IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 2, April 2026
Impact Factor: 8.2

Dynamic E–Vehicle Station Orchestration

Prof. Chintamani H. Kambale[1], Akshata P. Chougule[2], Mrunal R. Gawade[3], Sakshi N. Desai[4], Pranali G. Desai[5], Sanika U. Patil[6]
Assistant Professor, Department of Computer Science and Engineering[1]
Students, Department of Computer Science and Engineering[2-6]
Sant Gajanan Maharaj College of Engineering, Mahagaon,
Shivaji University, Kolhapur, India.
chkamble1@gmail.com[1],akshatachouguleac29@gmail.com[2], mrunalgawade06@gmail.com[3], sakshidesai082@gmail.com[4], pranalidesai7250@gmail.com[5], sanikap568@gmail.com[6]

Abstract: *The growing use of electric mobility, especially e-bikes and light electric vehicles, has led to a need for efficient, reliable, and smart charging infrastructure. Traditional charging stations use fixed slot allocation, have limited booking options, and offer little real-time visibility. This results in long waiting times, poor use of charging resources, and lower user satisfaction. To tackle these issues, this project introduces Dynamic E-Vehicle Station, an AI-driven web platform that aims to optimize e-bike charging, smart booking, and dynamic slot management. The system is built with Angular (HTML, CSS, TypeScript) for the frontend, Java Spring Boot for backend logic, and MySQL for the database. This approach ensures a scalable and modular design. The platform offers real-time charger availability, map-based station discovery, digital slot booking, monitoring of charging sessions, user authentication, and payment integration. A major innovation is the use of artificial intelligence to improve operational efficiency and decision-making.*

Reinforcement Learning (RL) is employed for dynamic slot allocation, which helps reduce user wait times, increase charger use, and fairly distribute charging resources. Genetic Algorithms (GA) are also used for conflict resolution and better scheduling during peak demand. The platform predicts future demand and user traffic using ARIMA and LSTM models that analyze historical data to forecast occupancy. This allows operators to prepare for peak loads and manage station capacity more effectively.

The system features an operator dashboard with real-time analytics, forecasting insights, revenue reports, charger performance metrics, and maintenance alerts. Secure communication is ensured through JWT authentication, RESTful APIs, and live updates via WebSocket.

In summary, Dynamic E-Vehicle Station offers a smart and user-focused solution for today's e-bike charging landscape, greatly improving resource use and helping to promote the widespread adoption of electric mobility.

Keywords: *electric mobility*

I. INTRODUCTION

The Dynamic E-Vehicle Station Orchestration application will be an efficient web application that will be highly beneficial to electric bike users, as the application will provide an efficient way of using electric bike charging services. Moreover, the electric bike users will be able to analyze the availability of electric bike stations and book the best slot to charge their electric bike without any conflicts and waiting issues.

As the trend of using electric bikes is increasing, the issues of overcrowding and unavailability of electric bike charging points, along with inefficient use of electric bike charging services, have become the most important issues for electric bike users. Therefore, the proposed application will be highly beneficial to electric bike users, as the application will provide an efficient way of resolving issues faced by electric bike users.

DOI: 10.48175/568

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The proposed application will be developed using the Angular, HTML, CSS, and TypeScript programming languages for the front-end of the application, which will provide an efficient way for the electric bike user to use the application. Moreover, the proposed application will be developed using the Java programming language for the back-end of the application, which will provide an efficient way for the electric bike user to use the application. Moreover, the proposed application will be developed using the MySQL database for efficient execution of the proposed application. Moreover, the proposed application will be developed using the AI programming language for efficient slot booking for electric bike users.

II. RELATED WORK

Research in the area of electric vehicle (EV) charging systems shows that earlier infrastructures were mainly based on fixed slot allocation and limited real-time tracking. Such systems often resulted in poor utilization of charging resources, increased waiting times, and unsatisfactory user experiences. Initial solutions primarily focused on simple station locating features and manual booking processes, without incorporating intelligent decision- making or forecasting capabilities.

With technological progress, more advanced charging systems have been developed by integrating features such as live monitoring, cloud-based platforms, and mobile application support. These improvements enhanced user accessibility and convenience. However, challenges still remain in areas like dynamic scheduling, handling uncertain demand, and ensuring fair distribution of charging slots among users.

Several research efforts have also concentrated on optimizing charging station placement and routing strategies using algorithms like shortest-path techniques and demand prediction models. While these methods help in improving accessibility and minimizing travel time, they often involve complex system requirements or lack proper integration with real-time booking and user interaction features.

Even with these advancements, current systems continue to face issues such as increased computational requirements, weak coordination between prediction models and allocation mechanisms, and limited ability to adapt instantly to changing conditions. In addition, many solutions fail to provide a unified platform that combines intelligent scheduling, demand forecasting, real-time monitoring, and a user-friendly interface.

Therefore, there is a strong need for an integrated solution that brings together AI-based slot allocation, accurate demand prediction, continuous real-time monitoring, and efficient booking management within a single system.

III. LITERATURE REVIEW V. PROPOSED SYSTEM OVERVIEW

Intelligent optimization and forecasting techniques play an important role in improving the management of electric vehicle (EV) charging infrastructure. In one study, reinforcement learning is used to optimize slot allocation, while genetic algorithms with priority scheduling enhance the reservation system. Additionally, ARIMA and LSTM models are applied for demand forecasting, leading to more efficient smart e-bike service management. Another research proposes a deep reinforcement learning-based charging scheduling approach, where the problem is modeled as a constrained Markov decision process and solved using a soft actor-critic algorithm with an augmented Lagrangian method, effectively handling uncertainties such as battery condition, arrival and departure time, and electricity cost. Furthermore, genetic algorithms and multi-objective optimization techniques are used to determine optimal charging station locations. In addition, NARX-based load forecasting combined with Dijkstra's algorithm helps in efficient charging station allocation based on demand and network optimization.

IV. PROBLEM STATEMENT

The increasing adoption of e-bikes has intensified the need for efficient and intelligent charging infrastructure. However, users currently face significant challenges such as difficulty in locating nearby charging stations, lack of real-time availability updates, unfair or inefficient slot bookings, long waiting times, and unpredictable demand variations.

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Existing charging systems are mostly static and manual, offering limited support for resource optimization and user convenience.

There is a clear need for a smart, AI-driven solution that can dynamically manage charging slots, predict future demand, and provide seamless booking and monitoring for users. The absence of such an integrated system leads to poor utilization of charging infrastructure, user dissatisfaction, and operational inefficiencies.

To address these issues, Dynamic E-Vehicle Station Orchestration aims to provide an AI-based web platform that uses Reinforcement Learning for optimal slot allocation and Genetic Algorithms with priority scheduling for fair bookings. The system also offers users real-time station updates, availability information and digital convenience.

The proposed system is an AI-based Dynamic E-Vehicle Station Orchestration platform designed to improve the process of locating and booking electric vehicle charging stations. It provides real-time station availability, smart slot booking, and reduces waiting time compared to traditional systems. Users can search nearby stations, check availability, and reserve slots through a web-based interface.

The system automatically allocates charging slots using intelligent algorithms and provides optimized scheduling. It ensures secure user authentication and protects booking data. Additionally, it helps station operators manage station details, availability, and usage efficiently.

By using modern web technologies and AI techniques, the system offers a reliable, user-friendly, and efficient solution that improves resource utilization and supports the growth of electric mobility.

V. SYSTEM ARCHITECTURE

This system architecture represents a charging station booking platform with two main roles: User and Admin. Users can register or log in, search for stations, book slots, and make payments, while admins manage bookings, services, and slot availability.

All interactions go through an authentication layer to ensure secure access and login verification. Once authenticated, requests are processed in the application logic layer, which handles core functionalities like booking and service management. These requests are then passed to the backend API, where different controllers manage booking, payment, and admin operations. The backend communicates with the database, which stores important data such as user details, charging stations, bookings, and payments. After processing, the system generates outputs like booking confirmation or payment success. These results are then returned to the user or admin. Overall, the architecture follows a structured and layered approach, making the system efficient, secure, and easy to maintain.

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SYSTEM AECHITECTURE

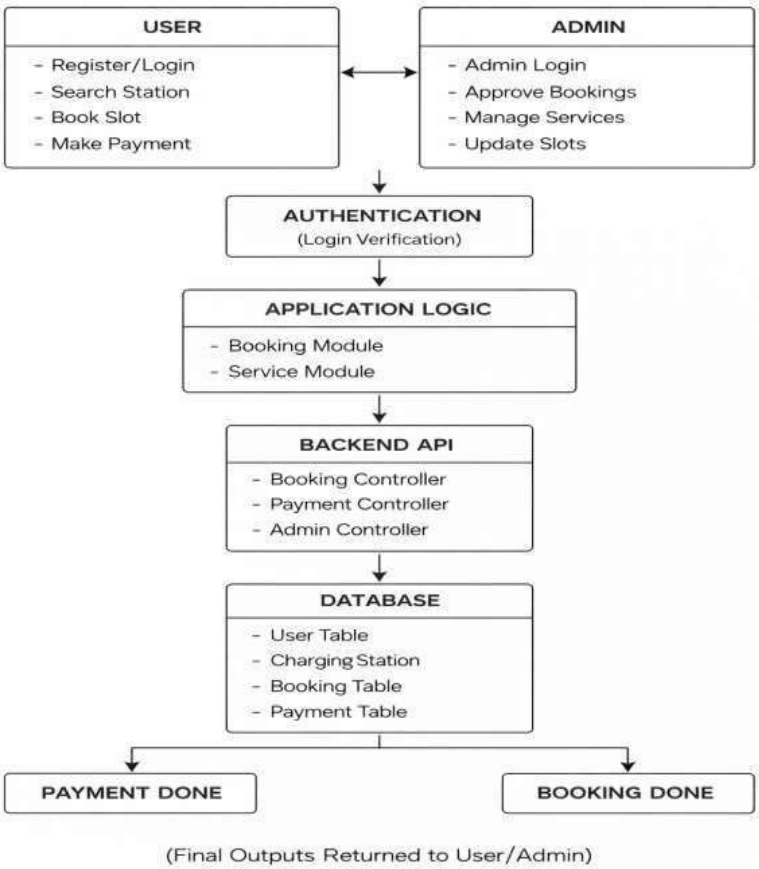

Figure 1: System architecture

VI. IMPLEMENTATION DETAILS

The Dynamic E-Vehicle Station Orchestration system aims to simplify the use of electric vehicle charging stations. Instead of waiting in long lines or searching for a station, users can easily find and reserve a spot through the platform in advance. This saves time and improves the overall experience.

The system is a web application featuring a simple and user-friendly interface. It is built using Angular along with HTML, CSS, and TypeScript. The application includes several pages such as the login page registration page, station search page, booking page, and user dashboard. The backend of the application manages all essential operations. This includes user verification, handling station data, and integrating with smart modules. Java, using Spring Boot, powers the backend services. The MySQL database stores all critical data in an organized manner. An admin panel is available for managing the entire application. Through this panel, the administrator can manage station data and update details as needed. They can also check the availability of chargers. This contributes to a smoother and easier process. In summary, the proposed system provides an effective solution for EV charging stations.

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TABLE I: TECHNOLOGY STACK USED IN THE PROPOSED SYSTEM

Module	Technology Used
Frontend	Angular, HTML, CSS, TypeScript
Backend	Java (Spring Boot)
Database	MySQL
Communication	REST APIs, WebSocket

Implementation of Registration, Login, and Access Control

The proposed system includes several security measures to ensure safe usage. User data is stored, so steps are taken to prevent misuse.

1. User Registration

Users can register by providing their name, email, phone number, and password. The system checks this information before storing it. Passwords are saved in an encrypted format.

2. Login Process

Users need to log in to access the system. They can log in only if their credentials match those in the database.

3. Access Control

Once logged in, users receive appropriate access. The system maintains proper access control.

VIII. ANALYSIS OF PROPOSED SYSTEM

The proposed Dynamic E-Vehicle Station Orchestration System was evaluated for its performance, efficiency, and reliability. The smooth and efficient charging experience. The following factors were considered:

1. Data Storage Efficiency

In the proposed system, user details, station information, and booking records are stored effectively in a structured database, MySQL. A well-designed database reduces redundancy and ensures accurate data storage. This improves data retrieval speed and boosts overall system performance.

2. Resource Utilization

The system optimizes the use of charging stations by managing slot availability and bookings well. By preventing overbooking and managing queues, it maximizes the use of available charging, resources and reduces idle time.

3. Saving Percentage

The system cuts down on manual work and paperwork by keeping all booking and transaction records digital. This lowers operational costs, reduces errors, and improves data management compared to traditional manual systems.

4. Processing Time

The system handles user requests like login, slot booking, and availability checking in real-time. Quick backend processing ensures fast response times, allowing users to book charging slots without delays. This improves user experience and system reliability.

5. Code Efficiency

The system is built using optimized and structured coding practices. Efficient backend logic and a well-designed frontend lower system load, memory use, and execution time. This ensures smooth operation even when many users access the system at the same time.

IX. MODULES

1. Vehicle Management Module

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The Vehicle Management Module is responsible for tracking all vehicles in real time. It monitors important parameters such as
location, speed, battery level, and availability status. The system continuously updates whether a vehicle is idle, charging, or in use. All collected data is sent to the central system for further processing and decision-making.

2. Station Management Module

The Station Management Module manages all information related to charging stations. It keeps track of station capacity, slot availability, queue length, and overall usage. The module also detects whether a station is full or free at any given time. Additionally, it monitors station health and ensures accurate status updates.

3. Demand Prediction Module

The Demand Prediction Module analyzes both historical and real-time data to forecast future charging demand. It helps in identifying peak hours and high-demand locations. This module plays a key role in reducing congestion and avoiding overload at stations. By predicting demand, it supports better planning and resource allocation.

4. Orchestration / Decision-Making Module

The Orchestration Module acts as the brain of the system, managing overall operations efficiently. It assigns vehicles to the most suitable charging stations based on various factors. The module uses optimization techniques, algorithms, and rules for decision-making. It also ensures load balancing and supports dynamic routing to improve system performance.

5. Communication Module

The Communication Module enables seamless real-time interaction between all system components. It connects vehicles, charging stations, central servers, and user applications. The module supports continuous data exchange to maintain system synchronization. It also handles notifications, alerts, and API-based communication.

X. EXPERIMENTAL RESULTS AND ANALYSIS

Account Access Portal

This interface shows the login page of the E Moto Hub system. It allows users to enter their email and password to access their account. Features like “Forgot password” and “Keep me logged in” improve usability. The interface is simple, secure, and user-friendly.

Station Management Module

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This interface represents the station management module of the E Moto Hub system. It enables users to update essential station details such as name, location, and address. The module also provides functionality to manage charging booths, including adding, viewing, and removing booth information like pricing and power output. It ensures efficient data handling and smooth system operation. The design supports easy and structured modification of station records.

Scheduling Module Interface

This interface shows the scheduling module of the E Moto Hub system. It allows users to manage station availability and open or close charging slots. Slot details like price, power, and charging time are also displayed. It helps in efficient scheduling and control.

Booking Record Dashboard

This interface displays a customer booking management system with details like date, time, name, contact information, booking ID, and amount. It helps track the status of appointments, including completed or cancelled entries. Users can update or manage bookings through available action options. Overall, it provides an organized way to handle and monitor appointments efficient

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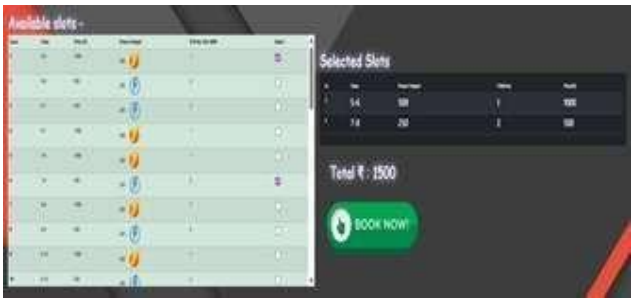
Charging Station Directory

This interface represents the station listing module of the E Moto Hub system. It displays multiple charging stations with their status, location, and basic details. Users can easily book charging slots or schedule service appointments directly from the interface. Ratings and reviews are also shown to help users choose suitable stations. It provides a clear and organized view for quick decision-making.Admin Dashboard

Slot Booking Module



This interface represents the slot booking module of the E Moto Hub system. It allows users to view available time slots with details like price, power output, and charging duration. Users can select preferred slots and see a summary of selected bookings. The total cost is calculated automatically for convenience. It provides a simple and efficient booking experience.

Secure Payment Gateway

The interface displays the online payment processing page with the total amount to be paid. It supports multiple payment options including UPI, Visa, and Mastercard. The system processes the entered UPI ID for transaction completion. A progress indicator shows the current payment status. The module ensures a secure and efficient payment process.

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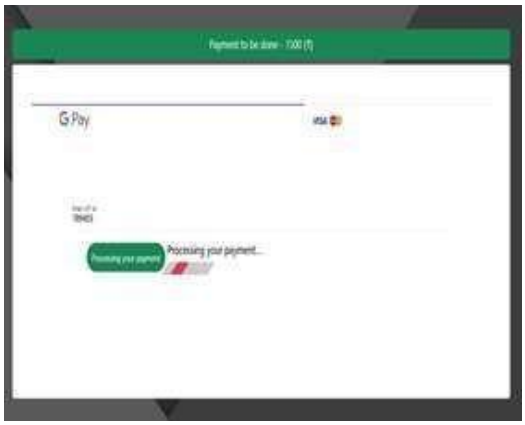
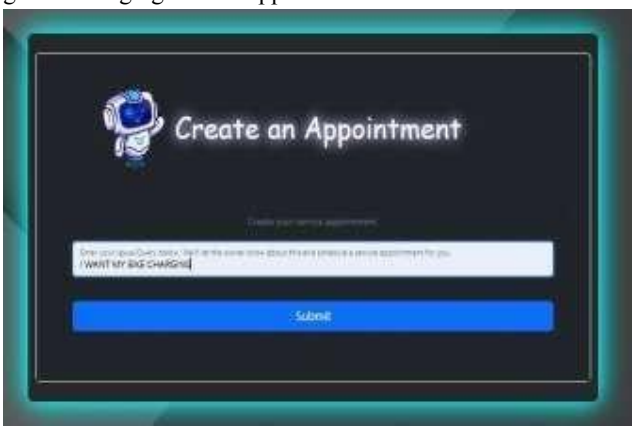


Create Appointment Module

The Create an Appointment interface allows users to submit their service requests easily. Users can enter their issue or query in the input field and send it to the service provider. The clean and simple design ensures smooth interaction. It helps in efficiently scheduling and managing service appointments.



Appointment Management Dashboard

The "Customer Appointments" section displays a list of all service requests made by users. It includes details such as customer name, contact information, appointment ID, and the issue description.

The system also allows the service provider to add replies and update appointment status. This helps in tracking and managing customer requests efficiently.

X. CONCLUSION

The Dynamic E-Vehicle Station platform uses AI and modern web technologies to make e-bike charging systems more efficient and user-friendly. It integrates Angular, Spring Boot, and MySQL for smooth operation and secure data

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management. Features like station discovery, booking, real- time monitoring, and payments enhance user experience. Advanced algorithms optimize slot allocation and reduce waiting time. Overall, the system improves performance, reliability, and supports sustainable electric mobility.

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