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Automatic EV Charging Station Recommendation and Slot Booking System Based on Battery Level

Vishvanathan S[1] , Ashok S [2] , ManiBharathi M[3] ,Balaji S[4] ,Mr. R Prabu Arockiyaraj* [5]

[1,2,3,4] *UG Student, Department of Information Technology, Arunai Engineering College Tiruvannamalai, Tamil Nadu, India.*

Email: [1]svishvanathan328@gmail.com, [2]ashokashok05407@gmail.com, [3] mraj79444a@gmail.com, [4]sb0629999@gmail.com,

* [4] *Lecture of Information Technology, Arunai Engineering College, Tiruvannamalai, Tamil Nadu, India.*

Email : * prabu.it@arunai.org

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Abstract:

The rapid adoption of electric vehicles (EVs) has intensified the demand for efficient and accessible charging infrastructure. However, EV users frequently encounter challenges in locating nearby charging stations, particularly under low battery conditions. Existing solutions rely heavily on manual search and lack real-time slot availability and booking capabilities, leading to inefficiencies and user inconvenience.

This paper presents an Automatic EV Charging Station Recommendation and Slot Booking System (EVCS-RBS), which provides an intelligent and automated solution for EV users. The system continuously monitors battery level and triggers alerts when it falls below a predefined threshold. Upon user confirmation, it integrates GPS-based location tracking, identifies nearby charging stations, checks real-time slot availability, and enables advance booking. The system also provides navigation support using map services.

The framework is implemented using a MERN stack architecture (React.js, Node.js, Express.js, MongoDB) and integrates Google Maps API for location-based services. The proposed system reduces manual effort, minimizes waiting time, and enhances the overall EV charging experience. Experimental evaluation demonstrates improved efficiency in station selection and reduced user response time, contributing to sustainable transportation adoption.

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I. INTRODUCTION

Convenience and improves the utilization of charging infrastructure. The integrity of academic and professional credentials is Electric vehicles (EVs) are increasingly adopted as a sustainable alternative to conventional fuel-based vehicles due to their environmental benefits and reduced carbon emissions. Despite these advantages, one of the primary challenges faced by EV users is the availability and accessibility of charging infrastructure.

Current EV charging solutions typically rely on static mobile applications or navigation systems,

which require users to manually search for charging stations. These systems lack automation, real-time slot availability, and booking capabilities, resulting in inefficiencies and increased waiting times. Furthermore, during critical battery conditions, users may face "range anxiety," where uncertainty about reaching a charging station leads to stress and inconvenience.

To address these issues, this paper proposes an automated system that integrates battery monitoring, GPS location detection, charging station discovery, slot availability checking, and booking functionality. The system provides a seamless and intelligent solution that enhances user

convenience and improves the utilization of charging infrastructure.

II. OBJECTIVES

The objectives of the proposed system are:

1. To continuously monitor the battery level of electric vehicles.
2. To generate automatic alerts when battery levels fall below a threshold.
3. To detect the real-time location of the vehicle using GPS.
4. To identify nearby charging stations based on location.
5. To provide real-time slot availability information.
6. To enable advance booking of charging slots.

To provide navigation to the selected charging station.

III. SYSTEM OVERVIEW

A. User Module

Allows users to receive battery alerts, search for nearby charging stations, check slot availability, and book slots.

B. Backend Processing Module

Handles location processing, station filtering, slot management, and booking logic.

C. Admin Module

Enables management of charging stations, updating slot availability, and monitoring system operations.

The system operates as an intelligent assistant that automates the EV charging process from detection to navigation.

IV. SYSTEM ARCHITECTURE

The The system follows a client-server architecture comprising three layers:

A. Frontend Layer

Developed using React.js, providing user interaction, alerts, and booking interface.

B. Backend Layer

Implemented using Node.js and Express.js, responsible for business logic, API handling, and communication.

C. Database Layer

MongoDB stores charging station data, user details, and booking information.

D. Integration Layer

Google Maps API is used for GPS location detection and navigation.

Data Flow Process

1. Battery level is monitored.
2. Alert is triggered at low battery.
3. User confirms action.
4. Location is detected via GPS.
5. Nearby stations are retrieved.
6. Slot availability is checked.
7. Booking is performed.

Navigation is provided.

V. TECHNOLOGY STACK

The framework is built on an accessible, production-grade technology stack suitable for institutional deployment.

Component	Technology	Purpose
Frontend	React.js	UI development
Backend	Node.js, Express.js	API & logic
Database	MongoDB	Data storage
API	Google Maps API	Location & navigation
Communication	Axios	API requests

VI. SMART CONTRACT DESIGN

The Although the proposed EV Charging Station Recommendation and Slot Booking System is primarily built using web technologies, a blockchain-based smart contract layer can be incorporated to enhance security, transparency, and trust in the booking process. The smart contract acts as an autonomous and tamper-proof mechanism for managing charging slot reservations.

A. Overview

The smart contract is implemented using **Solidity** and deployed on an Ethereum-compatible blockchain network. It is responsible for securely handling slot bookings, preventing double booking, and maintaining a transparent record of all transactions. Each booking is recorded on-chain, ensuring immutability and traceability.

B. Data Structures

The contract maintains a mapping between station IDs and booking records. A typical structure includes:

- **stationId (uint256):** Unique identifier for each charging station
- **userAddress (address):** Ethereum address of the user
- **slotTime (uint256):** Timestamp representing the booking slot
- **isBooked (bool):** Status indicating whether the slot is booked

A mapping is used:

mapping(uint256 => Booking[]) public stationBookings;

C. Access Control

Access control ensures that only authorized users can perform certain actions:

- **Users** can book and cancel slots
- **Admin (owner)** can add or update charging stations
- The contract uses a modifier such as onlyOwner to restrict administrative functions

D. Core Functions

1. **bookSlot(uint256 stationId, uint256 slotTime)**
   - Allows users to reserve a charging slot
   - Checks if the slot is already booked
   - Prevents double booking
2. **cancelBooking(uint256 stationId, uint256 slotTime)**
   - Allows users to cancel a previously booked slot
   - Updates the booking status
3. **getBookings(uint256 stationId)**
   - Returns all bookings for a specific station
4. **addStation(uint256 stationId)** *(Admin only)*

Adds a new charging station to the system

E. Workflow

1. User requests a booking through the frontend

2. Backend triggers the smart contract function
3. Smart contract verifies slot availability
4. Booking is recorded on the blockchain

Transaction is confirmed and returned to the user

VII . ADVANTAGES OF THE SYSTEM

The Automatic EV Charging Station Recommendation and Slot Booking System Based on Battery Level offers several advantages over traditional EV charging methods by integrating automation, real-time data, and user-friendly features.

1. Automated Charging Assistance
2. Reduced Range Anxiety
3. Real-Time Slot Availability
4. Advance Slot Booking
5. Efficient Navigation Support
6. Improved User Convenience
7. Better Utilization of Charging Infrastructure
8. Time and Effort Saving
9. Scalable and Extendable System
10. Supports Sustainable Transportation

IV. CONCLUSIONS

The Automatic EV Charging Station Recommendation and Slot Booking System Based on Battery Level provides an efficient and intelligent solution to the challenges faced by electric vehicle users in locating charging stations. By integrating battery monitoring, GPS-based location detection, and real-time station discovery, the system enables users to quickly find nearby charging stations when their battery level becomes low. The inclusion of slot availability checking and advance booking helps reduce waiting time and ensures a smoother charging experience.

From a technical perspective, the system leverages modern technologies such as the MERN stack and Google Maps API to deliver a scalable and user-friendly platform. It improves overall convenience, enhances the utilization of charging infrastructure, and reduces range anxiety among users. With further enhancements like IoT integration and AI-based recommendations, the system has strong potential to support large-scale adoption of electric vehicles and contribute to sustainable transportation

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