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Smart Electric Vehicle Charging Station Locator with Route Planning & Slot Booking

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Abstract- Electric Vehicle Charging Station Locator with Route Planning and Slot Booking using Blockchain is an online platform designed to improve the access, transparency, and reliability of the electric vehicles (EV) charging network. The customers can search the charging stations in a specified city or place, check the slot's real-time availability, plan the most efficient route, and even book a slot in advance securely to avoid waiting. The blockchain technology ensures the integrity and transparency of booking records as it logs all transactions through cryptographic hashing, thereby creating unalterable, permanent records. This decentralized approach is a win-win situation for both parties, users and administrators, as it not only gives them access to secure and verifiable documentary evidence of booking histories but also helps them to build trust. The admin module includes a centralized dashboard, thereby providing the city, location, station, slot, and user account manager the ability to supervise and control everything, thus, securing data handling and ensuring accurate slot utilization. The system comprises a user interface built in ReactJS, a server coded in Spring Boot (Java), and MySQL for database management. So in conclusion, the system not only provides higher convenience for EV charging but also reduces the waiting period and supports the green electric transport initiative.

Keywords: Electric Vehicle Charging, Smart Locator, Route Planning, Slot Booking, Blockchain, Hashing, ReactJS, Spring Boot, MySQL, Secure Transactions, EV Infrastructure Management.

I. INTRODUCTION

Electric cars have been a game-changer as far as the perceptions of transport are concerned, providing a greener alternative to fuel cars. Nowadays, as the world looks for greener ways for transport, the number of electric cars on the road has been escalating rapidly. Even while this development is quite exciting, the question that arises is: what are the safe ways to charge these cars when the time comes? For electric vehicle owners, the most frustrating task would be to have no idea about the location of the nearest charging station, whether an slot is available in that station, and the most optimal path to reach that station. A standard charging station would not provide adequate information about the location of the stations along with information about the slot availability in real-time, as well as a protected way for managing bookings. However, in order to address such concerns, it has become an increasing need in the market to build more intelligent and secure smart charging solutions. This is where our proposed solution will come in – the Smart EV Charging Station Locator with Route Planning & Slot Booking, driven by Blockchain Technology.

This solution will enable users to look for charging points by city or location, look at availability status, plan the most efficient routes, and even book slots in advance. The trick behind this system, however, is blockchain technology. Here, the system utilizes the encrypted, tamper-proof record capability provided by blockchain technology. This results in all slots booked and charged being safely stored and protected from alteration. This, as a result, makes this system not only more transparent but also more trustworthy than the previous system. Ultimately, the purpose of the project is the creation of a charging mechanism that will be easier, faster, and more reliable. With easy access to charging stations, no waiting times, and a completely smooth process in general, this solution will ensure that the drivers of these vehicles have a hassle-free experience while promoting sustainable transportation.

Objective

Primarily, this project aims to design an intelligent, secure, and user-friendly system that will facilitate

electric vehicle users in an efficient manner for finding adjacent charging stations, computing optimal paths, and booking slots in advance. This proposed system will allow users to book slots in real-time with minimized waiting times and an enhanced user experience for charging their respective electric vehicles. The second primary objective of this proposed project is to integrate Blockchain technology with secure slot creation and management and booking transactions for electric vehicle charging points.

By making use of cryptography hashing functions for secure storage of booking transactions in the blockchain, this proposed system will allow users to provide secured and untamperable integrity and immutability and an enhanced level of transparency against any kind of illegitimate modifications and bookings. This proposed blockchain system will provide users and system admins with an authenticated and verified version of booking transactions. The proposed system aims to provide system admins with efficient tools for managing cities, locations, electric vehicle charging stations, slot timing, and user details in an efficient centralized system utilized by making use of an authenticated and dependable electric vehicle booking transaction system utilizing blockchain technology.

Scope

This project will propose an extensive, online network that connects electric car owners with available stations for charging in selected cities and locations. Members can create accounts to access the system and connect to the stations based on their location and the cities they are in. They are also able to access the available slots in real time and map their routes to reach such stations. The key aspect of this project is to integrate Blockchain to create slots safely for charging while carrying out safe transactions to create slots and book for their use on the blockchain through cryptographic hash functions that make the records immutable and tamper-resistant. The blockchain acts like a trusted record of transactions between the members and the admin for transparency purposes.

Administrators have an analytics dashboard where cities/locales are managed along with EV charging points and slot schedules, along with user accounts. Blockchain technology secures records for the precise management of bookings and verification of bookings/testing. The entire project remains in the domain of web development, using React JS for client-side development and Spring Boot (Java) for server-side development, along with MySQL management for structured data management and Blockchain management for secured slot/transaction management. It does not address issues concerning direct hardware implementation or mobile or payment gateway solutions at this point in time.

II. LITERATURESURVEY

[1]Author: S. Ghosh, A. Gupta, and S. Deb Title: IoT and Cloud Computing-based Smart Charging Infrastructure for Electric Vehicles (IEEE, 2020) Outcome: It proposes an IoT-enabled platform for monitoring EV charging stations and managing data to enhance station visibility, [2]thereby improving accessibility. Disadvantage: Does not include route planning and slot-booking features, mostly hardware-level monitoring.

[3]Author: M. A. Hannan, F. A. Hussain, and A. Mohamed Title: Electric vehicle charging station management using smart technologies. Renewable & Sustainable Energy Reviews, 2018. Outcome: [4]Presented smart management strategies for EV charging using data analytics that improve user experience. Disadvantage: Does not offer a real-time user-side interface or city/location-based station filtering.

[5]Author: J. Shareef, M. S. Mutlag, and A. Mohamed Title: A Review of Smart Charging Management for Electric Vehicles (IEEE Access, 2016) Outcome: Described different models for efficient EV charging management and grid optimization. Disadvantage: Lacks user-oriented features like booking history, route guidance, or slot reservation.

[6]Authors: R. G. de Oliveira and F. S. Borges Title: A Mobile Application for Locating Public EV Charging Stations (ACM, 2019) Outcome: A mobile application

was developed to provide map-based EV charging station search capabilities. Disadvantage: Does not support real-time tracking of availability nor any admin-side management tools.

[7]Author: C. Luo, Y. Huang, and K. Meng Title: Optimal Routing for Electric Vehicles including Charging Stations - Energy Procedia 2017 Outcome: [13]Proposed an Optimized Routing Algorithm that integrates EV charging needs into the trip planning process. Disadvantage: Focuses on routing only and thus does not include slot booking or station management features.

[8]Author: S. Sundararajan and R. Rajesh Title: Smart EV Charging Station Locator Using Web Technologies (IJERT, 2021) Outcome: [14]Developed a web-based system that helps users find EV charging stations in selected areas. Disadvantage: No real-time slot availability or admin control over stations and cities.

[9]Author: P. K. Sharma and S. Singh Title: IoT-Based Real-Time Monitoring of EV Charging Stations International Journal of Computer Applications, 2020 Outcome: Demonstrated real-time data [15]collection of station operations and slot monitoring. Disadvantage: Focused on technical monitoring; route planning, booking system, and user dashboard were missing.

[10]Authors: K. Rahman, N. Jain, and M. Srinivas Title: Design and Implementation of EV Charging Slot Reservation System - IJEECS, 2022 [11]Outcome: Introduced an EV slot reservation framework that will help reduce waiting times and prevent station overload. Disadvantage: [12]Does not include city-based search, route optimization, and integrated admin module.

III. PROPOSED SYSTEM

The proposed system provides a Smart Electric Vehicle Charging Station Locator with Route Planning and Slot Booking, integrated with Blockchain technology. The platform will enable users to select their city and location, see nearby EV charging stations, check the availability of slots in real time, plan optimized travel routes, and book charging slots in advance to avoid waiting times. In particular, the proposed system improves current solutions by adopting Blockchain technology for generating and booking transactions of charging slots. Each slot booking will be treated as a blockchain transaction and stored using cryptographic hashing. Consequently, it is immutable, transparent, and resistant to data tampering. This decentralized ledger avoids double booking, ensures data integrity, and maintains verifiable and trustworthy booking history for the users. The admin module will provide a centralized dashboard for managing cities, locations, EV charging stations, slot schedules, and user accounts. All administrative operations with respect to slot scheduling and verification will be supported by blockchain-backed records, allowing for accurate monitoring, auditing, and decision-making.

The benefits which can be accrued from the proposed system include real-time charging slot availability-a user is always able to see current information about the available slots. It allows users to book slots in advance securely and gives users peace of mind, reducing waiting times at charging stations. The route to the charging stations is optimized; thus, a user will always be able to identify the best travel route, which saves them time and fuel.

Fig 1 : Block diagram for proposed system

IV. METHODOLOGY

The development of the Smart Electric Vehicle Charging Station Locator with Route Planning and Slot Booking follows a structured software engineering approach that includes requirement analysis, system design, implementation, and testing phases. Requirement Analysis: The identification of functional requirements for two main modules, namely User Module and Admin Module, which involved user/visitor registration and login, selection of city/location, viewing of stations, real-time slot availability, advance slot booking, route planning, history of bookings, profile management, secure login, dashboard, management of cities, locations, charging stations, slots, and users.

Non-functional requirements included performance-500 concurrent users with 2-3 second response times, scalability, security-SSL/TLS, RBAC, hashing, availability-99.9% uptime, usability, and data integrity-ACID compliance and concurrency control. System Design utilized all the UML diagrams, such as Use Case, Class, Sequence, Collaboration, Activity, Component, and Deployment diagrams, to model the actors, system structure, interaction, workflow, and relationships with data entities. Data Flow Diagrams- Level 1 and Level 2 described the flow of information among entities.

Implementation followed a full-stack approach, using ReactJS for the responsive frontend, Spring Boot (Java) for the backend RESTful services, and MySQL for structured data persistent storage regarding cities, locations, stations, and users. Blockchain technology was integrated for generating and booking slots securely, leveraging cryptographic hashing for ensuring immutability, transparency, and prevention of double booking. Route planning leveraged external mapping APIs. The testing done included unit testing, integration testing, functional testing, white-box and black-box testing, and user acceptance testing. All test cases passed successfully. This approach guaranteed a secure, highly scalable, and user-centric system to promote efficient EV charging infrastructure.

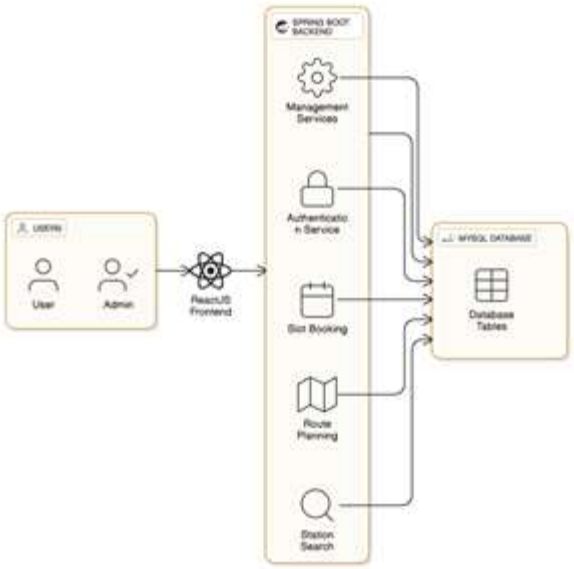

Fig 2 : Architecture

Working Principle

Working Principle: The idea of the Intelligent Electric Vehicle Charging Station Locator with Route Planning and Slot Booking would revolve around streamlining EV charging infrastructure management through an intelligent, secure, and user-centric platform. The web-based system will operate on a centralized yet decentralized hybrid architecture, enabling users to access features via any internet-enabled device. Users register and log in to select cities and locations, view nearby charging stations on interactive maps, check real-time slot availability, plan optimized routes using mapping APIs, and book slots in advance to eliminate waiting times.

Mainly, the underlying innovation consists of integrating blockchain technology into slot generation and booking transactions. Whenever an admin generates charging slots or a user books a slot, the transaction is recorded in the blockchain, along with cryptographic hashing to link such records together in an immutable chain. This implies tamper-proof storage, concurrency checks to prevent double booking, and verifiable transparency for booking history both for users and administrators.

Admin module consolidates the management of cities, locations, stations, and slots at the center and relies on blockchain for auditability. At the same time, real-time updates are stored in MySQL for fast access, while blockchain maintains data integrity. Role-based access control secures the system, with functionalities restricted to their roles. This automated and scalable workflow minimizes manual intervention, reduces inefficiencies, builds more trust, and fosters sustainable EV adoption through reliable charging services.

Technical Tools and Frameworks:

The proposed system is developed as a full-stack web application by integrating various modern web technologies along with blockchain for enhanced security. The front end is built using ReactJS, a responsive, intuitive interface that allows seamless interaction across different devices: dashboards, station maps, route planning, and booking forms. The back end has been implemented with Spring Boot (Java), ensuring RESTful APIs for handling user authentication, business logic, slot management, and database interactions.

MySQL stores structured data regarding the user profile, cities, locations, charging stations, and slot schedules, efficiently querying and making real-time checks on availability. Blockchain technology is integrated into security features for slot generation and booking management; it is enabled by cryptographic hashing, such as SHA-256, to create immutable transaction records. The decentralized ledger prevents tampering and allows verifiable histories.

Route planning will make use of external mapping APIs, such as Google Maps or OpenRouteService, integrated via backend services. The overall architecture is scalable, with modular components that can be extended further. The combination of ReactJS, Spring Boot, MySQL, and blockchain provides security, transparency, and efficiency in managing the EV charging ecosystem.

Methods

SHA-Based Deduplication

SHA is a family of cryptographic hash functions that produce a fixed-size message digest from an input message of any length. SHA-256 belongs to the SHA-2 family of hash functions, producing a 256-bit hash value and finds widespread use in data integrity applications. The basic operation of the algorithm includes processing input data in blocks of 512 bits, beginning with padding of the message so its length is a multiple of 512 bits.

The message is then processed one block at a time, first expanding each block into a schedule of 64 words. The heart of the SHA-256 process is a sequence of 64 rounds of transformation on the state. In each round, the eight working variables (a, b, c, d, e, f, g, h) are updated via bitwise rotations and modular additions. The step transformations make use of functions such as Ch (choice function), Maj (majority function), along with additive constants (K_t) and message schedule words (W_t). For each message block, this set of steps is repeated, culminating in the final hash value computation by adding the working variable results to the initial hash values. The result is a fixed-size output that is unique, making it computationally infeasible to invert. This process is utilized in applications like Blockchain, wherein a data set requires non-alterability in terms of integrity and security, and further provides an immutable and transparent record of transactions.

Equation:

Hash Function:

$H = H0 + a, H1 + b, H2 + c, H3 + d, H4 + e, H5 + f, H6 + g, H7 + h$ Where:

$H\,0\,, H\,1\,, \ldots\,, H\,7\;H\,0\;, H\,1\;\,, \ldots, H\,7$ are the initial hash values, and a, b, c, …, h a,b,c,, h are the updated working variables.

- The final result is a 256-bit (32-byte) hash value.
- This is the simplified approach to understanding how SHA-256 generates a secure hash.

V. MODULES AND ITS IMPLEMENTATION

1. Admin Module

Description:

The Admin Module is the primary control interface through which the whole ecosystem of EV charging

infrastructure can be managed. Besides, it allows the administrators to effectively control the cities, spots, charging stations, slot timings, user accounts, and system analytics while guaranteeing that all important booking records are secured by blockchain for both accuracy and security.

Features:

- **Secured Login:** Only the holders of authenticated credentials are allowed to access the administrator panel where the Admins can log in.
- **Dashboard:** It provides a summary of system activity showing the total bookings, station-usage statistics, active users, and slot-occupancy data.
- **Manage Cities:** The administrating function allows changing the cities the system supports by adding, changing or deleting.
- **Manage Locations:** An admin is allowed to add, modify, or delete some locations in every city to ensure that the mapping of the stations is done correctly.
- **Manage Charging Stations:** The administrators have the power to create new electric vehicle charging stations, change the details of the existing ones (name, capacity, address), or disable/remove them as they wish.
- **Manage Slots:** The admins can create, arrange, modify, or delete charging time slots for each station, and the creation of slots is recorded on the blockchain.
- **Manage Users:** The administrators have the ability to see, change, or deactivate the users who are already registered and have access to the system.
- **View Booking Analytics:** The administrators can access the user bookings, the slots usage and the blockchain-validated transaction history.
- **Profile Management:** The administrators can view, change the settings and even account details of their personal information.
- **Logout:** It guarantees a secure exit from the administrator session.

User Module

Description:

With the implementation of the User Module, electric vehicle (EV) owners can simply locate charging stations, monitor their real-time availability, plan the best routes and reserve places beforehand. The module consists of a simple-to-use interface that is aimed at providing convenience, transparency, and secure blockchain-backed booking history as trust-building mechanisms and reducing waiting times.

Features:

- **Registration & Login:** This characteristic permits the users to create their accounts and authenticate themselves on the platform securely which in turn allows them to utilize its functions.
- **Dashboard:** The dashboard shows the user the nearest stations, their reserved slots, and the quick navigation options that they can easily access.
- **Select City & Location:** The user has to first choose their city and locality, so that, in this way, the charging stations are totally separated from one another.
- **View Charging Stations**: The user can see a list/map of the nearby EV stations with their specifications including capacity, distance, and current status.
- **Real-Time Slot Availability:** The users can view the slots that are available and booked at the stations which they have chosen as their preferred ones.
- **Route Planning:** It provides the fastest way to the charging station using the mapping services.
- **Book Slots:** The users are permitted to book their charging slots quite a long time ahead, and the entire procedure is securely recorded on the blockchain.
- **View Booking History:** The users will have their entire previous booking along with the genuine blockchain-based records accessible to them.
- **Profile Management:** The users have the option to update their personal information, vehicle details, and preferences.
- **Logout:** It guarantees a reliable log-out of the user session.

Blockchain Integration Module
Description:
The integration of Blockchain technology into the system is a major security feature that allows the generation and booking of charging slots to be transactions with no chance of being altered. The module allows the storing of essential records in a decentralized and unmodifiable way which, in turn, prevents double booking, alteration of data, and improves the visibility of transactions for both users and administrators.

Features:

- Slot Generation Security: The authority of the administration over the slot generation procedure is constantly checked by using blockchain transactions together with cryptographic hashing.
- Unchangeable Booking: The booking of the slot by the user is recorded as a non-reversible transaction on the blockchain that contains the details like user ID, station ID, slot, and timestamp.
- Transaction Hashing: The links between the transactions are made through SHA-based cryptographic hashing, and hence any modification done is very easily recognized.
- History that can be Checked: Both users and administrators have the entitlement to view and authenticate the genuine booking records directly from the blockchain ledger.
- Double Booking Avoided: The combination of concurrency controls and atomic blockchain transactions ensures that it is not possible for two users to book the same slot at the same time.
- Auditability: There is an audit trail of all the slot allocations and bookings that is open and traceable.
- Data Integrity Secured: It provides the indelible and credible nature of records without being entirely dependent on decentralized storage.

VI. DISCUSSION AND RESULTS

Homepage:
This is the first page will be displayed after execution started.

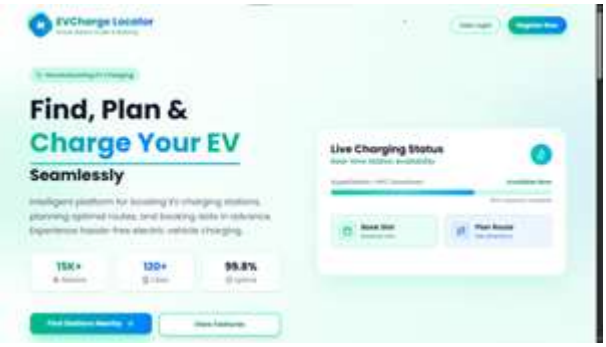

Fig 3: Homepage functionality

Register Page
This is the register page for the user.


Fig 4: Register page functionality

Login Page:
This is the login page for admin, user.


Fig 5: Login page functionality

Admin Dashboard
After the successful login of admin with default credentials this page will be displayed.

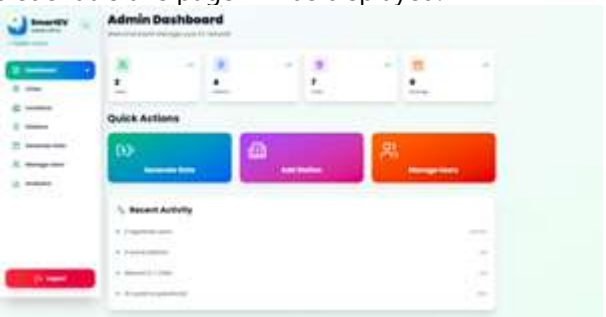

Fig 6: Admin Dashboard functionality

View Users

In this page the admin can see all the registered users.

Fig 7: View Users functionality

Manage Cities:

In this page the admin can manage all the cities.

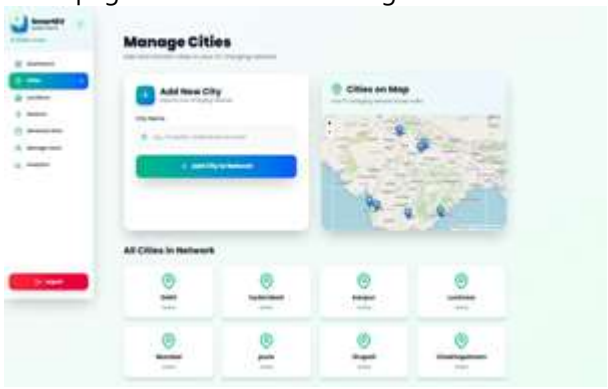

Fig 8: Manage Cities functionality

Manage Locations:

In this page the admin can manage locations.

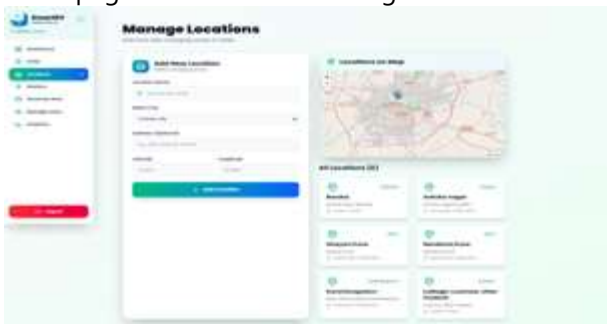

Fig 9: Manage Locations functionality

Manage Charging stations:

In this page the admin can manage charging stations.

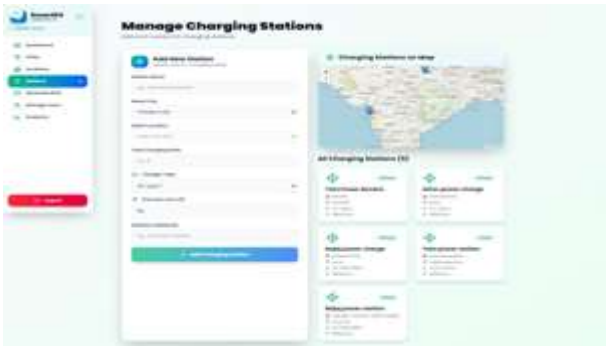

Fig 10: Manage charging stations functionality

Generate Charging slots:

In this page the admin can generate charging slots based on the location.

Fig 11: Generate Charging slots functionality

Analytics & Bookings:

In this page the admin can monitor the slot bookings of users.

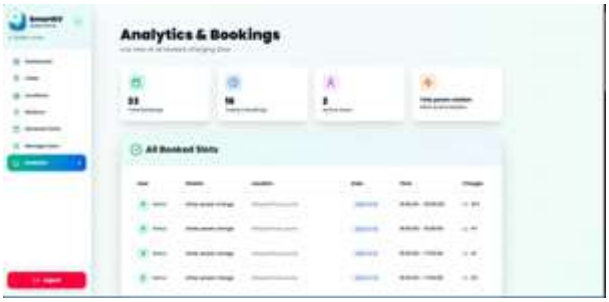

Fig 12: Analytics & Bookings functionality

User Dashboard:

After the successful login of user this dashboard will be displayed.

Fig 13: User Dashboard functionality

Find Charging stations:
The user can find the charging stations by selecting the city and location.

Fig 14: Find Charging stations functionality

Book Slot page:
In this page the user can book the slot by selecting the date and time.

Fig 15: Book Slot page functionality

My bookings page:
In this page the user can monitor their bookings.

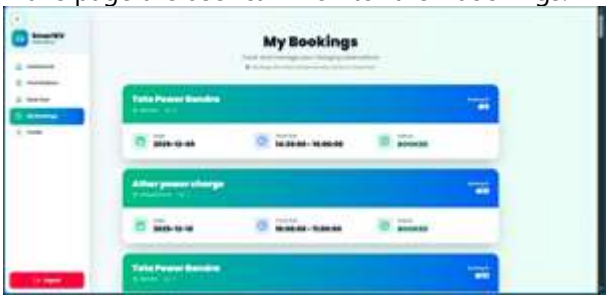

Fig 16: My bookings page functionality

Profile Page:
In this page the user can update their profile.

Fig 17: Book Slot page functionality

VII. CONCLUSION

The Smart Electric Vehicle Charging Station Locator with Route Planning and Slot Reservation system that utilizes Blockchain technology is not only an all-in-one but also a secure solution to the problems of electric vehicle users and administrators at the same time. The combined effect of the real-time charging slot availability display, route planning, and slot booking has greatly increased the convenience as well as the efficiency of the electric vehicle charging process. Blockchain technology is used to guarantee data integrity, transparency, and impersonation-proof booking records that consequently bring about the elimination of issues like overbooking and unauthorized data manipulation.

The centralized admin dashboard not only acts as a differentiator but also facilitates the efficient management of cities, locations, stations, and users thus empowering the operational control. This system is a fantastic achievement in the development of a charging infrastructure for electric vehicles that is not only reliable and scalable but also environmentally friendly as it promotes the use of electric cars and consequently the continuation of clean transportation. The platform with its solid construction and secure design is a significant step towards fulfilling the requirement of the electric vehicle ecosystem, thus making the planet a cleaner and greener one.

Future Enhancements
Smart Electric Vehicle Charging Station Locator with Route Planning and Slot Booking is an application

that is going to have a very bright future when it comes to its innovations. Improving its functionalities, making it more user-friendly, and increasing the scalability of the system are the main issues to be addressed when it comes to enhancements. The smartphone apps for Android and iOS will be the mobile access for the users to get information about charging stations, plan their routes, and book slots - the mobile access will be very convenient for the users. The integration of a real-time payment gateway would ensure that the payments made through the platform are secure and hence fast connecting the user to the charging service.

The system will consist of IoT-enabled hardware that will be able to communicate with the users about the charging stations and slots by sending notifications automatically, thus making the whole process more accurate and less dependent on human input. On top of that, the application of the AI-based predictive analytics technique can be quite beneficial in predicting the availability of slots and providing individual users with routes according to their preferences. To take it further, the blockchain technology can be utilized not only for tracking energy consumption and reporting carbon footprint but also for developing environmental awareness and helping eco-friendly practices through rewards. One more thing, the support for multiple languages and the incorporation of a voice assistant feature will definitely make it easier to reach out to and gain acceptance from a wider user group, which, in turn, will lead to enhanced electric vehicle use and greater sustainability.

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