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Review of ChargeEase: A cloud-based solution for charging and management of Electric Vehicles in Pakistan

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Abstract - With the rapid adoption of electric vehicles in Pakistan, there is rise of issues faced by owners of electric vehicles which includes searching for nearest charging station, remotely booking slot of charging station, making payments of charging sessions through local payment gateway and trip planning for long drives on electric vehicles. To address these issues, I have developed and implemented a web-based application that allows user to find nearest charging station according to their location using Open Street Maps API, see reviews of charging station left by other users, remotely book charging slot of station with simulated local gateway of payment and leave review of charging station after charging session. The application solves the queuing problem at charging station by showing charging slots status to all users in real-time. The application also allows users to chat with other users of this application, the greedy algorithm is implemented to plan optimized long drive trips according to available battery percentage available, mileage and speed of electric vehicle. The application is managed by admin panel with its functions including adding and removing stations, moderating user reviews and viewing user booking history. The frontend of application is made in HTML, CSS and Javascript for web while mobile web-application is wrapped in Flutter [1] using Webview. The backend of application is powered by Firebase [2]. With development of this application, I propose a prototype solution with some functionality limitations for charging and management of electric vehicles in Pakistan and aim to show as proof-of-concept.

Index Terms: Charging station finding application, Charging & Management of EV in Pakistan

1 INTRODUCTION

As use of electric vehicles is increasing in Pakistan, so is increasing the need of proper infrastructure to facilitate electric vehicle owners. When a person buys an electric vehicle, they face many issues like physically searching for nearest charging station, lack of information about availability of charging slot and service of station. The payment of charging session is also hectic process either based on cash or debit/credit cards. This traditional process is not only very time-consuming but also very unproductive and causes inconvenience for EV owners to stay updated. Secondly, there is no such application available for electric vehicle owners that work properly in Pakistan. This gap is to be filled with ChargeEase which provides a digital platform to electric vehicle owners to address all their concerned issues. The main objectives of ChargeEase includes simplifying the process of electric vehicle charging by locating nearest charging station according to user's location, allowing user to remotely book charging slot of station upon confirmation of payment, provide feedback system to user to improve charging experience, plan trip of long drives for electric vehicles according to their available battery percentage, speed and mileage, and lastly provide a platform to build an online community of electric vehicle owners where they can chat with each other. The key contribution of this application is that it provides a basic framework and an idea of infrastructure of electric vehicle's management application which can decrease issues faced by electric vehicle owners and can promote use of electric vehicles,

this idea of infrastructure can be refined to form actual digital platform which will facilitate electric vehicle owners in real-time. The remaining paper is as follows; Section 2 discusses literature review of existing similar systems, Section 3 discusses methodology which includes algorithms and experimental setup which is used in developing this application, Section 4 discusses results of this developed application and discussion on these results, and Section 5 discusses conclusion and lessons and learning for future work direction.

2 LITERATURE REVIEW

The increase in use of electric vehicles has led to increase in large number of research in developing a simplified platform to ease the process of charging and provide a basic infrastructure to address these related issues. When we look at solutions available in market, there are just small applications that solve only a certain part of problem and lack an integrated approach. However, there has been research conducted by following V. Kumar *et al.* [3] presented mobile application on finding charging station based on location. But it lacked reviews and other user community related features. There is another application available "Plugshare" [4], it is mobile application that assists electric vehicle owners in searching for nearest charging station, payments by its own wallet system, etc., but since it is not supported in Pakistan, it is of no use for electric vehicle owners in Pakistan. Though there are other applications and solutions too, but we won't go in detail as they are not officially supported in Pakistan. From this discussion, we can confidently say that there is no single simplified digital solution available to electric vehicle owners in Pakistan which can ease the process of charging for them. The discussed solutions either lack features or are simply not available in Pakistan. The ChargeEase application contributes to this domain by providing an idea of single unified comprehensive digital solution to electric vehicle owners in Pakistan.

3 METHODOLOGY

3.1 Application Architecture

The ChargeEase consists of cloud-based client-server architecture using BaaS (Backend as a Service) as its backend features like database, user authentication, and hosting are through services of platform of Firebase. The frontend is developed in HTML, CSS and Javascript to handle user input, show output according to input, use APIs to communicate with different services like OpenStreetMap[5] to find location of nearest charging station to user and simulate Payment Gateway API's behaviour to mimic real transaction to book charging slot of station. The web pages were designed with responsive design to make easily accessible through mobile web too. The web-application is hosted on Firebase Hosting due to its real-time synchronization and scalability. The mobile version is basically WebView wrapper developed in Flutter to open only web-application ChargeEase's URL, and it uses location services of the mobile to locate user's current location. The admin panel of this application is also developed to manage (add/delete) stations, view user's booking history, moderate reviews left by the user and manage user profiles. The payment feature is only simulated (dummy) for now which books slot only when pre-defined input is given as phone number and PIN and confirms the booking of slot, although no transaction takes place in real-time and no other input is taken as valid to confirm the booking of slot. To give this dummy payment an effect of actual transaction to user, a delay of 5 seconds is simulated by default. This all was done due to non-availability of any actual local payment API.

The architecture of ChargeEase can better be understood by looking at following Figure 1.

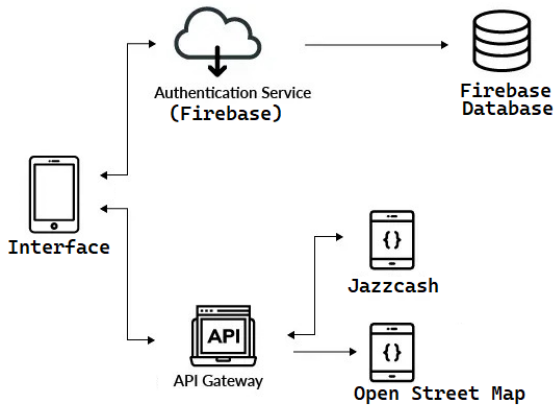

Figure 1 – Application Architecture

3.2 Application Modules

The application ChargeEase consists of 2 main modules

- User Module: For registration of user, login of registered users, search for nearest charging station, view station details, book charging slot of station, view own booking history, chat with other users and plan trips for long drives

- Admin Module: For adding new charging station, delete any existing charging station, view all users and their booking history, view all reviews left by a user, delete any review left by a user, and delete any user profile

3.3 Use Case Diagrams

3.3.1 User

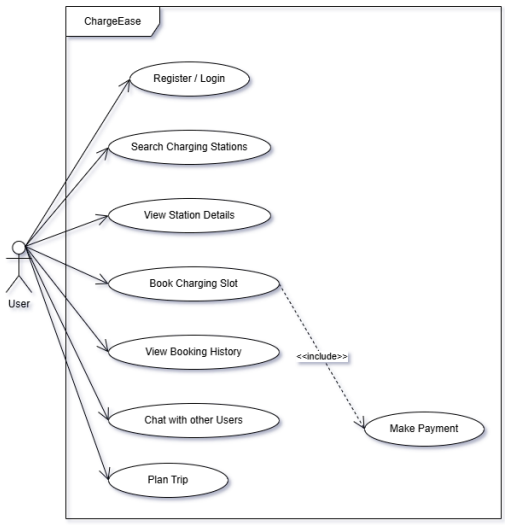

Figure 2 – Use Case Diagram of User

3.3.2 Admin

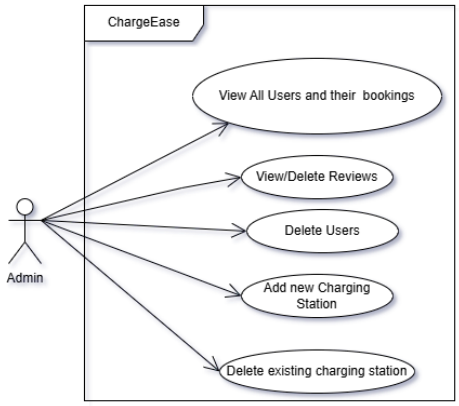

Figure 3 – Use Case Diagram for Admin

3.4 3.4. Implementation

The ChargeEase application is already hosted and is available for use. Now we will discuss its flow of use in sequence as new user.

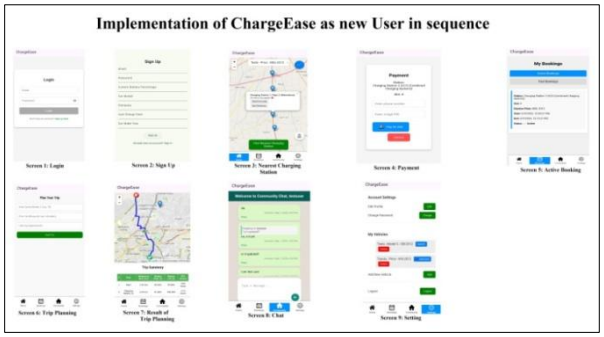

Figure 4 - Screens of ChargeEase Application

Screen 1: Screen which appears when we launch application on phone or visit URL in web browser: https://chargeease-a46b8.web.app/

Screen 2: Sign up screen asking for details

Screen 3: First screen that you see when we login as new user after input of basic details of vehicle

Screen 4: Payment screen when we want to book available slot of charging station

Screen 5: Booking screen showing active booking which appears only if payment is confirmed

Screen 6: Trip planning screen asking for details

Screen 7: Showing total route after selecting starting and ending point in trip planning

Screen 8: Chat screen showing all users chat

Screen 9: Showing setting options

3.5 Algorithm

The ChargeEase uses greedy heuristic search algorithm for trip planning used on Open-Source Routing Machine (OSRM)[6] from OpenStreetMap's data. It basically uses iterative approach to reach destination by first finding nearest charging station then move to next charging station and so on. Let's discuss in detail that how this algorithm works:

First Step: Calculate route between starting and ending point using OpenSourceRoutingMachine's algorithm

Second Step: If vehicle already has charging and mileage to reach destination directly then go for it. Else go to third step.

Third Step: This step is divided into following sequence: i) Searches for all nearest charging stations which are

reachable according to current battery percentage and mileage
ii) Selects station which is more near to the destination
iii) Assumes that battery now will be charged to 100% from the station and only then travel will be continued
iv) Repeats all steps from (i) until destination is reached
Fourth Step: Calculate whole route based on OSRM with all stops for charging from starting point to ending point

This algorithm works fine when stations are dense, are at regular even distance from each other, for small routes and is to be implemented at client side only. This algorithm was chosen due to its simple and fast implementation in this proof-of-concept application.

4 RESULTS AND DISCUSSION

After implementing this application ChargeEase, I have done its user testing by asking my university fellows to check its proper working and submit feedback if there are any issues. The results showed that sign up, login features were working properly. The location of user was also accurate most of the time, although it also depends on user's internet speed and mobile's GPS module's accuracy. The application showed accurate details of charging stations as added by the admin with availability of slot according to booking data fetched from Firebase Database. The payment feature was simulated to mimic real transaction which worked fine if pre-defined input is given and does not work on any other input as I intended it. The active booking and booking history both features worked fine as intended. The chat feature also works fine and as intended. Then trip planning feature was used by multiple users, but results showed that users who selected short and small route, trip plan feature worked fine for them but the users that selected long and complex route, trip plan feature didn't work correctly for them. The admin panel also worked correctly as intended. From the feedback, I also got to know that once a slot was booked, it didn't become available to other users even after the booking time was expired which was intended to be 15 minutes. From all this feedback, I came to know about following limitation of this application ChargeEase:

- Once a charging slot is booked, it does not become available to other users after 15 minutes which it should
- Trip planning algorithm was not optimal for long routes
- User was still able to book charging slot even when they deleted records of their vehicles
- User cannot edit the review that they have left
- There are route accuracy issues of sides of lanes on road
- The verification of email at time of sign up is not implemented
- Actual API of local payment gateway is not used

So as far as know, these are some of the major limitations and drawbacks of this application ChargeEase. However, there can be more minor limitations or issues in this application that I might have missed due to small sample data of feedback.

5 CONCLUSION

I have developed and implemented this application as proof of concept of this type of application due to growing demand of electric vehicle in Pakistan. Soon in market, we need this type of application to facilitate the actual electric vehicle owners. ChargeEase tries to mimic the functionalities of actual fully working application such as working in real-time to locate user, using algorithm to calculate route etc. But still, there is a lot of room for improvement in this application. Although this application can serve as basic framework for future references and can be upgraded with actual APIs and better optimal algorithms to become commercial grade application.

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