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A Novel Charging Management and Security Framework for the Electric Vehicle (EV) Ecosystem

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Abstract: The EV charging network has witnessed significant growth in the UK in the last few years due to the net zero emission target of the government by 2030. The related literature in EV charging management mainly focuses on road-traffic-parameter-based optimization and lacks detail in terms of charging statistics and cyber–security-enabled charging management frameworks. In this context, this paper proposes a novel EV Charging Management and Security (EVCMS) framework using real-time charging statistics and an Open Charge Point Protocol (OCPP). Specifically, a system model for EVCMS is presented considering charging data management and security protocols. An EVCMS framework design is detailed, focusing on charging pricing, optimization, and charging security. The experimental implementation is described in terms of client–server and charge-box-based simulation. The performance of the proposed EVCMS framework is evaluated by considering different charging scenarios and a range of charging-related metrics. An analysis of results and comparative study attest to the benefits of the proposed EVCMS framework for enabling the EV charging ecosystem.

Keywords: electric vehicle; charging optimization; charging security; OCPP

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1. Introduction

Governments all over the world are supporting Electric Vehicles (EVs) to achieve the goals of cleaner transportation [1]. EVs play a vital role in lowering air pollution, reducing noise, and cutting carbon emissions compared to traditional vehicles running on fuel. For instance, the UK government plans to stop selling fuel-driven vehicles by 2030, with hybrids following in 2035, aiming to reach net-zero emissions by 2050 [2]. This shift towards EVs aligns with global efforts to decrease fossil-fuel-driven vehicles and create a more sustainable future [3]. The increase in EV sales has been driven by notable enhancements in the technology and design of EVs [4]. These improvements include the development of more efficient and high-capacity batteries, which have increased the energy density, extended the driving range, and significantly reduced charging times, addressing some of the initial limitations of EVs [5]. Furthermore, advancements in design and features, along with an increased emphasis on sustainability, have made EVs more attractive to environmentally conscious consumers [6]. However, the surge in EV sales has also exposed the need for a more extensive and reliable charging infrastructure [7]. To meet this demand, governments and private entities have invested in expanding the charging network, with the establishment of fast charging stations and the introduction of smart charging management systems [7]. Fast charging stations play a pivotal role by significantly reducing charging times, while smart charging management systems ensure efficient resource utilization and cost minimization for EV users. Leveraging cloud services in EV charging infrastructure enables real-time monitoring and data analysis, elevating user experience and infrastructure efficiency [8]. These enhancements to EV infrastructure have played a vital role in addressing the challenges associated with EV adoption, further promoting the growth of the EV market.

The rapid expansion of the EV charging infrastructure has brought forth a new set of challenges, such as user inconvenience, cyber-security, optimal scheduling, and poor real-time performance. According to [9], the use of an online reservation system can significantly reduce long wait times, thereby preventing congestion and improving customer satisfaction. With the integration of internet-connected systems, charging stations are increasingly susceptible to cyber threats, such as hacking and data breaches [10]. Safeguarding the personal and financial data of EV users is paramount, requiring robust cyber-security measures to protect against potential attacks. In addition to security concerns, ensuring the optimal scheduling of charging sessions is another critical aspect. Smart charging management systems are being developed to address this challenge, allowing for efficient resource allocation and the distribution of charging demand [11]. By analysing charging data, these systems aim to minimize costs for EV users while balancing the grid's load. Furthermore, the use of software systems with an OCPP protocol is considered a suitable solution for large-scale infrastructures that can enhance real-time performance and security requirements [12]. Consequently, addressing the above issues will be pivotal in ensuring the seamless and secure operation of the EV charging infrastructure.

Driven by these issues and challenges, this paper introduces the EVCMS communication protocol architecture as shown in Figure 1. The proposed architecture addresses the issues of optimizing charging schedules at an Electric Vehicle Charging Station (EVCS) by allowing EV users to make reservations through a web application using HTTP. Utilizing an optimization algorithm, charging plans are dynamically generated based on user preferences and EV charging requirements. Once the user selects a plan and confirms the reservation, a booking is made. Upon arrival at the charging station, EV drivers can connect to chargers using the ISO 15118 [10] protocol. Once the user enters the booking ID, the charging connection is remotely controlled via the OCPP protocol to manage each EV charging point. The aim is to enable users to reserve charging outlets in advance and charge at charging stations without human intervention. The optimization method applied in the framework aims to minimize the wait time and the total charging cost for both EV drivers and the EVCS, ensuring cost-effective and efficient charging operations. The novelty of this study lies in the unique integration of real-time charging statistics with the OCPP protocol, which enhances both the charging plan optimization and the security of EV charging sessions. This differentiates the proposed framework from existing studies, which primarily focus on road-traffic-parameter-based charging session planning without much focus on EV charging session security. Thus, the objective of this study is to improve the charging infrastructure by optimizing charging plans, facilitating real-time access, and strengthening the security of smart charging management systems.

The key contributions of this paper can be summarized as follows.

1. A system model for the proposed EVCMS framework is presented considering the overall implementation architecture of the framework.
2. An EVCMS framework is proposed as a system design considering technical details of charging pricing and charging optimization.
3. Implementation details and critical performance evaluation of the proposed EVCMS framework are carried out with a focus on a realistic EV charging environment.

The remainder of this paper is organized as follows. In Section 2, a comprehensive literature review is presented. Section 3 outlines the methodology used for implementing the EVCMS framework. Section 4 presents the results of implementation. Section 5 focuses on performance evaluation. Section 6 concludes the paper with future research directions.

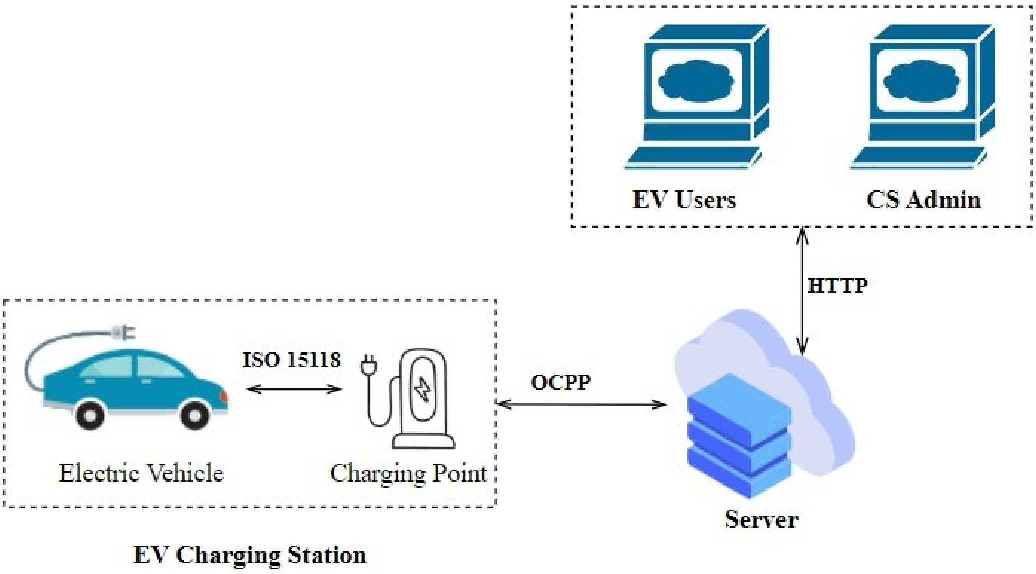

Figure 1. EVCMS communication protocol architecture.

2. Literature Review

Several research studies and commercial implementations are aiming at modernizing the charging procedure for EVs. The enhancement of fast charging technology was incorporated to reduce charging time and improve EV user convenience [13]. The EV user experience was also improved by means of user-friendly mobile interfaces and customer-oriented features to increase user demand [13]. The public found inconvenience with wired charging infrastructure, so implementing wireless charging technology to eliminate the need for cords and improve user convenience was an example of progress [14]. There are many studies showing problems with low EV batteries in long-distance journeys. This prompted the use of advanced battery-management systems for improved and longer-life batteries [15]. Optimized charging stations and cost-effective charging methods were adapted to minimize production costs and maximize profitability [16]. For instance, ref. [17] suggests some sustainably rechargeable options in an effort to minimize carbon emissions and support a cleaner transportation system. In [18], the authors suggested charging stations be integrated with the smart grid to enhance power usage optimization and address imbalances in networks. All these studies and implementations demonstrate the importance of improving the EV charging process to provide a more convenient, efficient, and cost-effective EV charging experience. Through this proposed work, the intention is to improve EV charging with improved security.

2.1. EVCS Optimization

Several studies and commercial implementations have focused on enhancing real-time operation, as well as optimizing EV charging plans. The authors of [19] used real-time data and optimization algorithms, which led to improved performance by dynamically adjusting the EV charging prices. As indicated in [20], predictive maintenance algorithms may help avoid possible charging station failure and enhance general reliability. As the number of EVs is increasing, more EVCSs and better load-balancing schemes are needed to manage charging needs. The authors of [21] provided a smart routing system for EVs for load balancing in smart grids, which also helps in balancing the charging demand at different charging stations, which increases efficiency, thereby reducing or limiting grid imbalances. The emergence of smart EVCSs in recent years has raised various privacy and security issues related to the smart grid, which may generate legal challenges [22]. These challenges affect how private, sensitive information is transmitted among EVs, EVCSs, and smart grids. Therefore, securing communications in EVCS infrastructure is crucial.

2.2. EVCS Communication Security

Safe communication channels between the charging station and the cloud-based management system should be ensured, preventing malicious users. Moreover, secure authentication processes should be used to allow only legitimate users to access charging facilities. The encryption of sensitive information like billing information and energy data could prevent data leakage and unwanted data disclosure. Therefore, it is crucial to have knowledge of various EVCS communication protocols utilized for effective EV charging infrastructure.

A connection is needed between an EV's charger and the EV itself. Commonly used EV communication standards are the International Standard Organization 15118 (ISO 15118), the International Electrotechnical Commission 61851 (IEC61851), and OCPP [23]. These standards have different uses and applications. ISO 15118 is a communication protocol used to secure and streamline communication between the EV and EVCS. It is used to confirm the EV's identity and manage charging details [24]. IEC61851 defines the general requirements, testing methods, and test procedures for EV charging systems and equipment [25]. It also defines AC and DC charging modes and the requirements for each mode. OCPP is an open-source communication protocol that is widely used in EVCSs to communicate with EV charging stations [26]. It is a widely adopted communication protocol for EVCSs as it is an open standard [12] and can be used by any EV charging station manufacturer. OCPP has been designed with simplicity and efficiency. It is built on a client–server architecture. OCPP can be used to exchange basic information like charging station availability, charging status, and real-time pricing [26].

One of the main differences between these protocols is that IEC61851 focuses on the technical aspects of the EV charging equipment and the communication between the EV and the EVCS, whereas OCPP and ISO15118 are more focused on the communication protocols and the information exchanged between the EV and EVCS [23]. Both standards are important to ensure the compatibility and safety of EV charging systems. OCPP in EVCS provides a convenient, efficient, and cost-effective solution for managing and controlling EV charging process [12]. OCPP also ensures security in EVCSs by providing access to real-time information. As the objective of the proposed system is to ensure real-time performance along with security, we intend to opt for an OCPP communication protocol for this design. There are certain measures that need to be adapted to ensure security in EVCSs with the use of OCPP.

These studies and implementations demonstrate the importance of optimizing EV charging plans, improving real-time performance, and ensuring security in EV charging management systems. The proposed system aims to optimize the EV charging plans with real-time optimization in compliance with industry standards and provide improved security by incorporating secure communication, customer authentication, and data encryption.

3. EVCMS Framework

Within the EVCMS framework, this discussion encompasses the system model, detailing its structure and components, followed by the system design, outlining the implementation of charging price and charging optimization. Additionally, the focus extends to system security, addressing measures to safeguard against potential threats.

3.1. System Model

A cloud-based smart charging management architecture for EVCMSs, as shown in Figure 2, is designed to manage the charging of EVs through a cloud-based platform. The system provides a centralized platform to manage the charging of EVs and track the reservation for EV users. It utilizes the OCPP protocol to communicate with charging stations and manage the charging process. It can be used to manage multiple charging points and provide a seamless charging experience for EV users through an easy-to-use interface.

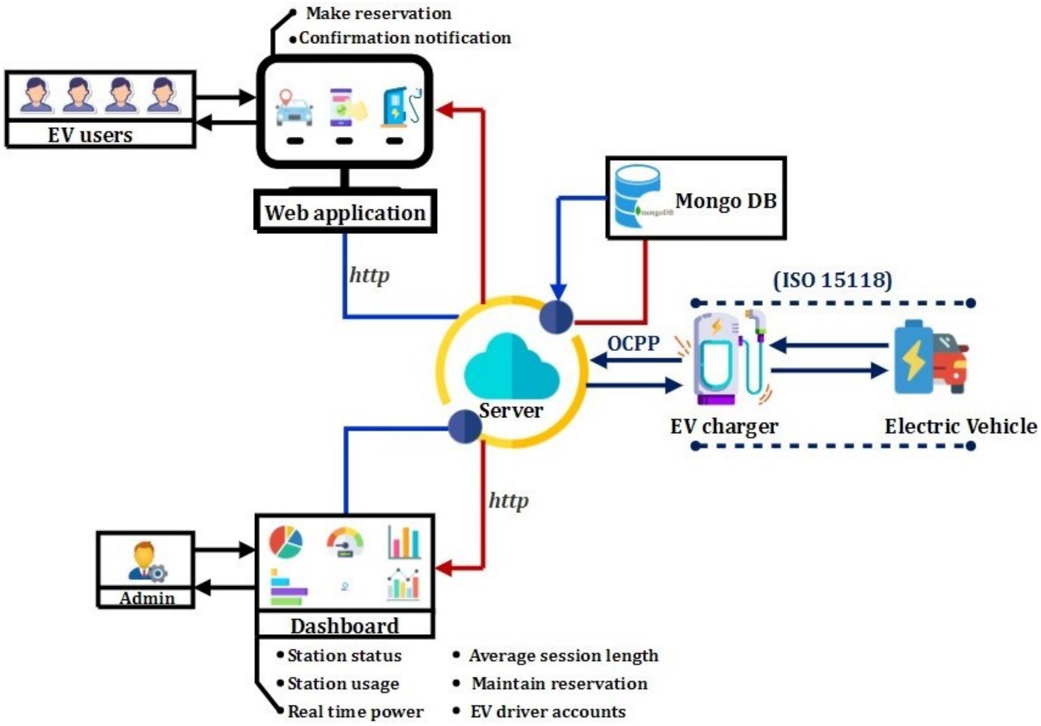

Figure 2. EVCMS framework.

The system aims to enhance the EV charging experience by optimizing charging plans for efficiency, convenience, and cost-effectiveness. This is achieved through dynamic pricing based on real-time energy demand, supply, and pricing data, enabling adjustments to charging prices for improved cost efficiency. Additionally, customer engagement features offer personalized charging experiences with a web charging control, customized plans, and money-saving suggestions, all geared toward enhancing user satisfaction. Another key objective is the automation of the EVCMS to efficiently manage all reservations through smart charging operations conducted remotely. This is achieved by implementing the OCPP protocol, enabling the automatic and smart operation of the charging station based on scheduling results. This integration of the OCPP protocol enhances the charging system's intelligence and efficiency.

The client-side web application enables users to reserve charging slots for EVs, specifying parameters like booking date, arrival time, duration, and charging power. It optimizes reservations to prevent queuing and provides features to pair with reserved charging units. Post-charging, the application displays essential information such as the time taken, the current battery status, the power consumed, and the session cost. On the server side, a dashboard using the OCPP protocol remotely manages the charging station. It displays booked slots, the individual and overall state of charge, the number of vehicles charged, the time taken, the power consumed, and the cost of the session. The server allows remote start/stop of charging sessions and notifies users when the EV is connected or fully charged.

3.2. System Design

In the system design of the proposed EVCMS framework, three crucial components are addressed: charging price, charging optimization for generating optimized plans, and system security. In the EVCMS framework, EV drivers set charging preferences and make reservations. The system dynamically generates charging solutions through optimization, factoring in user preferences, station availability, and peak OFF/ON times, allowing drivers to confirm or cancel their chosen plan.

3.2.1. Charging Pricing

The cost of a charging session is calculated based on the charging station and the pricing model selected. In general, the price per session for a charging station is the factor of the amount of energy in kilowatt-hours (kWh) delivered during the session multiplied by the cost per kWh. There are also some instances whereby additional fees may be charged on certain charging stations or even as time-based object prices, as well as pricing plans or discounts, due to availability, which may affect the amount of app credit to be expended per charging session. To derive the formula for the EV charging price for each session of the proposed system, the following parameters have been taken into consideration:

1. Cost of energy price: the price per unit of energy (kWh) used during the charging session.
2. Duration consumed: the total time in hours (h) that the EV was connected to the charging station and consuming energy.
3. Charging rate: the rate at which the EV battery is charged at the EV charging station. It is measured in kilowatts (kW) and can be considered as the power output of a charging station.
4. Power output: the maximum power output of the charging station (in kW) per day.
5. Charging efficiency: The charging station needs to convert electrical energy into battery energy for an EV to charge at the charging station. The measure with which this is carried out is the charging efficiency, and it is represented as a decimal value between 0 and 1, where 1 indicates that charging efficiency is 100%, considering all electrical energy supplied to the charging station is utilized to charge the EV batteries.
6. Time-of-use charges: the time when an EV is charged at the charging station. As at some times of day, electricity prices are high, represented as the Peak On Time, and time of day when electricity prices are low, represented as the Peak Off Time. Along with the time of day, the availability of the charging station is also considered, and the ToU factor is decided as shown in Table 1.
7. Peak demand charges: If the EV is charged at a charging station when the electricity prices are high, then this charge will be taken into consideration. Peak On Times are defined in legislation as 8 a.m. to 11 a.m. and 4 p.m. to 10 p.m. on weekdays.
8. Availability in station: whether the charging station is available to use or not at the desired time.
9. Service Charge of Station: additional charges applied by a charging station for utilizing their service.

Table 1. Parameters for the ToU.

Factor	Availability	Peak Time
0	Available	Peak OFF
0.25	Partially Available	Peak OFF
0.5	Available	Peak ON
1	Partially Available	Peak ON

To derive the pricing model for EV charging, the following nomenclature is used as defined in the Abbreviations section.

With these parameters, the following formula was derived for the EV charging price for each session:

$$\text{EV Charging Price} = (Ec \cdot Es) + \text{ToU} + \text{SC}_{CS} \tag{1}$$

where

Energy Consumed (in kWh) = Duration Consumed (in hours) × Charging Rate (in kW)

$$i.e., \; Es = Dh \cdot Crate \tag{2}$$

Charging Rate (in kW) = Maximum Power Output of the Charging Station (in kW) × Charging Efficiency (as a decimal)

$$i.e.,\ Crate = Pmax \cdot Ceff \tag{3}$$

Time-of-Use Charges = Availability × Peak Demand Charges

$$i.e.,\ ToU = \mathrm{A}_{CS} \cdot PDC \tag{4}$$

Substituting (2), (3), and (4) into (1), the following formula can be derived:

$$EVChargingPrice = (Ec \cdot Es) + ToU + \mathrm{SC}_{CS} \tag{5}$$

$$= (Ec \cdot Dh \cdot Crate) + ToU + \mathrm{SC}_{CS} \tag{6}$$

$$= (Ec \cdot Dh \cdot Pmax \cdot Ceff) + ToU + \mathrm{SC}_{CS} \tag{7}$$

$$= (Ec \cdot Dh \cdot Pmax \cdot Ceff) + (ACS \cdot PDC) + \mathrm{SC}_{CS} \tag{8}$$

3.2.2. Charging Optimization

Generating optimized plans for EV users based on various parameters can be a complex task, but by leveraging cloud services and data analytics tools, one can achieve this efficiently and effectively [27]. The proposed EVCMS framework optimizes the charging plans, by reducing the EV charging price parameter through efficient scheduling and pricing strategies. To generate optimized plans for EV users, parameters such as power requirement and the time requirement of the user are taken into consideration, along with the availability of the charging station and the Peak Off/On Time of the charging station.

The Algorithm 1 checks availability and assign time slot to EV users. This algorithm begins by initializing variables such as the start time (startTime), end time (endTime), and a flag (isTimeSlotOverlapping) to track the overlap status. It then iterates through existing bookings, comparing their time slots with the user-requested time. If there is an overlap with existing bookings, then the algorithm sets the flag to true and searches for an alternative time slot by increasing the start time of the requested booking by 15 min. This is continued in a loop unless a nonoverlapping slot is found. Once a suitable time is identified, the algorithm finalizes the new date and time (finalDateTime). If there is no initial overlap, the algorithm directly finalizes the date and time to the user's requested time. The algorithm returns a value (isAvailable) indicating whether the requested time slot is available and the finalized date and time for the booking (finalDateTime). Thus, the algorithm efficiently manages booking conflicts, ensuring users are assigned available time slots or proposing suitable alternatives when needed.

The Algorithm 2 generate plans to optimize charging cost for an EV user. It begins by determining if the requested charging time falls within a peak period. The algorithm first determines the peak status of the final date and time. Based on availability and peak status, the algorithm then calculates cost multipliers. If isPeakOn is true and there is a time slot overlap, it assigns a cost multiplier of 1, indicating that the charging is not available in the Peak On Time period. Otherwise, if there is no time slot overlap, it sets the cost multiplier to 0.5, signifying availability in the charging station but in the Peak On Time period. On the other hand, if isPeakOn is false, the algorithm assigns a cost multiplier of 0.25 in the case of a time slot overlap, indicating that charging is not available in the Peak Off Time period.

Algorithm 1: Check Availability and Assign Time Slot

```
Input: dateTime (givenDate & givenTime), duration, allBookings
Output: isAvailable, finalDateTime
Start:
startTime ← givenTime
endTime ← givenTime + duration
isTimeSlotOverlapping ← false
for booking in allBookings do
    bookingStart ← booking.time
    bookingEnd ← booking.time + booking.duration
    if current booking start and end overlap with user requested time then
        isTimeSlotOverlapping ← true
        break
if isTimeSlotOverlapping then
    newStartTime ← givenTime + duration
    while true do
        newStartTime ← previous start time + 15 min buffer
        newEndTime ← newStartTime + duration
        isTimeSlotOverlapping ← false
        for booking in allBookings do
            bookingStart ← booking.time
            bookingEnd ← booking.time + booking.duration
            if user requested date-time overlaps with new date-time then
                isTimeSlotOverlapping ← true
                break
        if isTimeSlotOverlapping then
            update the time to the next 15 min from the original time and continue
              checking for overlap
        else
            finalize the new date-time
            finalDateTime ← newStartTime
            break
else
    finalize the given date-time
    finalDateTime ← givenDateTime
Return: isAvailable, finalDateTime
```

If there is no time slot overlap during the Peak Off period, the cost multiplier is set to 0, implying that charging is available at no additional cost. The algorithm then returns the computed Availability Cost Multiplier (ACM). The overall charging price is then computed, including the time-of-use charges, considering energy cost, duration, charging rate, and additional service charge.

Based on the availability of charging stations and Peak Off/On Time data analyzed by the cloud server, further plans will be generated. These plans might involve determining the most efficient time to charge based on the user's power and time requirements and the Peak Off/On Times of the charging station. Based on the parameters taken into consideration, the following optimized plans can be generated to suit user requirements considering the charging station's requirements:

1. Plan 1 (Duration): The user has entered the arrival time, duration, and power required. However, the power required is not sufficient to charge the EV as per the time requested. So, another plan is provided with updated charging power to meet the time constraints.

2. Plan 2 (Power): The user has entered the arrival time, duration, and power required. However, the required time is not sufficient to charge the EV as per the charging power requested. So, the time is updated in one plan to meet charging needs.
3. Plan 3 (Duration Eco): An enhancement is made to plan 1 by shifting the time slot to Peak Off Time period. In this plan, the system suggests the nearest possible Peak Off Time slot with respect to the required time duration. This plan minimizes the charging cost compared to the plan 1 charging cost.
4. Plan 4 (Power Eco): An enhancement is made to plan 3 by shifting the time slot to Peak Off period. In this plan, the system suggests the nearest possible Peak Off Time slot with respect to the power required. This plan minimizes the charging cost compared to plan 3's charging cost.

Algorithm 2: Generate Plan

```
Input: finalDateTime, isAvailable,CostOfEnergy (Ec), Chargingrate(Crate),
 peakDemandCharge(PDC), ServiceCharge(SCcs)
Output:List of Plans
Start:
if ((dT ≥ 8am AND dT ≤ 11am) OR (dT ≥ 4pm AND dT ≤ 10pm)) then
    isPeakOn ← true;
isPeakOn ← false;  if isPeakOn ==true then
    if isAvailable then
        availabilityCostMultiplier ← 0.5
    else
        availabilityCostMultiplier ← 1
else
    if isAvailable then
        availabilityCostMultiplier ← 0
    else
        availabilityCostMultiplier ← 0.25
TimeOfUseCharge (ToU) = availabilityCostMultiplier × PDC
ChargingPrice = (Ec × duration × Crate) + ToU + SCcs
if isPeakOn ==false then
    Power ← duration × chargingRate
    Plan 1:Based on "duration" requirement, adjust power
    Plan 2: Based on "power" requirement, adjust duration
else
    Power← duration×chargingRate
    Plan 1:Based on "duration" requirement, adjust power
    Plan 2:Based on "power" requirement, adjust duration
    dateTime ← get a time-slot available in the peakOff period
    Plan 3:Based on "duration" requirement, adjust power in peakoff
    Plan 4:Based on "power" requirement, adjust duration in peakoff
Return: List of Plans
```

The first two plans are generated in both statuses (Peak On and Peak Off) by adjusting either power or duration to meet specific user requirements. If the charging time is during the Peak On period, the algorithm generates the first two plans in the Peak On Time period and also seeks an alternative slot in the Peak Off Time period and creates two more plans with adjusted power or duration in the Peak Off Time period. These plans are considered as Eco plans. Thus, the algorithm outputs a list of plans tailored to user preferences, availability constraints, and cost optimization.

Figure 3 presents the flowchart of the EVCMS optimization algorithm. This flowchart serves as a roadmap for the EVCMS framework, enabling it to optimize its operations and enhance service efficiency. The flowchart visually guides the process of resource management and overall optimization process.

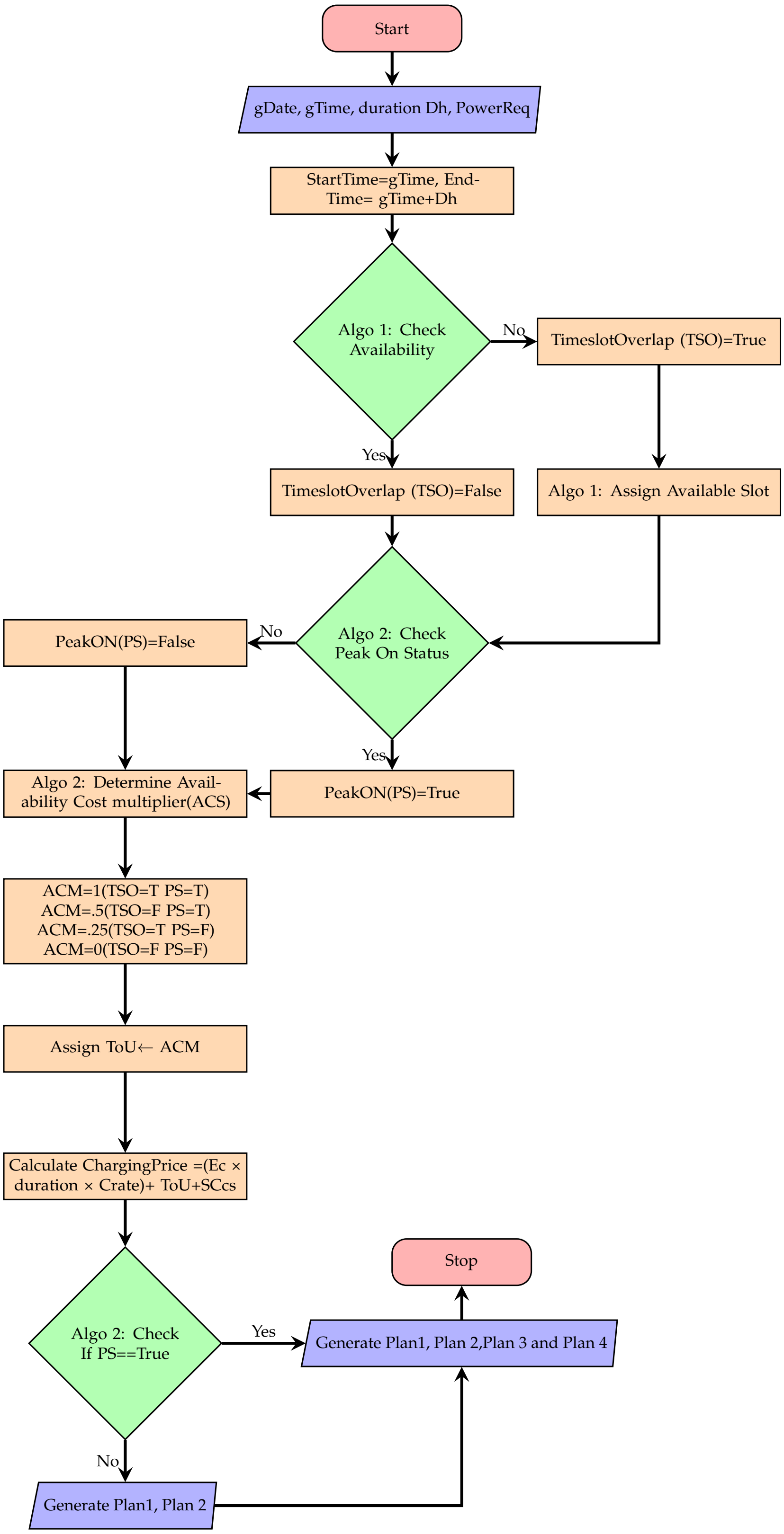

Figure 3. Charging plan optimization flowchart.

The complexity of the optimization algorithm can be described using two components, namely space and time complexity. Time complexity indicates how the algorithm's execution time grows relative to the input size. Lower time complexity signifies better efficiency. Similarly, space complexity reflects how much memory the algorithm requires as the input grows. Lower space complexity indicates more efficient memory usage. Considering that the EVs for charging will be limited each day, time complexity analysis is the major component in the complexity analysis of the proposed optimization technique. Let Tg be the time gap between each EV booking time, and let Nb be the number of bookings per day. To determine the available slot, we linearly scan through all bookings (Nb) and find the available slot. The time complexity of the step is O(Nb). If there is no available slot, then the algorithm seeks the next available slot in the increment of the time gap (Tg). If the time gap (Tg) is checked for, the next available constant is slot found (15 min). If the time gap (Tg) is set to 15 min, the system will check for the next available slot 15 min after the current slot becomes unavailable.

For any day, the max gap available is calculated by the total time per day in minutes/time gap = 24 × 60/15 = 96, which can be considered constant. Thus, the worst-case complexity of this step would be O(96 × Nb) = O(Nb). Using these notations, the time complexity of the algorithm is linear and can be expressed as O(Nb). The plan generation is a constant time operation based on the peak status and the availability it can generate, which is a maximum of four plans. So the space complexity is also constant and can be expressed as O(1). As the proposed algorithm has a lower time complexity when O(Nb) and space complexity when O(1), the algorithm is highly efficient and can process larger inputs quickly while using minimal memory.

3.3. Charging Security

The implementation process of integrating the OCPP-RPC (Open Charge Point Protocol Remote Procedure Call) library [28] and the OCPP-1.6 Chargebox Simulator [29] involved several steps to achieve seamless communication and control within the EV charging ecosystem. Initially, the OCPP-RPC library was employed as a foundational component due to its capabilities in managing remote procedure calls in the OCPP. The process commenced by obtaining the library from its GitHub repository and incorporating it into the project. This library served as the bridge to initiate communication between the EVCMS framework and the Chargebox simulator. Simultaneously, the OCPP-1.6 Chargebox Simulator was sourced from its repository [29]. This simulator, designed for OCPP version 1.6, was selected for its compatibility with the chosen OCPP-RPC library. The simulator's setup involved configuring essential parameters, including the supported OCPP version, the charging point details, and the communication settings, ensuring alignment with the chosen library. Next, the integration efforts focused on coordinating the functionalities of the OCPP-RPC library and the OCPP-1.6 Chargebox Simulator. This involved modifying the EVCMS backend to accommodate interactions using the OCPP-RPC library. Communication endpoints were established within the EVCMS framework to facilitate the exchange of OCPP messages with the simulator using an encrypted channel. Instances of the OCPP-1.6 Chargebox Simulator were then linked to these communication endpoints, enabling a streamlined flow of OCPP messages between the EVCMS and the simulator. The communication protocol was precisely defined, outlining the specific messages required for actions like connecting, authorizing, initiating, and stopping charging sessions. By doing so, the communications channel can be encrypted such that the charger and EVCMS server have a secure connection to avoid any unauthorized access.

4. Implementation

The cloud-based EVCMS framework depicted in Figure 2 comprises two key modules: the client–server and the OCPP Chargebox simulator. These critical components work together to ensure the system's functionality. Further details on each module will be explored in subsequent subsections.

4.1. Client Server

React was chosen as the framework for developing the front end of the EVCMS client–server module due to its ability to create intricate user interfaces using reusable components. A variety of additional tools and packages were leveraged alongside React to expedite development and introduce extended functionalities [30]. The unique way React manages updates ensured a swift and seamless user experience, a critical aspect given the frequent UI changes required [31]. Node.js was selected as the back-end technology owing to its scalability, robust security features, and strong performance [32]. Notably, Node.js includes built-in support for secure communication between the server and clients through TLS/SSL encryption [33]. Its adeptness at managing multiple simultaneous connections made it apt for real-time data processing and rapid data retrieval, which are both essential for the project's needs [32].MongoDB was the preferred database solution due to its adaptability and scalability. Its support for data sharing and replication contributed to high data availability and reliability [34]. MongoDB's dynamic schema allowed for the efficient storage and retrieval of complex data structures, aligning well with the evolving data requirements of the project.

The integration of various technologies played a pivotal role in achieving the project objectives, ensuring a secure and user-friendly charging experience for EV owners. The web application developed for cloud-based client-side EVCMS architecture shown in Figure 4 proved to be highly effective in enhancing the user experience and streamlining the charging process. The implemented features aimed to enhance user experience and streamline the EV charging process. One significant aspect was the introduction of Reservation Flexibility, allowing users to customize charging parameters and plan sessions in advance. This eliminated the need for queuing, ensuring a seamless charging experience. Additionally, the application offered Slot Reservations, enabling users to secure a charging slot at their preferred time. Pairing this with the reserved charging unit further improved the overall convenience. Post-charging, users could access detailed Charging Status and Information, offering insights into the state of charge, charging duration, battery status, energy consumption, and session costs. This transparency empowered users to effectively manage their charging expenses.

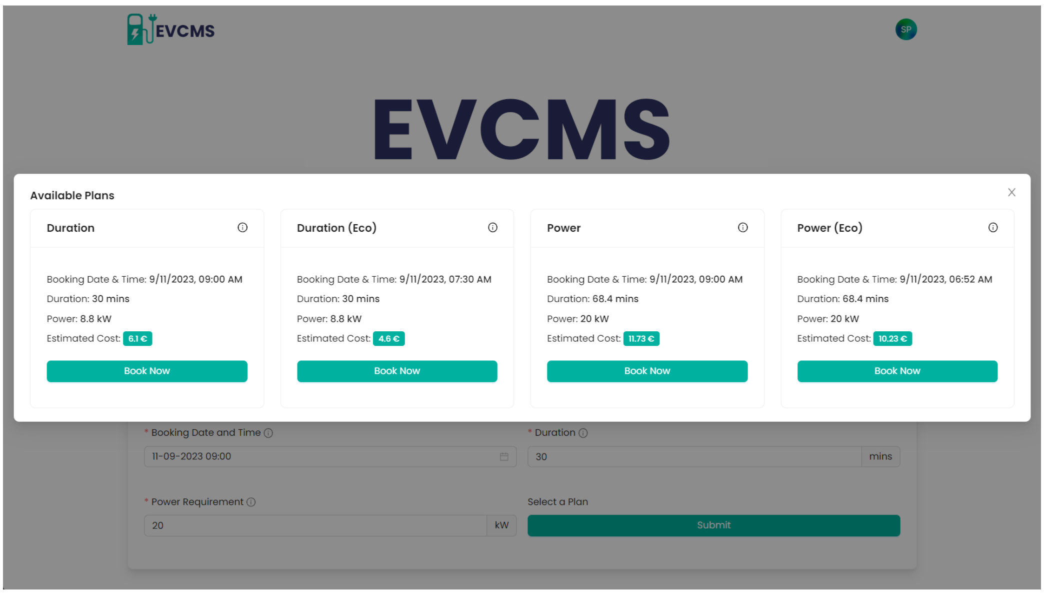

Figure 4. Client-side user interface for the cloud-based EVCMS framework.

The cloud-based server-side dashboard for the EVCMS framework, shown in Figure 5, serves as a central control hub, empowering operators with essential tools to monitor and manage charging stations efficiently. The server-side UI introduces key features that significantly enhance the management and user experience of EV charging stations. A central component is the provision of real-time access to Booking and Charging Data through a comprehensive dashboard. This feature facilitates the efficient monitoring of booked slots and vehicle charging status, empowering operators to make informed decisions for optimizing station utilization. Another noteworthy feature is Remote Charging Session Control, which utilizes the OCPP protocol. This capability allows operators to remotely initiate and conclude charging sessions once vehicles are paired with the charging unit. By minimizing the need for manual intervention, this feature not only streamlines the charging process but also boosts operational efficiency. Both charging station operators and EV users benefit, as operators can manage multiple stations remotely while users enjoy a convenient and seamless charging experience. The implementation also incorporates User Notifications, adding a layer of proactive communication for EV owners. Automated notifications inform users when their EV is successfully connected to the charging unit and when the charging session is complete. This real-time feedback ensures that users stay informed about their charging progress, contributing to a user-friendly and satisfying overall experience.

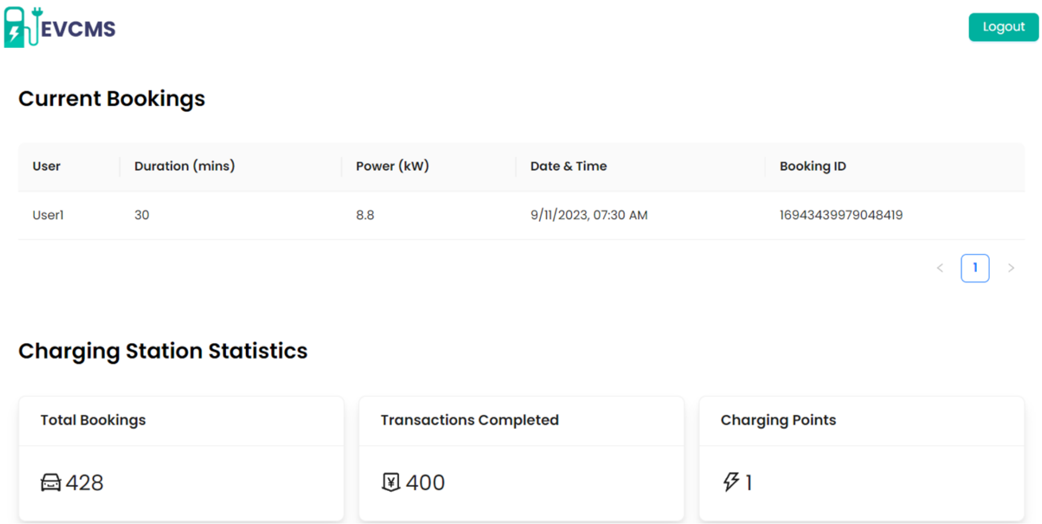

Figure 5. Server-side user interface for the cloud-based EVCMS framework.

4.2. OCPP Chargebox Simulator

The framework utilized OCPP to communicate with charging stations, seamlessly managing reservation, charging, and billing operations. The UI for the Chargebox simulator is designed to be user-friendly and intuitive. It provides a clear and straightforward interface that allows users, including EV drivers and operators, to easily interact with the simulator. Figure 6 showcases the user interface of a Chargebox simulator used within the EVCMS framework. The UI is a user-friendly gateway for both EV drivers and operators, providing intuitive controls to configure connections to the EVCMS framework. It includes authentication features for secure access, real-time connection status indicators, and a log panel for messages and error notifications. Action buttons for Connect and Disconnect simplify the connection process, with feedback mechanisms ensuring that users are well informed about the connection status. This UI's role is pivotal, enabling users to seamlessly interact with the charging management system and manage charging sessions effectively, all within an accessible and user-centric environment.

The connection between the EVCMS framework and the Chargebox simulator is made smooth and is controlled with the help of OCPP 1.6. Figure 7 highlights the central role of OCPP in the integration of EV charging services within a cloud-based EVCMS and the Chargebox simulator's various functions. This pairing lets users interact easily with the simulator, creating a link between the virtual environment and the real charging setup. To initiate this process, the OCPP client within the Chargebox simulator first establishes a secure connection and obtains authorization from the OCPP server within the EVCMS.

This foundational step sets the stage for subsequent interactions between the charge point and the EVCMS. Once authorization is secured, users can input their booking ID within the simulator's interface, which then leverages OCPP to validate the booking ID by forwarding it to the primary EVCMS server.

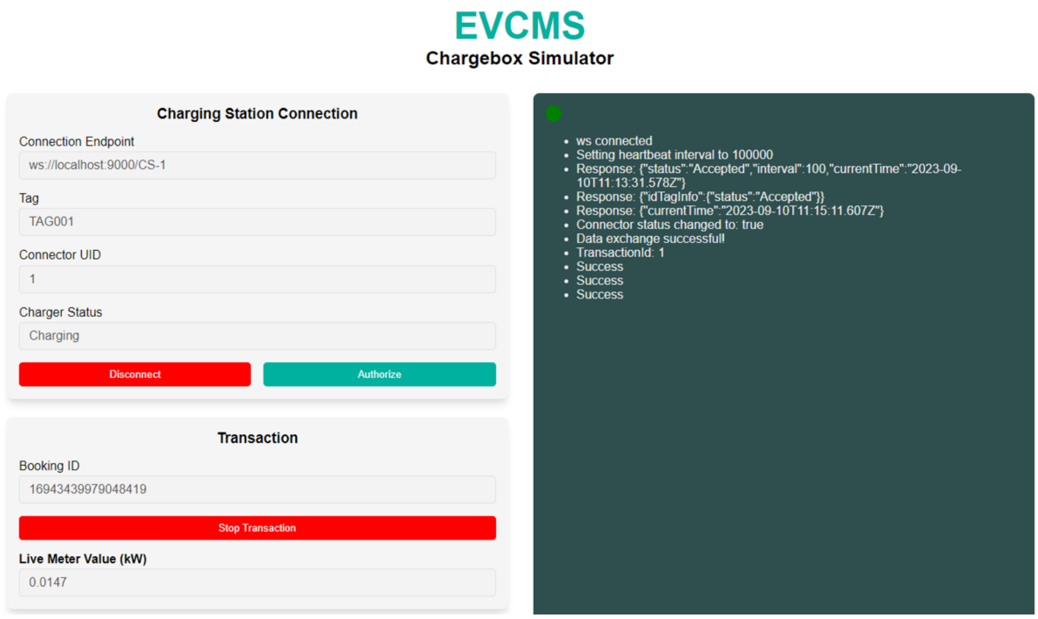

Figure 6. Chargebox simulator user interface for the cloud-based EVCMS framework.

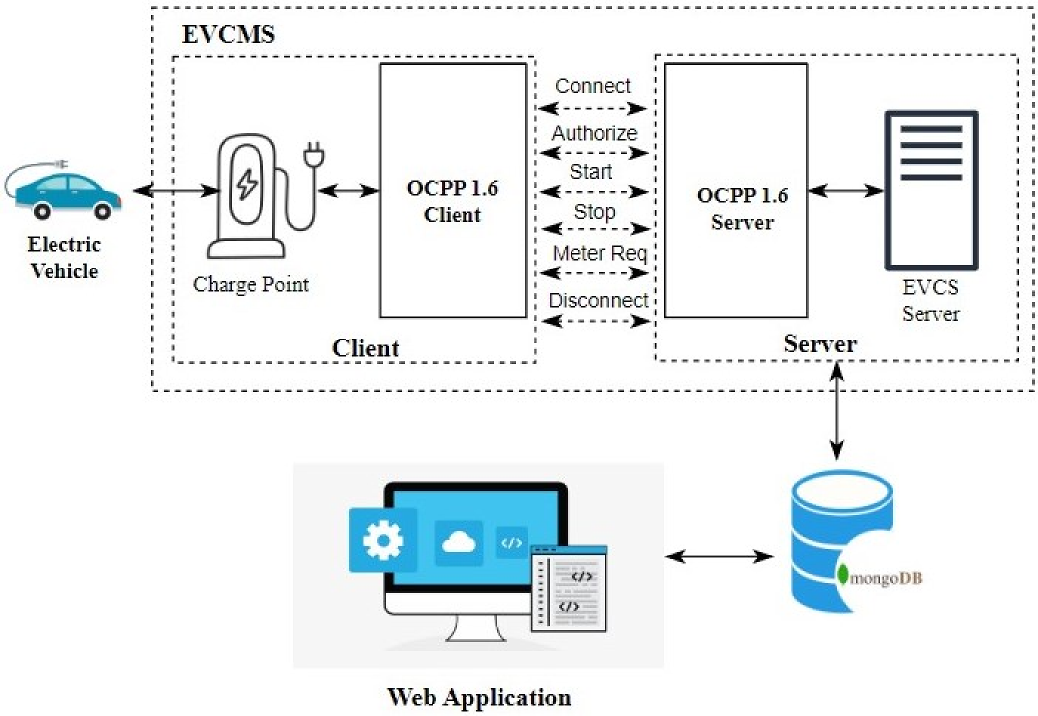

Figure 7. Integration of OCPP in the cloud-based EVCMS framework with the Chargebox simulator functions.

Following successful validation, OCPP is employed once more, this time to transmit specific authorization instructions back to the Chargebox simulator. This essential authorization process ensures that the EV is granted access to the charging infrastructure. With authorization in place, users gain the capability to interact seamlessly with the Chargebox simulator via its user interface. OCPP functions for the Chargebox simulator, such as

Connect, Authorize, Start Charging, Stop Charging, Meter Values Request, and Disconnect in an EV charging system, involve integrating the protocol into both the client and server EVCMS.

Below is a high-level representation of each function request and response with the charge box simulator:

1. Connect
   In the Chargebox implementation, the Connect function utilizes the OCPP BootNotification message, facilitating communication between the Chargebox and EVCMS, as illustrated in Figure 8. When the EV connects or the Chargebox boots up, it sends a BootNotification request to the EVCMS, carrying the charge point information. The Chargebox then handles the BootNotification response, containing configuration data about the OCPP server. For the EVCMS, the system actively monitors incoming BootNotification requests from various Chargeboxes. Upon receipt, it rigorously validates the charging station's identity. Subsequently, EVCMS promptly sends a BootNotification response, indicating the approval or denial of the connection request. If accepted, the response may include relevant configuration parameters for subsequent setup procedures. This ensures a safe handshake between the client and the server before the actual charging session starts.

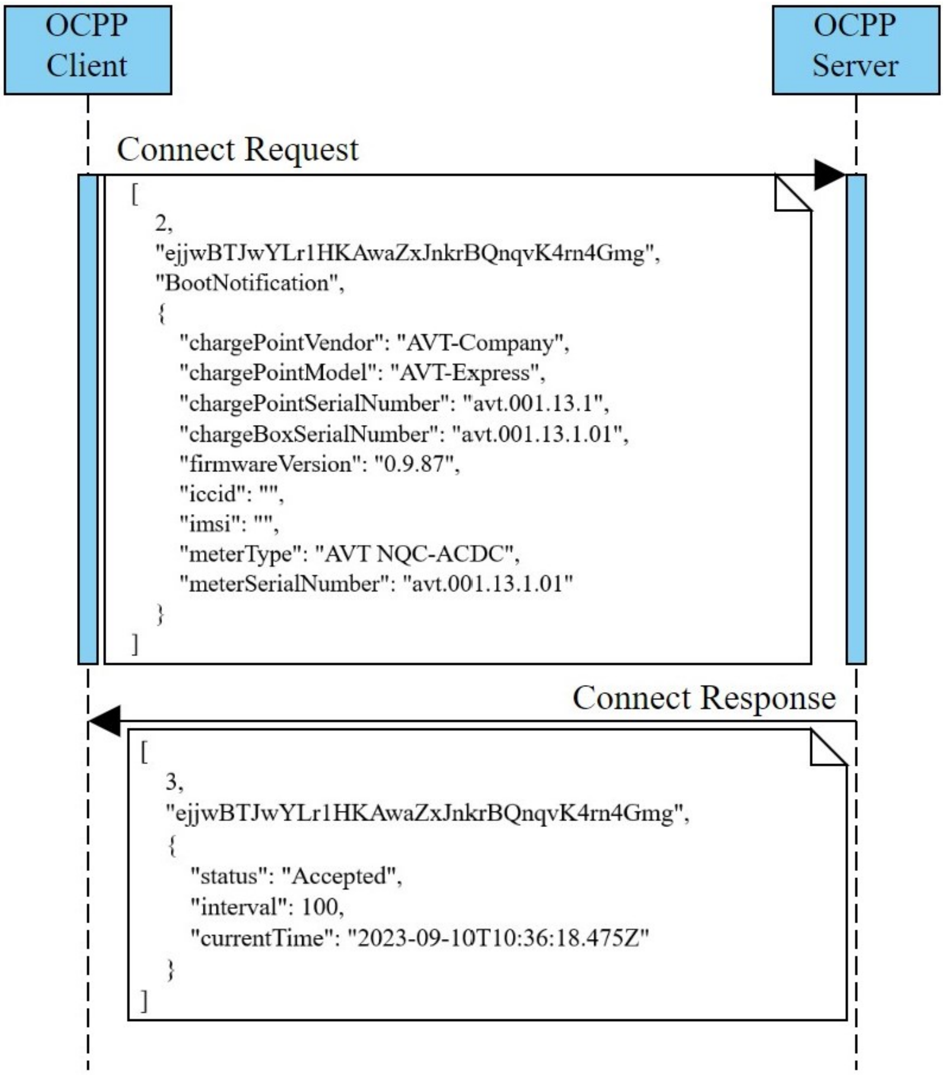

Figure 8. Request and response for the Connect function.

2. Authorize
In the Chargebox Authorization function, illustrated in Figure 9, the process of handling authorization requests is outlined. When an EV driver seeks permission to use a specific charging slot, the Chargebox initiates an Authorize request to the EVCMS. This request, including the slot preference, prompts the EVCMS to respond, indicating whether the driver can proceed with the charging session. This authentication step ensures user verification before access to the charging station is granted or denied. In the EVCMS implementation, the system monitors incoming Authorize requests, authenticates the driver, and responds to the Chargebox accordingly.

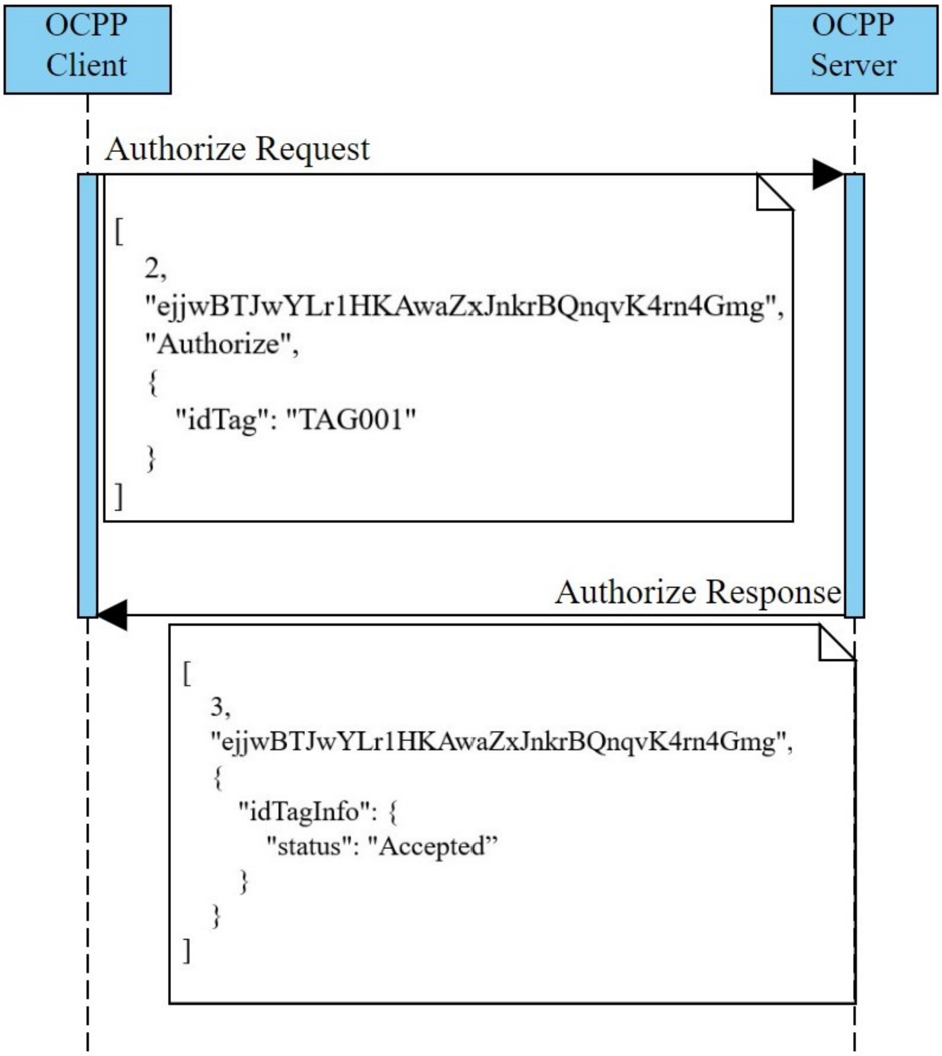

Figure 9. Request and response for the Authorize function.

3. Start Charging
In the Start Charging function of the Chargebox, as illustrated in Figure 10, a Start Transaction request is sent to the EVCMS when a charging session begins. This request includes essential transaction details such as connector Id, Slot Id, timestamp, initial meter value set to 0, and reservation ID. The Chargebox then carefully handles the Start Transaction response, ensuring the correctness of the details before responding with an accept message. In the EVCMS implementation, the system listens for incoming Start Transaction requests from the Chargebox, assigning a unique transaction ID upon reception and processing the relevant session data. The EVCMS promptly issues an accepted Start Transaction response by verifying transaction details to ensure they

match the reserved charging session. This verification process contributes to a smooth and reliable start for the charging session, enhancing the EV's user experience.

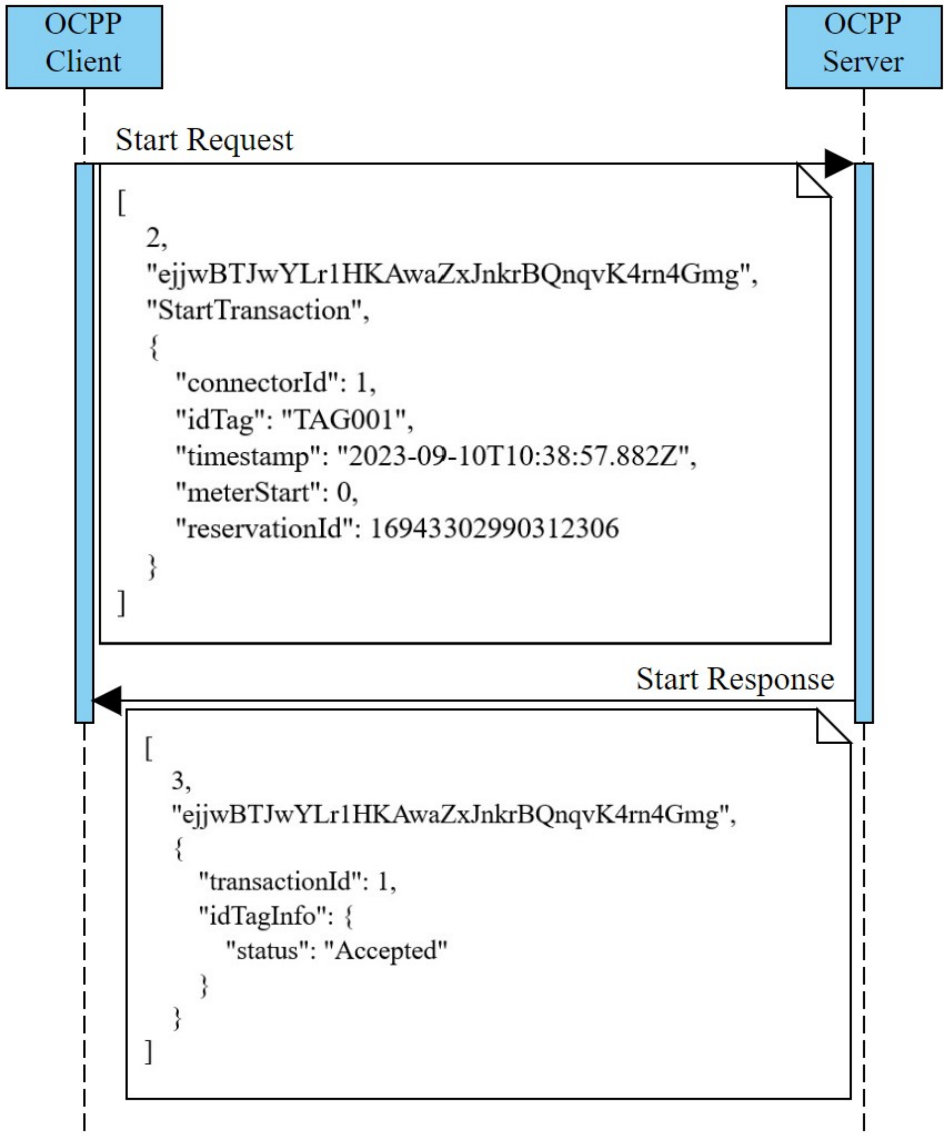

Figure 10. Request and response for the Start Charging function.

4. Stop Charging
   In the Stop Charging function of the Chargebox, as illustrated in Figure 11, a Stop Transaction request is sent to the EVCMS when a charging session concludes. This request includes transaction ID, Slot ID, timestamp for the charging duration, and meter values. The Chargebox then handles the Stop Transaction response from the EVCMS, confirming the end of the session and potentially providing billing information. In the EVCMS context, the system actively listens for incoming Stop Transaction requests from the Chargebox. Upon reception, it efficiently processes the requests, evaluating relevant data. One crucial task is calculating the total energy consumed during the charging session, enabling the system to determine associated costs. The EVCMS then formulates a comprehensive Stop Transaction response, serving as an acknowledgment of the successful completion of the charging session. The stop charging function can be initiated manually by the user or can be automatically initiated by the EVCMS as per the reserved charging duration. This process ensures a safe end of communication between the client and the server.

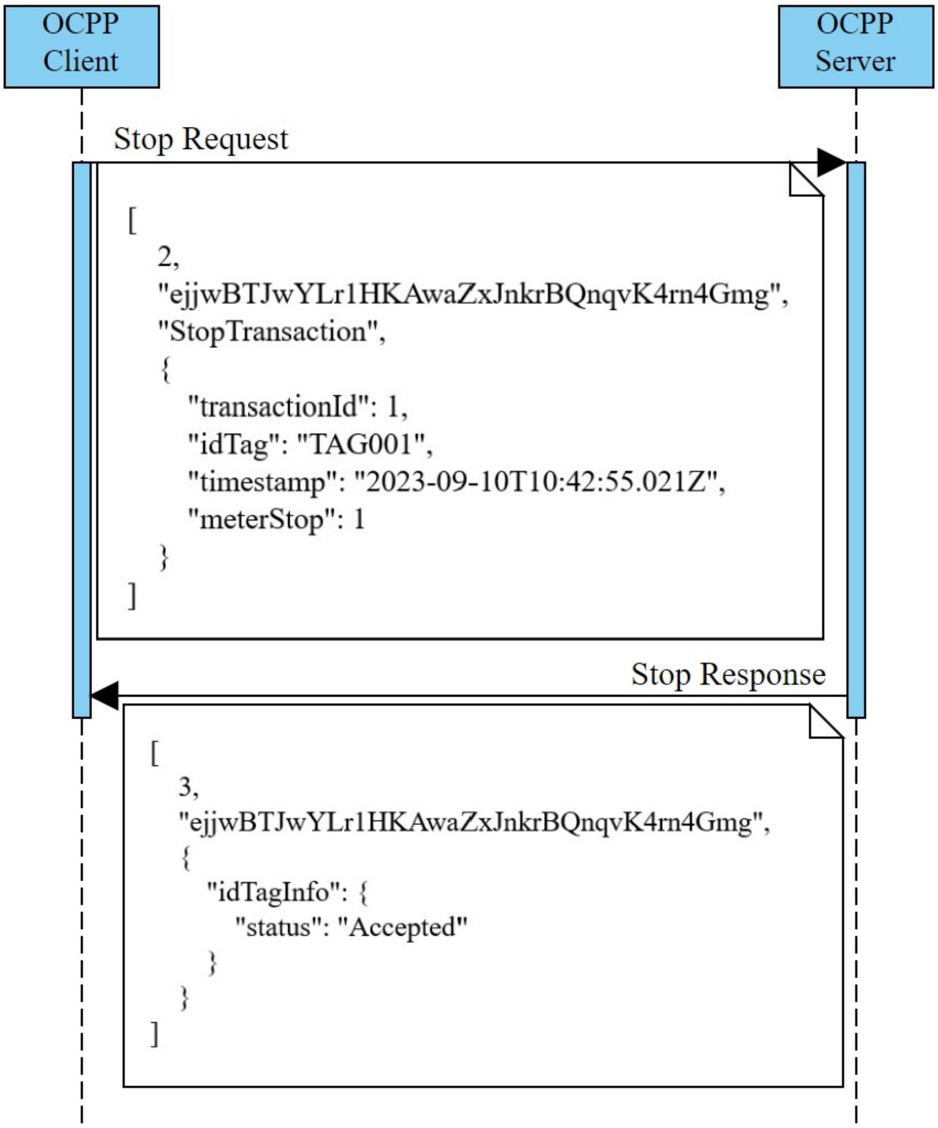

Figure 11. Request and response for the Stop Charging function.

5. Meter Values Request
   In the Meter Values Request function of the Chargebox illustrated in Figure 12, periodic or on-demand meter values requests are sent to the EVCMS. These requests provide real-time data about the ongoing charging session, including connector ID, transaction ID, current meter value, and other session details, enabling comprehensive monitoring. In the context of the EVCMS, the system actively anticipates and receives incoming meter value requests from the Chargebox simulator. Upon reception, the EVCMS initializes the meter value with the current timestamp and sampled value as a reference. It processes the meter data, storing them if necessary for billing or monitoring. Following data processing, the EVCMS responds with an acknowledgment to the Chargebox, confirming the receipt of meter values. This data exchange ensures the accurate relay of essential information, contributing to the efficient management and oversight of charging sessions, ensuring well-organized and closely monitored EV charging.
6. Disconnect
   In the Disconnect function, both the Chargebox and the EVCMS implementations establish procedures for effective disconnection management, catering to various scenarios, whether concluding a charging session smoothly or addressing unexpected

errors. The Chargebox ensures a graceful disconnect, smoothly wrapping up sessions, considering factors like session completion and unforeseen issues. On the other hand, the EVCMS proactively monitors the Chargebox connection status, handling disconnections seamlessly for a smooth transition from an active to a terminated charging session. It also efficiently manages the release of allocated resources, which is crucial for overall system efficiency. Notably, the disconnection process does not involve specific user or system requests but centers around the careful closure of the WebSocket connection initially established with the OCPP server.

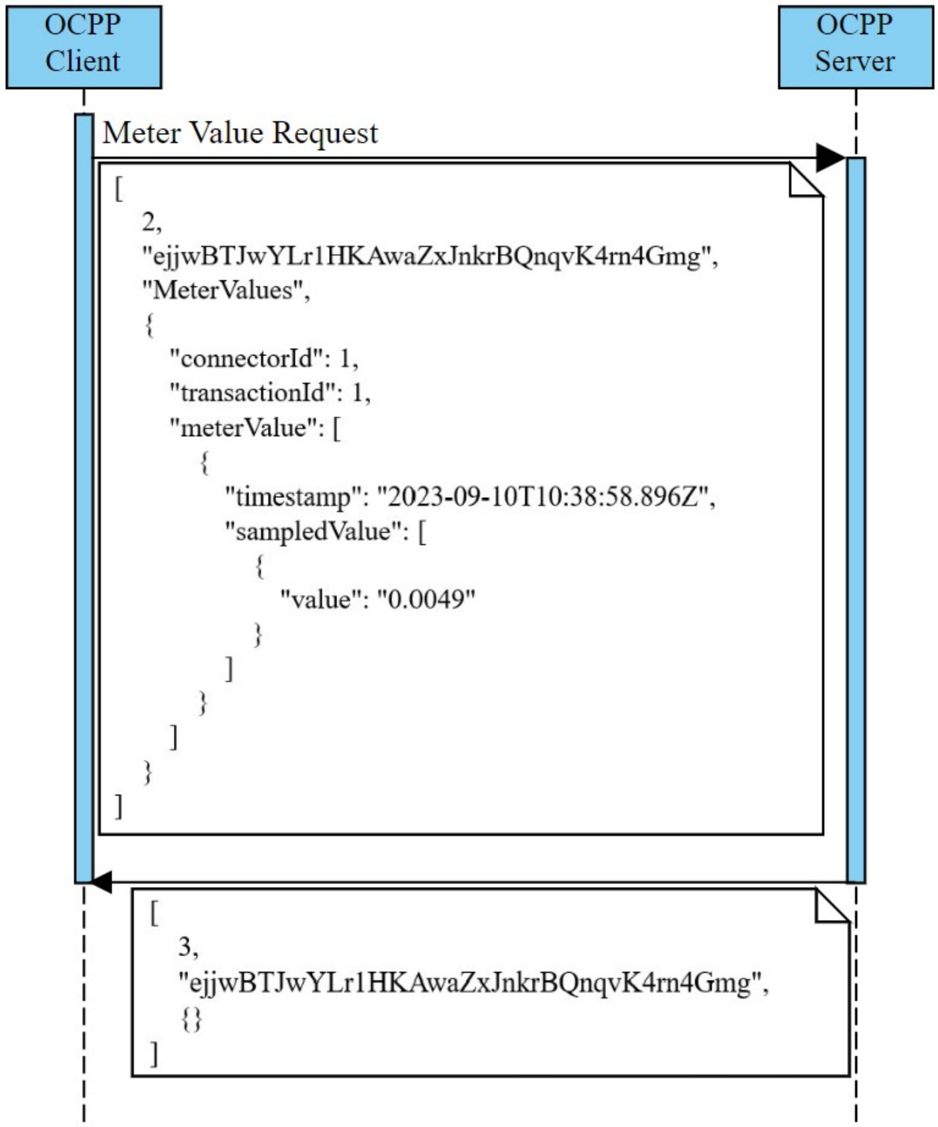

Figure 12. Request and response for the Meter Values function.

All these functions incorporated with OCPP communication improve security and make EVCMS robust against cyber attacks.

4.3. EVCMS Integration with Manufacturers

The EV charging market is currently dominated by several key manufacturers. Tesla, known for its Supercharger network offering high-speed charging, primarily for Tesla vehicles, is a major player [35]. Tesla employs an integrated approach [36], managing all aspects of its charging infrastructure from equipment manufacturing to network operation and revenue collection. ChargePoint, one of the largest and most open EV charging networks globally [36], provides solutions for both commercial and residential customers.

ChargePoint installs and manages a network of charging stations but does not own the hardware; instead, it sells the equipment to host sites, which then handle the billing, access, and revenue collection. This approach allows host sites to control payment structures and retain revenues, shifting significant business risk to them. Similarly, SemaConnect follows the network-operator model [36], focusing on network management and installation, while the host sites own the equipment. On the other hand, companies like EVgo and Blink Charging use the "owner–operator model" [36]. These companies own and operate their charging networks, including hardware, billing, and revenue management, providing a vertically integrated service. Shell Recharge, part of the broader Shell group, is also expanding its EV charging network across various locations [36]. These manufacturers collectively hold significant market shares, with Tesla and ChargePoint often leading in terms of technological advancements and coverage.

Manufacturers can integrate the EVCMS framework into their existing infrastructure through a combination of software and hardware modifications. Initially, it is crucial that the existing charging infrastructure supports OCPP or can be upgraded to do so. On the software side, the process involves developing and implementing APIs to enable communication between the EVCMS and existing charge points installed at the charging station. This integration requires incorporating the OCPP model with existing charging points to ensure seamless operation. Additionally, the manufacturer's web platform must be integrated to provide real-time information on charging availability, costs, and optimized plans, alongside advanced data analytics tools for real-time data processing and optimization. On the hardware side, manufacturers need to equip existing charging stations with communication controllers to handle communication between the stations and the EVCMS. They should also ensure the availability of network interface modules, including Ethernet, Wi-Fi, or cellular, for connectivity. An IoT gateway is essential to facilitate secure and reliable data transmission. Smart meters are necessary to measure electricity consumption and provide real-time data. User interface displays should be installed to provide users with real-time information and updates.

Manufacturers integrating the EVCMS framework into existing infrastructure face several challenges [37], such as compatibility with current systems and substantial upfront costs. However, adopting open standards like the OCPP can significantly mitigate these issues by standardizing communication between different components [38], thereby simplifying the integration with proprietary systems and legacy infrastructure. This interoperability not only reduces the complexity but also lowers costs by avoiding vendor lock-in and allowing the use of diverse equipment from different vendors [38]. To address the need for specialized technical expertise, manufacturers should invest in ongoing training and participate in interoperability testing events, which can help identify and resolve compatibility issues early in the implementation process. A phased approach, starting with a pilot program, and forming strategic partnerships with technology providers can further ease the integration process by providing additional resources and support [38].

5. Performance Evaluation

In the performance evaluation section, the system is assessed using specific metrics for result analysis, emphasizing result interpretation. Additionally, a case study analysis and comparative analysis are undertaken against similar existing models to assess effectiveness and identify potential improvements.

5.1. Result Analysis

The evaluation also utilized real booking data gathered from the server, as shown in Table 2, and concentrated on two main aspects: reducing costs and spreading out charging demand.

Table 2. Data generated by the EVCMS system.

TID	Dh	Pow	PS	AS	ACM	AC	SPS	OC
0	30	8.8	0	0	0	4.6	0	4.6
1	60	17.6	1	1	1	12.0	0	9.0
2	75	22	0	1	0.25	11.2	0	12.0
3	120	35.2	1	1	1	20.8	1	17.8
4	30	8.8	1	1	1	7.6	0	4.6
:								
495	60	17.6	0	1	0.25	9.0	0	9.8
496	30	8.8	1	1	1	7.6	1	4.6
497	75	22	1	0	0.5	12.7	0	11.9
498	120	35.2	1	0	0.5	19.3	0	18.6
499	120	35.2	0	0	0	17.8	0	17.8

Table 2 provides a detailed breakdown of each charging transaction, including the transaction ID (TID), the duration of charging (Dh), the power consumption (Pow), the peak status of the charging event (PS), the availability status of the charging station (AS), the availability cost multiplier applied (ACM), the actual cost of the transaction (AC), whether the charging event was shifted to Off Peak hours (SPS), and the optimized cost after applying various strategies (OC). The above table presents data for 500 charging transactions, allowing for the assessment of the system's performance, and enabling informed decisions to optimize the charging infrastructure. The above data were collected from the server based on booking time, duration, and power requirements. The booking time was categorized as Peak On/Off Time for further analysis. Thus, the peak status, Availability status, and shifted peak status can be expressed by Equation (9), Equation (10), and Equation (11) respectively.

$$\text{Peak Status (PS)} = \begin{cases} 1, & \text{if Peak On,} \\ 0, & \text{if Peak Off.} \end{cases} \tag{9}$$

$$\text{Availability Status (AS)} = \begin{cases} 1, & \text{if available,} \\ 0, & \text{if not available.} \end{cases} \tag{10}$$

$$\text{Shifted Peak Status (SPS)} = \begin{cases} 1, & \text{if shifted,} \\ 0, & \text{if not shifted.} \end{cases} \tag{11}$$

The ACM is a factor representing the ToU parameter from Table 1. It is taken as per the Peak Status and Availability Status. Based on PS, AS, and ACM, the result is classified into four cases. In the regular system, the charging cost was generated based on the booking time, whether it was in Peak On/Off Time, but in the optimized system, users are given a preference to shift to Peak Off Time with a lower price. These data, generated by the optimized system, were compared against the original system, where charging times were not optimized. The results found were quite interesting.

Figure 13 displays a line plot graph illustrating four distinct system cases. The x-axis represents the time in hours, while the y-axis denotes the associated cost. In Case 1 and Case 2, the optimized system demonstrates a noticeable reduction in cost. This reduction is a direct result of efficiently shifting peak-hour bookings to off-peak hours, mitigating costs for users and grid operators alike. Case 3, on the other hand, portrays a scenario where neither the original nor the optimized system incurs a cost change. This situation arises when users schedule their bookings during times when charging stations are both fully available and during off-peak hours. This represents an ideal, cost-neutral scenario. Case 4 presents an intriguing dynamic. Here, bookings are scheduled during off-peak hours in the original system. However, due to limited charging station availability, a cost multiplier of 0.25 is factored into the optimized cost. Importantly, if charging station availability were not an issue, the original cost in Case 4 would be the same as that in Case 3. Consequently, in Case 4, the optimized cost appears slightly higher, primarily due to the availability constraint imposed by the optimized system.

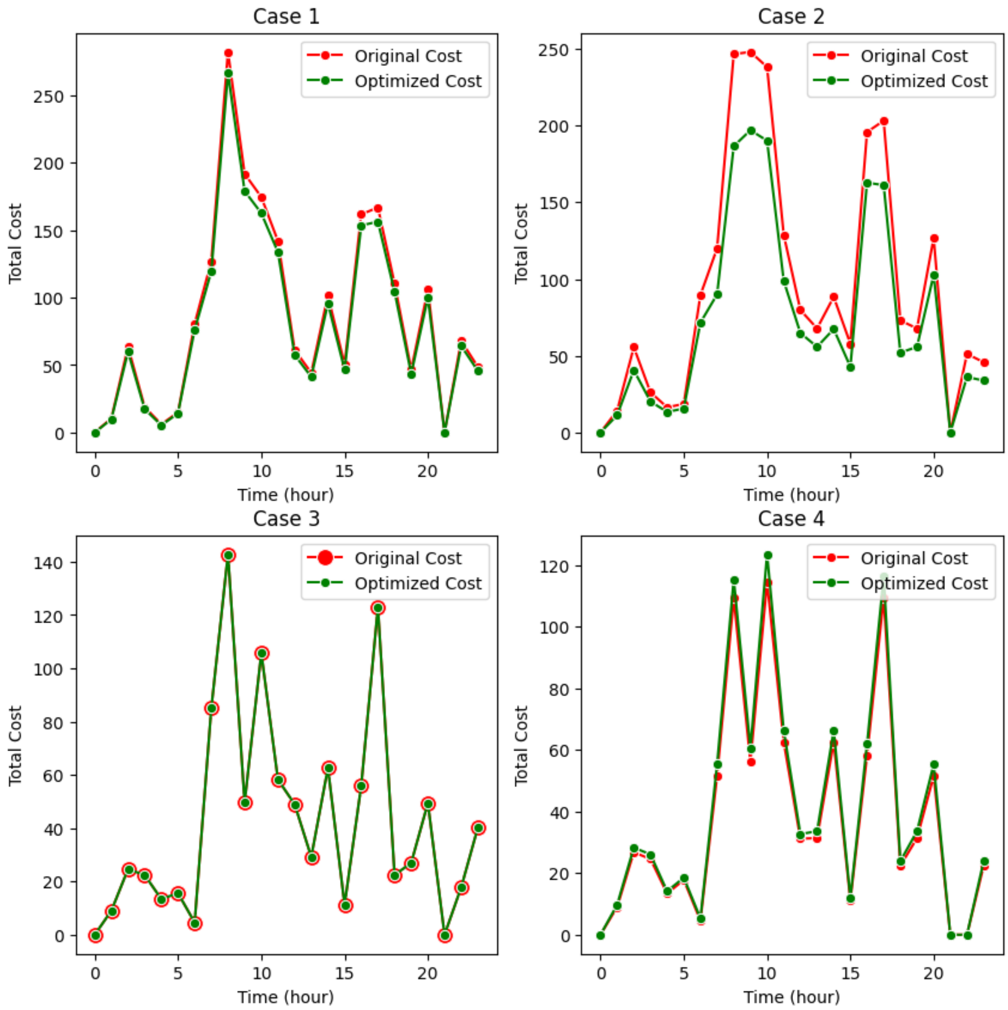

Figure 13. Total charging cost comparison of the original and the optimized system cases.

Table 3 summarizes average cost-related information for the four different cases, each representing a scenario within a system. This table provides a clear comparison between the original cost and the cost after optimization for each case, considering factors like peak demand and system availability. It allows for an assessment of the effectiveness of optimization measures in reducing costs for different system conditions.

Table 3. Result of the average charging cost comparison.

Case	Peak	Availability	Original	Optimized
	Status	Status	Cost	Cost
Case 1	Peak On	Available	12.44	11.69
Case 2	Peak On	Not Available	13.86	10.86
Case 3	Peak Off	Available	11.45	11.45
Case 4	Peak Off	Not Available	11.39	12.14

Figure 14 illustrates the discount and profit achieved through optimized booking scheduling, with the x-axis representing time and the y-axis indicating costs in GBP. The discounts are presented as cost reductions in GBP for each unique case. Moreover, the figure also showcases profits, expressed in GBP, which are observed exclusively in Case 1 and Case 2. In these cases, bookings are effectively shifted to off-peak hours, resulting in tangible profits. Based on the observed discounts and profits, it becomes evident that optimization has effectively managed costs across multiple transactions, ultimately leading to enhanced system performance and improved cost-effectiveness.

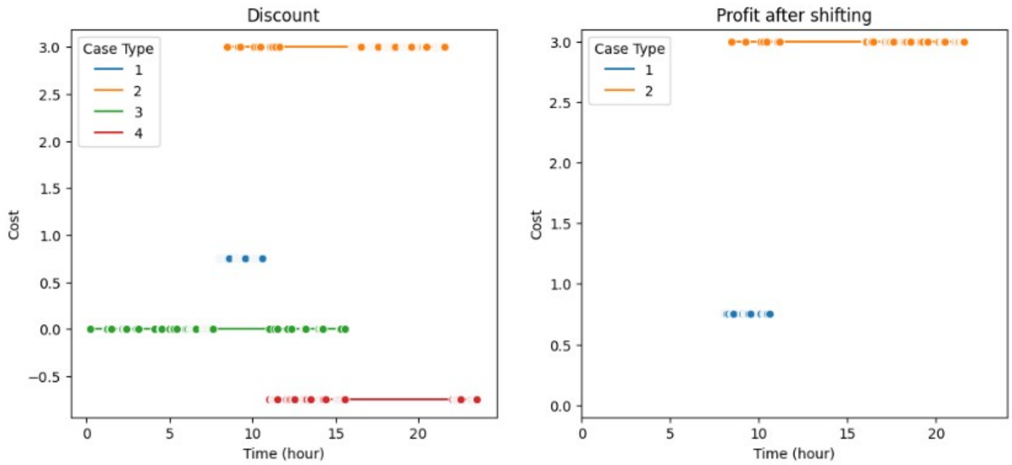

Figure 14. Discount and profit in an optimized system with respect to the system cases.

To assess the load balancing achieved by the optimized system, a comparison of charging demand and power demand was conducted between two scenarios: before and after optimization. The x-axis represents time in hours, while the y-axis depicts the number of EV bookings for the charging demand graph and the total power demand each hour for the Power Demand graph as shown in Figure 15. It is evident from the graph that before optimization, both the charging demand and power consumption peaked during on-peak hours, potentially straining the grid at these times. However, after optimization, a portion of the EV bookings was intentionally shifted to Off Peak hours to reduce costs. Consequently, in the post-optimization scenario, both the charging demand and power consumption also shifted towards the Off Peak hours, contributing to a more balanced and efficient utilization of resources.

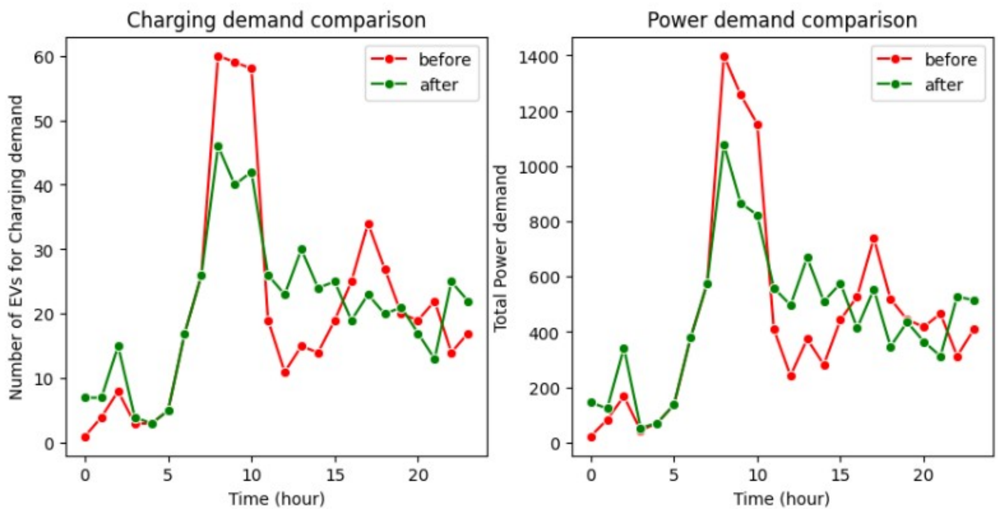

Figure 15. Charging and power demand comparison with respect to before and after optimization.

Figure 16 effectively presents the charging demand and power consumption after optimization, distinctly classifying them with respect to Peak On and Peak Off Times. The green color indicates the charging demand and power consumption during Peak Off hours, while red signifies the same during Peak On hours. This visualization evaluates the performance of the system indicating optimization of resource usage to balance peak demands.

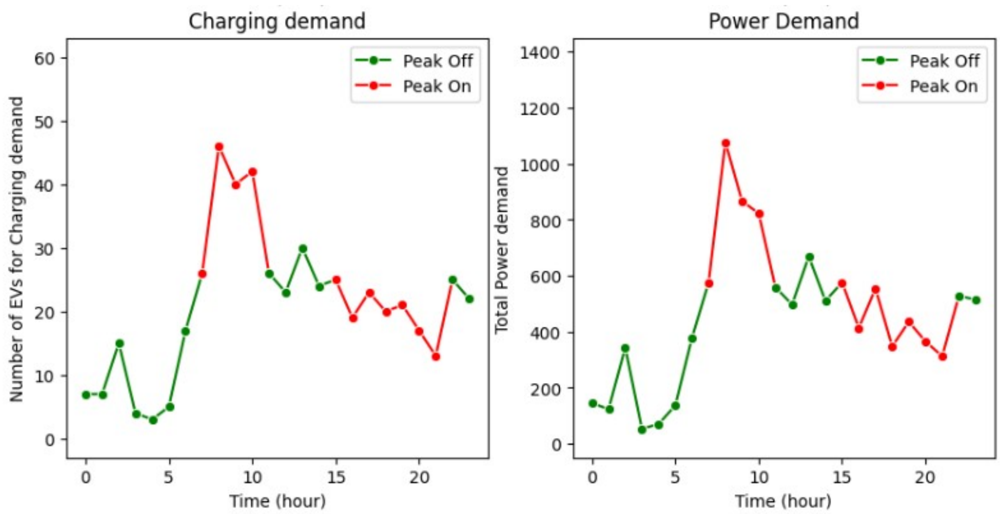

Figure 16. Charging and power demand after optimization with respect to Peak Off/Peak On Times.

5.2. Case Study: Mapping the EVCMS Framework with Local EV Charging Infrastructure

This case study examines the integration of the EVCMS framework with the infrastructure of Fuuse, a Lancaster-based EV charge point management platform [39]. With recent investments and plans to expand across the UK and Ireland, Fuuse aims to optimize its charging operations, enhance security, and provide a superior user experience [39]. The EVCMS framework, with its focus on interoperability, security, and real-time optimization, presents a strategic opportunity to support Fuuse's growth and innovation in the EV charging market.

The first step in mapping the EVCMS framework with Fuuse's infrastructure involves leveraging the OCPP. OCPP will ensure compatibility and interoperability between different charging systems and devices. By integrating OCPP, Fuuse can ensure that its existing charge points communicate effectively with the EVCMS framework, simplifying management and coordination across its network. The EVCMS framework offers the optimization of its charging price, which can be tailored to Fuuse's platform. This customization allows Fuuse to align charging plans with local energy tariffs and user preferences, enhancing both operational efficiency and customer satisfaction. This feature is particularly valuable for Fuuse, as it enables the company to offer competitive and responsive charging solutions that meet the specific needs of its users.

A key component of the EVCMS framework is its user-friendly interface, designed to provide real-time updates on charging availability, costs, and optimized charging plans. Integrating this interface into Fuuse's management platform would enhance the overall user experience, making it easier for customers to manage their charging sessions. This improvement in user engagement is likely to lead to higher customer satisfaction and loyalty, positioning Fuuse as a preferred provider in the competitive EV charging market. This case study highlights the potential for the EVCMS framework to be a key enabler of Fuuse's continued success and expansion in the EV charging industry.

5.3. Comparative Analysis

To evaluate the performance of the system against existing systems, the focus was on minimizing the charging cost and balancing charging demands more effectively. One way to balance charging demands in Peak On Time is to encourage users to charge their vehicles in Peak Off Time by reducing the charging price in Peak Off Time. Using the current state-of-the-art work [8,12,40–42] as a reference point, the proposed EVCMS was compared against these systems. Table 4 provides a comparative analysis between the EVCMS framework and the contributions of different researchers, highlighting the advantages of the EVCMS in the context of EV charging systems.

The comparison focuses on five critical properties: cloud infrastructure, OCPP Protocol implementation, optimal charging schedule management, charging cost reduction strategies, and peak load balancing techniques. Upon evaluation, it becomes evident that the proposed EVCMS framework excels in fulfilling all five properties comprehensively, whereas the other work has incorporated some of the properties from all the mentioned properties. This comparative analysis proves the effectiveness of the EVCMS framework with respect to its minimum charging cost, balanced peak demand loads, and enhanced security solution.

Table 4. Comparison with state-of-the-art work.

Parameters	**EVCMS**	**[40]**	**[41]**	**[42]**	**[8]**	**[12]**
Cloud	Yes	Yes	Yes	Yes	Yes	Yes
OCPP	Yes	Yes	Yes	No	No	Yes
Optimal charge	Yes	No	No	Yes	Yes	Yes
Less charge cost	Yes	No	No	Yes	Yes	Yes
Peak Load Balance	Yes	No	No	No	No	No

The performance evaluation validated the efficacy of the optimization strategy in achieving the dual goals of cost minimization and load balancing. The deliberate shift of Peak On charging to Peak Off charging not only led to significant cost savings but also fostered better resource utilization and load distribution. These findings provide valuable insights for system enhancement and lay the groundwork for future optimization work.

6. Conclusions

The EVCMS framework introduced a cloud-based solution for smart charging management that optimizes EV charging dynamics. The system's primary goal is to provide EV users with tailored, optimized charging plans that match their preferences and the charging station's capabilities. This is facilitated through real-time data sharing and an intuitive web interface, streamlining the process of reserving charging slots, thereby minimizing wait times and ensuring efficient, cost-effective charging strategies. The proposed EVCMS framework allows remote charging process management via OCPP remote procedure calls, providing an additional layer of convenience and control for EV users and charging station operators, along with enhanced security. The comparative analysis demonstrated that the EVCMS framework outperforms the existing system, highlighting its potential to reduce charging costs and distribute charging demand more evenly during peak times. This achievement underscores the significance of a cloud-based approach in enhancing the charging experience for EV users and optimizing infrastructure efficiency.

The EVCMS holds promising potential for expansion and improvement. Scaling the system from managing one charging station to multiple stations can greatly enhance its scalability, enabling a wider network of charging infrastructure to be efficiently managed and optimized. This evolution would not only accommodate a larger user base but also facilitate load balancing across various charging points. By aggregating and distributing charging demand intelligently, the EVCMS could contribute to a more evenly distributed load, preventing congestion during peak periods. Expanding the existing EVCMS framework to include multiple charging stations presents a synergistic approach. As the network grows, the model becomes more refined, enhancing load balancing across a broader spectrum of charging points. Users would experience improved convenience due to minimized wait times, while charging infrastructure operators would benefit from optimized resource allocation. Ultimately, this approach aligns well with the primary goal of creating a robust, efficient, and user-centered EV charging ecosystem with improved security.

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Conflicts of Interest: The authors declare no conflicts of interest.

Abbreviations

The following abbreviations are used in this manuscript:

EVs	Electric Vehicles
EVCS	Electric Vehicle Charging Station
EVCMS	EV charging Management and Security
OCPP	Open Charge Point Protocol
ISO 15118	International Standard Organization 15118
IEC61851	International Electrotechnical Commission 61851
OCPP-RPC	Open Charge Point Protocol- Remote Procedure Call
Ec	Cost of energy price
Es	Energy Consumed in session (in kWh)
Dh	Duration Consumed (in hours)
Crate	Charging Rate in kW
Pmax	Max Power Output of Charging Station per day
Ceff	Charging Efficiency
ToU	Time-of-Use Charges
PDC	Peak Demand Charges
A_{CS}	Availability in charging station
SC_{CS}	Service Charge of Charging Station

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