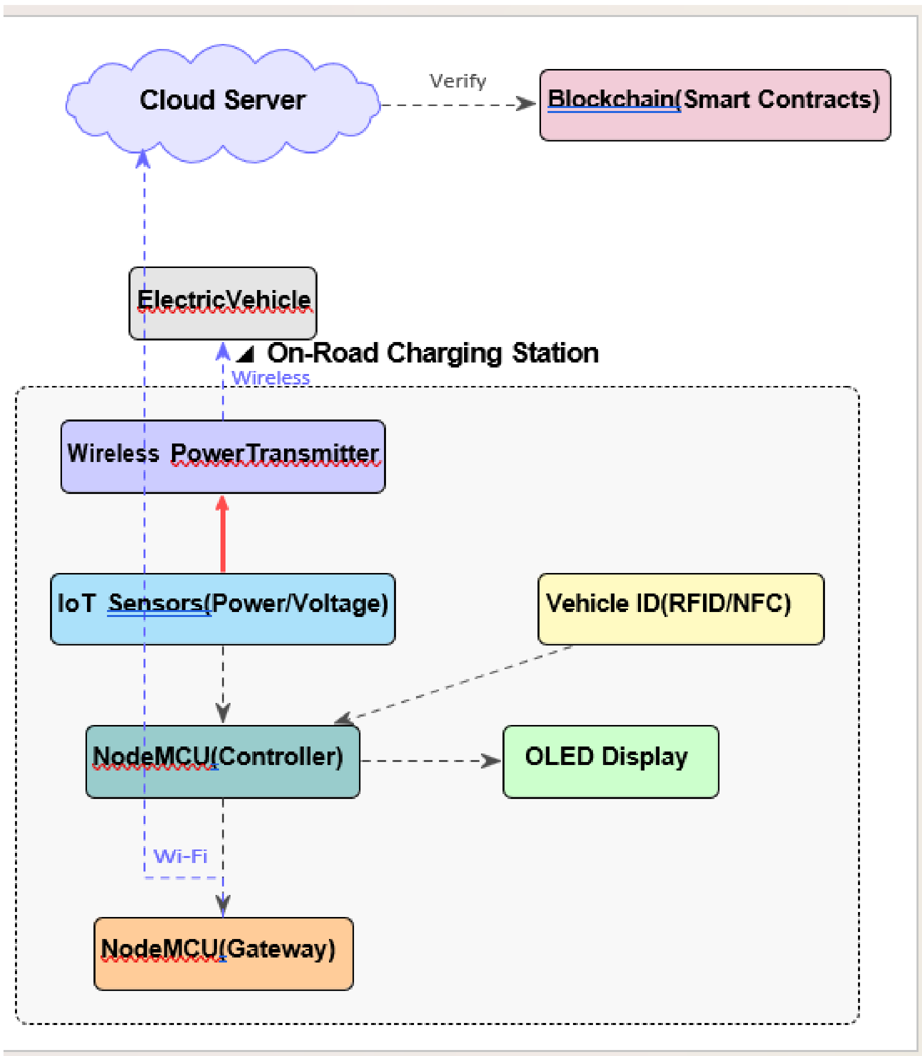

Fig1: Block diagram of decentralized tracking and billing for on-road wireless charging

The NodeMCU gateway connects the system to the cloud server through Wi-Fi, enabling real-time data transmission. All the collected data, including vehicle identification, entry/exit time, and energy consumption, is sent to the blockchain network. Blockchain technology is used to securely store the transaction data in a decentralized manner, ensuring transparency and preventing data tampering.

Smart contracts deployed on the blockchain automatically handle the billing process. Based on the charging duration or energy usage, the smart contract calculates the cost and records the transaction securely. This eliminates the need for manual billing and ensures accurate and trustworthy operations.

5. WORKING PRINCIPLE:

The working principle of the proposed system is based on the integration of wireless power transfer, vehicle identification, real-time sensing, and decentralized billing using blockchain and smart contracts. The system operates in a sequence of steps to ensure efficient charging, accurate tracking, and secure billing.

Initially, when an electric vehicle (EV) approaches the on-road wireless charging station, the RFID reader scans the RFID tag attached to the vehicle. This process verifies the identity of the vehicle and ensures that only authorized users can access the charging facility. Once the authentication is successful, the system is activated for charging.

As the vehicle enters the charging zone, an infrared (IR) sensor detects its presence and triggers the start of the charging session. The wireless power transmitter then transfers energy to the vehicle without any physical connection using inductive coupling. During this period, the system continuously monitors the charging duration or energy consumption.

The NodeMCU microcontroller acts as the central control unit, collecting data from the RFID module and IR sensors. It processes the information, including vehicle ID, entry time, and charging parameters. When the vehicle exits the charging zone, another IR sensor detects the movement and signals the end of the charging session.

All the collected data is transmitted via Wi-Fi to a blockchain network. The blockchain securely stores the transaction details in a decentralized and tamper-proof manner. Smart contracts deployed on the blockchain automatically calculate the billing amount based on predefined conditions such as charging time or energy usage. The generated bill is recorded and can be accessed by the user.

Thus, the system ensures seamless wireless charging, accurate vehicle tracking, secure data management, and automated billing without human intervention, making it efficient and reliable for modern EV infrastructure.

6. CENTRALIZED TRACKING AND BILLING:

In conventional electric vehicle (EV) charging infrastructure, tracking and billing are primarily managed using centralized systems. In this approach, a single authority or central server is responsible for monitoring vehicle data, managing charging sessions, and processing billing transactions. Most existing charging stations rely on plug-in charging methods, where users manually connect their vehicles to the charging unit and the system records charging details through a centralized database.

In centralized tracking systems, all information such as vehicle identification, charging duration, energy consumption, and billing details is stored and processed in a central server. This server acts as the main control unit, handling communication between users, charging stations, and service providers. Although this approach simplifies system design and implementation, it introduces several limitations and challenges.

One of the major drawbacks of centralized systems is the lack of transparency. Since all data is controlled by a single authority, users must rely on the service provider for accurate billing and transaction records. This creates trust issues, especially when there is no direct way to verify the data independently. Additionally, centralized systems are more vulnerable to data manipulation, cyberattacks, and unauthorized access, which can compromise sensitive user and transaction information.

Another limitation is the dependency on continuous network connectivity and server availability. If the central server fails or experiences downtime, the entire system can be disrupted, affecting charging operations and billing processes. This reduces the reliability and efficiency of the system, particularly in large-scale deployments.

Furthermore, centralized billing systems often require manual intervention or third-party involvement, which increases operational complexity and cost. Delays in billing, errors in calculation, and lack of real-time processing are common issues in such systems. These systems are also less scalable, as the central server must handle increasing amounts of data and transactions as the number of EV users grows.

Overall, while centralized tracking systems are widely used, they suffer from limitations in terms of security, transparency, scalability, and efficiency. These challenges highlight the need for a more advanced and decentralized approach, which is addressed in the proposed system using blockchain and smart contracts.

7.DECENTRALIZED TRACKING AND BILLING:

The proposed system introduces a decentralized approach for tracking and billing in on-road wireless electric vehicle (EV) charging by integrating blockchain technology, smart contracts, RFID-based identification, and IoT-enabled sensing. Unlike traditional centralized systems, this model eliminates the dependency on a single controlling authority and ensures secure, transparent, and automated operations.

In this system, each electric vehicle is equipped with an RFID tag containing a unique identification number. When the vehicle approaches the wireless charging station, the RFID reader scans and verifies the vehicle details. This authentication process ensures that only authorized vehicles are allowed to access the charging facility. Infrared (IR) sensors are installed at the entry and exit points of the charging zone to detect the movement of vehicles, enabling accurate tracking of charging duration.

Once the vehicle is authenticated and enters the charging area, wireless power transfer is initiated. The system continuously monitors charging parameters such as energy consumption or time duration. The NodeMCU microcontroller acts as the central processing unit, collecting data from the RFID module and IR sensors, and managing system operations efficiently.

The collected data, including vehicle ID, entry and exit time, and charging details, is transmitted through Wi-Fi to a decentralized blockchain network. Blockchain technology ensures that all transaction data is securely stored in a distributed ledger, making it tamper-proof and transparent. This eliminates the risk of data manipulation and enhances trust among users and service providers.

Smart contracts are implemented on the blockchain to automate the billing process. These self-executing programs calculate the charging cost based on predefined parameters such as energy usage or time spent in the charging zone. Once the conditions are met, the smart contract generates the bill automatically and records the transaction securely on the blockchain.

The proposed system offers several advantages, including improved security, transparency, reliability, and scalability. It reduces human intervention, eliminates intermediaries, and ensures real-time processing of charging and billing operations.

Overall, this system provides an efficient and future-ready solution for EV charging infrastructure, supporting the development of smart transportation and sustainable energy systems.

9. CONCLUSION:

The increasing adoption of electric vehicles (EVs) demands advanced charging solutions that are efficient, secure, and user-friendly. This project presents a decentralized tracking and billing system for on-road wireless charging, integrating modern technologies such as blockchain, smart contracts, RFID, and infrared sensors. The system effectively addresses the limitations of conventional charging methods by enabling automatic vehicle identification, real-time tracking, and contactless energy transfer.

The use of RFID technology ensures secure and accurate vehicle authentication, while IR sensors enable precise detection of vehicle entry and exit within the charging zone. These components work together to monitor the charging duration and usage efficiently. The NodeMCU controller plays a vital role in coordinating system operations and facilitating communication between hardware components and the cloud network.

One of the key highlights of the project is the implementation of blockchain technology, which provides a decentralized and tamper-proof platform for storing transaction data. This enhances transparency, security, and trust among users and service providers. Smart contracts further improve system efficiency by automating the billing process based on energy consumption or charging time, eliminating the need for manual intervention and reducing errors.

Overall, the proposed system offers a reliable, transparent, and scalable solution for next-generation EV charging infrastructure. It not only simplifies the charging process but also ensures secure data handling and accurate billing. This project contributes to the advancement of smart transportation systems and supports the vision of sustainable and intelligent energy management in the future.

10. REFERENCE:

(1) A. Kurs, A. Karalis, R. Moffatt, J. D. Joannopoulos, P. Fisher, and M. Soljačić, "Wireless Power Transfer via Strongly Coupled Magnetic Resonances," *Science*, vol. 317, no. 5834, pp. 83–86, 2007.

(2) S. Li and C. C. Mi, "Wireless Power Transfer for Electric Vehicle Applications," *IEEE Journal of Emerging and Selected Topics in Power Electronics*, vol. 3, no. 1, pp. 4–17, 2015.

(3) M. Andoni et al., "Blockchain Technology in the Energy Sector: A Systematic Review of Challenges and Opportunities," *Renewable and Sustainable Energy Reviews*, vol. 100, pp. 143–174, 2019.

(4) K. Christidis and M. Devetsikiotis, "Blockchains and Smart Contracts for the Internet of Things," *IEEE Access*, vol. 4, pp. 2292–2303, 2016.

(5) J. Kang et al., "Enabling Localized Peer-to-Peer Electricity Trading Among Plug-in Hybrid Electric Vehicles Using Consortium Blockchains," *IEEE Transactions on Industrial Informatics*, vol. 13, no. 6, pp. 3154–3164, 2017.

(6) S. Lukic and Z. Pantic, "Cutting the Cord: Static and Dynamic Inductive Wireless Charging of Electric Vehicles," *IEEE Electrification Magazine*, vol. 1, no. 1, pp. 57–64, 2013.

(7) A. Ahmad, M. Saad, and S. A. Vorobyov,"Blockchain-Based Charging Coordination Mechanism for Smart Electric Vehicles," *IEEE Access*, vol. 6, pp. 65609–65618, 2018.

(8) Y. Zhang, J. Wen, and M. Wang, "A Review on Blockchain-Based Secure Energy Trading Systems," *Energy Procedia*, vol. 159, pp. 193–198, 2019.

(9) H. H. Zeineldin and V. Khadkikar, “Smart Grid and Electric Vehicle Integration: Challenges and Opportunities,” *IEEE Power and Energy Magazine*, vol. 11, no. 2, pp. 33–41, 2013.

(10) N. Kshetri, “Blockchain’s Roles in Strengthening Cybersecurity and Protecting Privacy,” *Telecommunications Policy*, vol. 41, no. 10, pp. 1027–1038, 2017.

(11) M. Yilmaz and P. T. Krein, “Review of Charging Power Levels and Infrastructure for Plug-in Electric and Hybrid Vehicles,” *IEEE Transactions on Power Electronics*, vol. 28, no. 5, pp. 2151–2169, 2013.

(12) A. Dorri, S. S. Kanhere, and R. Jurdak, “Blockchain in Internet of Things: Challenges and Solutions,” *IEEE Communications Surveys & Tutorials*, vol. 22, no. 2, pp. 1250–1278, 2020.

(13) V. Hassija et al., “A Survey on IoT Security: Application Areas, Security Threats, and Solution Architectures,” *IEEE Access*, vol. 7, pp. 82721–82743, 2019.

(14) R. Want, “An Introduction to RFID Technology,” *IEEE Pervasive Computing*, vol. 5, no. 1, pp. 25–33, 2006.

(15) T. Campi, S. Cruciani, and M. Feliziani, “Wireless Power Transfer Technology Applied to Electric Vehicle Charging: A Review,” *Energies*, vol. 11, no. 10, 2018.

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