

IoT-Based Smart Booking of Electric Vehicle Charging Station

**Gowtham R¹, Guganesh P², Ilanchelvan Harikumar V³,
Ramachandran K⁴, Udhaya Kumar C⁵, Priyadharshini A⁶**

Department of EEE, Coimbatore Institute of Technology, Affiliated by Anna University, Coimbatore, Tamil Nadu, India

E-mail: ¹rockgowtham79@gmail.com, ²gugan582@gmail.com, ³hariv1708@gmail.com, ⁴rcrama2001@gmail.com, ⁵udhayakumar6608@gmail.com, ⁶priyadharshini.a@cit.edu.in

Abstract

The Immense growth in the implementation of electric vehicles (EVs), has established a path in the advancements of charging infrastructure. Interlinking and connecting the charging stations to a common server is essential for future EV adoption, and this can reduce the user's anxiety. The existing charging stations have not implemented charging slot availability and time scheduling management. The objective of this research is to enhance the current electric vehicle (EV) charging infrastructure by gathering and sharing real-time information about the availability of reserve slots at charging stations. This information is made available to users through an interactive application created with Android Studio, allowing them to locate the closest charging station for their EV. The application utilizes the State of Charge of the EV to assign available charging slots. The proposed real-time predictive charging server infrastructure avoids latency, effectively manages time scheduling, and avoids draining electric vehicle batteries. This proposed system uses the real-time traffic database to estimate the minimum distance path to reach the charging station.

Keywords: Internet of Things, Firebase, State of Charge, Electric Vehicle, Application

1. Introduction

As fuel prices rise, the popularity of electric vehicles are growing. As a result of these factors, some automobile manufacturers are investigating alternate fuel sources. Because electrical energy sources emit fewer pollutants, as they are better for the environment. Furthermore, electric vehicles provide significant energy reduction and environmental

protection benefits. In the majority of electric vehicles, Li-ion batteries are used. It is a significantly smaller battery than lead acid. In reality, a Li-ion battery provides more consistent power and has a longer life cycle than a lead-acid battery. Lithium-ion batteries' life cycles can be shortened by both overcharging and harsh discharges. On the other hand, EVs have a restricted range of travel due to battery capacity and body architecture. The absence of a connection between electric vehicles (EVs) and software platforms means that these systems remain separate and require drivers to use multiple software products at the same time. As a result, drivers have to come up with their own strategies to manage the situation, such as searching for charging options during the day, arranging alternative routes, or resorting to other modes of transportation [1].

The safety of present battery technology is now one of the key problems restricting EV adoption. Overcharging a battery can shorten its life duration, while also posing a major safety risk, such as fire. An EV battery monitoring system that can advise the user about battery condition is essential to avoid the aforementioned difficulties. The major goal of this initiative is to shorten the time for charging the electric vehicles. This project establishes a priority-based charging station slot booking system. Priority is given to the first booking vehicle with the shortest projected range. The car with the lowest State of Charge is assigned to the nearest charging station. The vehicle's booking procedure begins with the maximum estimated range and gradually drops to the shortest estimated range.

2. Problem Statement and Objectives

Developing and implementing a system that uses computerized reservation-based charging techniques that effectively manages to book and assign the charging stations based on the real-time State of Charge of the EV battery.

3. Related Works

Although Wireless communication refers to the transmission and delivery of data through wireless signals between two or more devices. This term encompasses all methods and forms of wireless connectivity and communication, using various wireless technologies and devices. In previous work, different technologies have been employed for wireless battery monitoring systems, including GSM, ZigBee, GPRS, Android, WIFI, and Bluetooth communication [2]. The State of Charge is the remaining percentage of a battery's capacity and is calculated by dividing the current available capacity by its maximum capacity when fully

charged. The monitoring and regulation of battery states are managed by a BMS, which uses a battery analytical model and comprises hardware and software for battery management. This system includes algorithms that determine the battery's critical states. In Electric Vehicle (EV) applications, batteries not only need to provide a specific amount of energy to the drive train during operation but also provide power in different road conditions. Hence, it is crucial to know the maximum power that the battery can deliver to and from the battery by charging or discharging, respectively, and SoC is necessary to make decisions about battery's health and its operation [3]. Real-time scheduling of Electric Vehicle (EV) charging is dependent on battery dynamics and charging slots availability. The system uses a scheduling management facility to provide the users with information about the charging station which is near to the user and booking slots is based on the estimated SoC of the vehicle's battery. Providing this information the application enables the energy management system to respond to the vehicle's peak demand and the vendor's perspective. [4,5].

4. Methodology

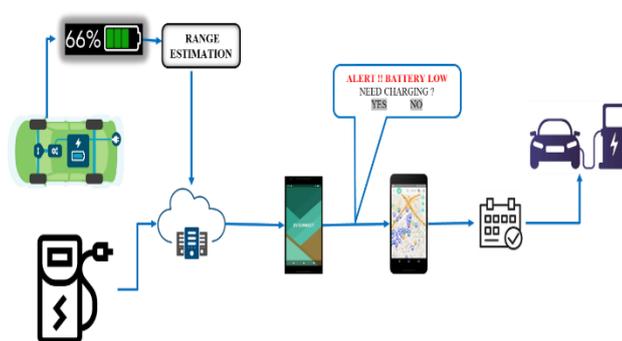


Figure 1. Overview of the proposed system

The block diagram of the proposed system consists of an electric vehicle battery, Cloud storage, and charging Station connected to the Android Application to book the slots in Charging Stations as shown in Figure 1. The SoC from the electric vehicle is taken for estimating the range of the vehicle and the estimated data will be sent to the cloud in a real-time manner. The availability of slots in the charging stations is collected concurrently and stored in the cloud. Then the information in the cloud is transferred to the android application. The application reads the data and sort the nearby charging stations based on the collected information. Then the filtered charging stations is shown in the android application for

booking. By using this proposed system users can easily find out the nearest available charging station.

5. System Flowchart

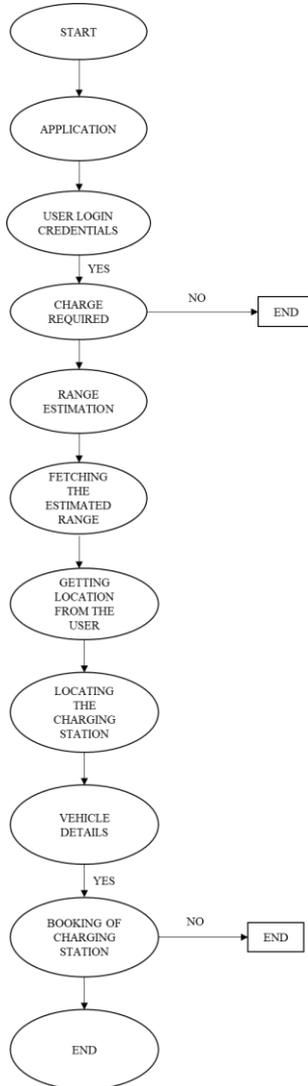


Figure 2. System Flowchart

The proposed android application works based on the reservation algorithm as shown in Figure 2. Initially, the application pops up an alert message and asks the user whether charging is required or not. If the user needs to charge, the ER from the cloud is retrieved. Then the ER is calculated for the charging station booking and the user’s location is fetched. The user selects the wheeler type which needs to be charged. Then the allocation process for the charging station takes place based on the priority of booking.

6. Hardware Design

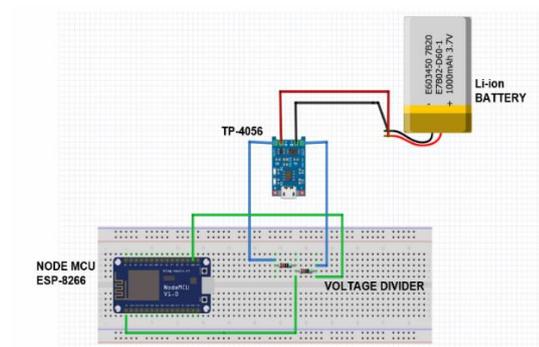


Figure 3. The design of the SoC estimation circuit using Fritzing software

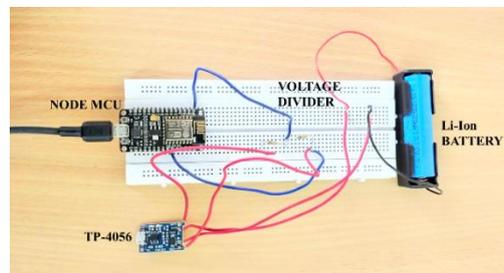


Figure 4. The actual design of the SoC estimation circuit

The proposed schematic design and actual design of the hardware consists of a Lithium-ion battery, TP-4056, Node MCU ESP-8266, Voltage divider, and TP4056 Battery Charging Module as shown in Figure 3. and Figure 4. The voltage obtained from the battery is stepped down by using a voltage divider and the data are transferred to Node MCU. In Node MCU the SoC is calculated by the code dumped in Node MCU by using Arduino IDE. The State of Charge of the battery is shown in the serial monitor. Then, Node MCU sends the data to ESP8266 Wi-Fi Module. The ESP8266 Module transfers the data to the firebase Console.

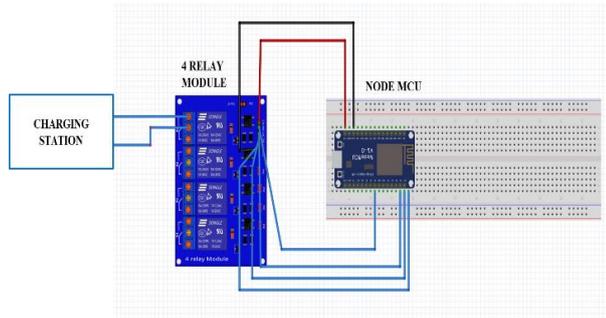


Figure 5. The design of the Charging station control circuit using Fritzing software

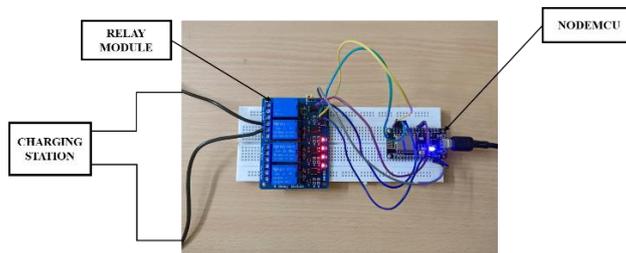


Figure 6. The actual design of the Charging station control circuit

The proposed schematic design of the charging station control circuit hardware consists of Node MCU, a 4-Relay module, and the Charging station as in Figure 5. and Figure 6. The Node MCU retrieves the information of booking status from the firebase. The collected data is processed by the Node MCU and sends the signal to the relay module. The relay module controls the voltage flow in the charging station.

7. Real-Time Monitoring System

Firestore is a collection of cloud-based services provided by Google, including user authentication, real-time databases, storage, hosting, and instant messaging. This research mainly utilizes user authentication and real-time database features, along with instant messaging, to implement event and SMS notifications. Additionally, Firestore's cloud system ensures secure data transmission through SSL encryption. The data collected from the hardware is stored in JSON format in the cloud-hosted Firestore Realtime Database. Every connected client receives a real-time synchronization of the data. In which every client automatically receives updates with the most recent data and shares a single instance of a real-time database.

7.1 Authentication

Firebase Authentication offers functions for creating and managing users in which the users can sign in using their email and password. It also manages the process of sending password reset emails to users. Figure 7 represents the Firebase Authentication database.

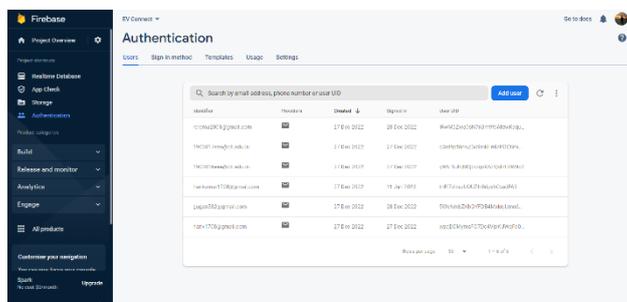


Figure 7. Firebase Authentication

7.2 Real-Time Database

Firebase Realtime Database offers offline support, allowing users to access and update data even when they're not connected to the internet. Once the device reconnects, the updates are automatically synced with the cloud-hosted database. It also provides robust security features, including user authentication and access controls, that help developers secure their data. It also includes a web-based console for managing data and monitoring usage. It's easy to integrate with Firebase's other services such as Firebase Authentication, Firebase Cloud Storage, and Firebase Cloud Functions for building complete, full-featured apps. The data fetched by the user in the application is sent to the firebase cloud storage as in Fig. 8. These data are used for sorting the charging station based on distance.

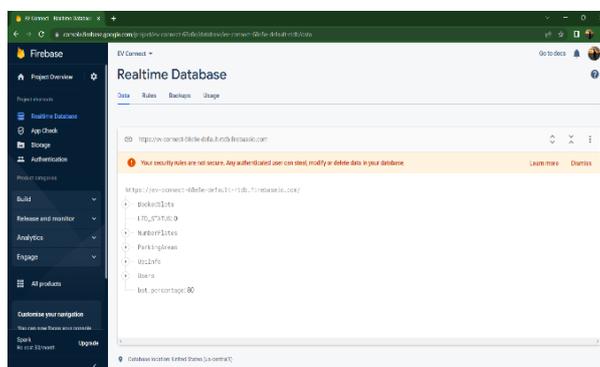


Figure 8. Firebase Realtime Database

8. Software Design

The android application is developed by using the IDE called android studio which has the features of code editing, layout editing, debugging, testing, and profiling tools. The proposed android application contains two categories one is for the user who is looking for a charging station and another one is for owners who can be able to register their charging station in the android application which will be displayed as a recycler view in the application. From this user can easily select and book the available charging station.

Sorting of Charging Station based on distance: The sorting algorithm requires the latitude and longitude of the user's current location and the latitude and longitude position of the registered charging station. Then with the help of the google map places API key, the accurate distance is calculated. The developed android application is integrated with Google Maps for navigation and distance estimation. The application is developed as the nearest available charging stations are listed first in ascending order. The user can easily book the charging station as per their required time slot.

Reservation algorithm: The user requests a charging station and provides information such as location, preferred charging time, and required charging time. The system checks the availability of the charging station and identifies the nearest available station that meets the user's requirements. The developed application reserves the station for the requested time period and sends a confirmation to the user. This monitors the status of the reserved station and updates the user in case of any changes or issues. If the user cancels the reservation, the application releases the station and makes it available for other users. To optimize the charging stations allocation and minimize waiting time, the algorithm could use historical data and real-time information about the availability and usage patterns of charging stations. It could also consider factors such as the battery level of the user's vehicle, the distance to the nearest charging station, and the predicted charging time based on the charging rate and the battery capacity. The allocation and deallocation of a particular slot of the charging station to the user are worked based on the below sample code.

```
allocateSpace(){
    this.availableSlots -= 1;
    this.occupiedSlots += 1;}
deallocateSpace(){
    this.availableSlots += 1;
    this.occupiedSlots -= 1;}
```

9. Results and Discussion

Arduino IDE is a tool that allows the users to communicate with the microcontroller on the Arduino board. The serial monitor allows the user to configure the settings of the monitor, such as the voltage range or SOC calculation algorithm. It also shows the Analog value, Output voltage, and Battery percentage collected from the battery in real time as in Figure 9.

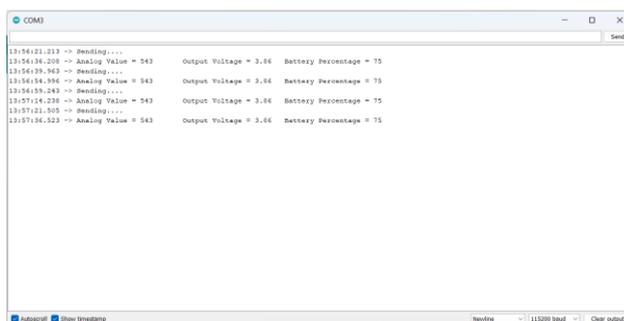


Figure 9. Serial Monitor in Arduino IDE

The state of charge from the battery is estimated using the SoC algorithm as shown in Figure 10. The SoC algorithm is based on the sensor value obtained from the ESP8266 and the battery calibration value obtained from the battery pack datasheet. The source code in the Arduino IDE is typically written in a variant of C/C++, designed to interact with the hardware of an Arduino board through a set of pre-defined libraries.

```

    Firebase.setInt("soc", 0);
  }

void loop()
{
  senout = analogRead(analogInPin);
  float V = ((senOut * 3.3) / 1024) * 2 + calibration);

  soc = mapfloat(V, 2.8, 4.2, 0, 100);

  if (soc >= 100)
  {
    soc = 100;
  }
  if (soc <= 0)
  {
    soc = 1;
  }
}

```

Figure 10. SoC Estimation algorithm in Arduino IDE

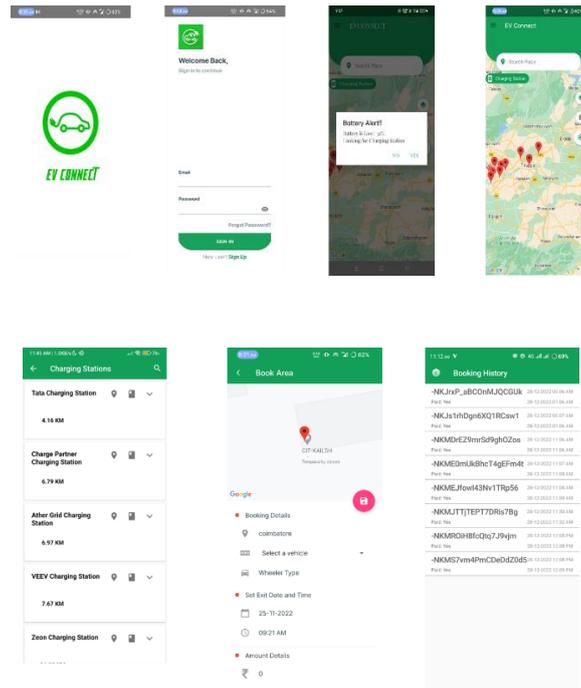


Figure 11. Working process of Mobile Application

The developed android application using the android studio as shown in Figure 11 contains a signup page, login page, Google Map with nearby charging station, booking page, booking history and charging station owners control page. The design of the signup page contains the username, Email, Password, and Image credentials. The signup page integrates the login page. Once the credentials are entered, the Email is sent for verification, by using the verify link, the user can verify their credentials. The design of the homepage contains different types of maps, user locations, and traffic data. After sign-in it displays a pop-up message which shows the real-time battery percentage. The charging station activity contains the list of charging stations and the distance between the users and charging stations. The users can access the charging station page and get information regarding the charging stations. The drop-down menu consists of the availability of slots in the charging station and the number of slots occupied in the charging station. It also addresses the location of that charging station and the amount for the booking of the charging station on a time basis. On the Booking Area page, the user can book their respective slots in the charging station. This page contains the charging station location and booking details. The booking details contain the vehicle information such as Number plate details, the type of vehicle that needs to be charged, the date and time for booking, and the amount that needs to be paid. The details of the booking can be viewed on the booking history page. It contains all the necessary information.

10. Conclusion

The Internet of Things (IoT) refers to the concept of connecting ordinary objects to the internet, and it has greatly contributed to the booming growth of electric vehicles (EVs). However, there is a risk of damaging the battery if it is over-drained in EVs. To overcome this issue, a solution has been proposed that would allow EVs to be used more effectively by sending important information like state of charge (SOC) to the user through a convenient interface. The proposed application shows the nearest charging stations and plug-in options for different EVs, including the estimated distance and real-time traffic information. Users can choose from a list of recommended charging stations closest to them and access the slot booking page to view available slots. This system saves users time waiting for a charging slot at the station. In cases where charging station applications are not regularly updated with the latest locations of chargers, drivers may avoid taking trips due to concerns that they may not be able to reach their desired destination. To help drivers efficiently plan their trips and achieve their desired range and trip time, they require a "trip plan" that guides them in the most efficient way possible. The application is built on Java and Android platforms, making them easily upgradeable for future technological advancements and increasing their adaptability within the network. To meet the needs of EV users, applications and platforms have been developed that connect EVs, users, and charging infrastructure. This application provides a range of useful features, including roadside assistance, remote door unlocking, charging activity feedback, navigation services, and collision notifications.

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Author's biography



Gowtham R is currently pursuing final year BE- Electrical and Electronics Engineering in Coimbatore Institute of technology, Coimbatore, Tamil Nadu. His research area of interest includes Digital Electronics and Internet of Things.



Guganesh P is currently pursuing final year BE- Electrical and Electronics Engineering in Coimbatore Institute of technology, Coimbatore, Tamil Nadu. His research area of interest includes Digital Electronics and Electric Vehicles.



Ilanchelvan Harikumar V is currently pursuing final year BE- Electrical and Electronics Engineering in Coimbatore Institute of technology, Coimbatore, Tamil Nadu. His research area of interest includes Internet of Things and Electrical Machines.



Ramachandran K is currently pursuing final year BE- Electrical and Electronics Engineering in Coimbatore Institute of technology, Coimbatore, Tamil Nadu. His research area of interest includes Java programming and Power system Analysis.



Udhaya Kumar C is currently pursuing final year BE- Electrical and Electronics Engineering in Coimbatore Institute of technology, Coimbatore, Tamil Nadu. His research area of interest includes Digital Electronics and Control Systems.



Priyadharshini A is currently working as Assistant Professor in the Department of Electrical and Electronics Engineering, Coimbatore Institute of Technology, Coimbatore. She did her master's in electrical and Electronics Engineering at PSG college of Technology and bachelors in Maharaja Engineering College, Avinashi. She has 17 years of teaching experience.

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