International Journal of Scientific Engineering and Technology ISSN : 2277-1581
Volume No. 12, Special Issue No. 1 29 Dec. 2023

Integrated Open Charge Point Protocol Electric Vehicle Charging : Advanced Systems for Sustainable Mobility

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Abstract— This research introduces a cutting-edge paradigm in Electric Vehicle (EV) charging infrastructure—a robust Open Charge Point Protocol (OCPP) compliant smart EV charging station aligned with the ISO 15118 standard. Encompassing a Charging Station Management System, Energy Management System, user-friendly mobile application, and seamless integration with grid devices, this system offers optional solar panels for sustainable energy augmentation. In the face of grid interruptions, or interference, the station seamlessly transitions to solar power, ensuring uninterrupted service.Advanced features include camera surveillance for security enhancement and a penalty system to promote responsible usage. The entire infrastructure is hosted on the reliable Amazon Web Services (AWS) Cloud network, providing scalability, resilience, and advanced analytics capabilities.

Keywords— Open Charge Point Protocol 2.0.1, Amazon Web Service Cloud, Central Control System, V2G and Solar Panel System.

I. INTRODUCTION

Paper [1] presented a review of electric vehicle (EV) smart charging, encompassing solutions, strategies, technologies, and challenges. The paper critically analyzes the current landscape, offering a comprehensive foundation for understanding the intricate facets of EV charging optimization. [2] presents an OCPP-based framework for Electric Vehicle Charging Management. The study addresses crucial aspects of efficient charging infrastructure. In [3] focused on enhancement of Electric Vehicle (EV) smart charging through an advanced reservation extension to the Open Charge Point Protocol (OCPP) standard. [4] presents a groundbreaking prototype—a Monitoring System for Electric Vehicle Charging Stations, tailored for the unique challenges of the Amazon region and also the development and implications of this innovative solution, addressing critical needs in sustainable energy infrastructure. [5] explores OCPP-based Electric Vehicle Supply Equipment (EVSE) and its user interface for AC charging. Investigating critical aspects of EV infrastructure, the study addresses key challenges and proposes solutions.

Paper delves into the security issues and challenges associated with the Open Charge Point Protocol (OCPP) in electric vehiclecharging infrastructure, offering a comprehensive survey. [7] identifies threats and proposes countermeasures, contributing valuable insights to enhance the security of contemporary charging systems. [8] delves into the critical domain of Cyber-Physical Energy Systems Security, offering a comprehensive exploration of threat modeling, risk assessment, resources, metrics, and case studies.

The authors in [9] investigates the pivotal role OCPP plays in shaping an inclusive and accessible charging infrastructure, paving the way for a sustainable and widespread adoption of electric mobility. [10] presents a comprehensive assessment of the Open Charge Point Protocol (OCPP) within the context of electromobility. [11] addresses the efficient management of Electric Vehicle (EV) charging stations through advanced reservation schemes in electricity markets. [12] delves into a comprehensive understanding of OCPP, providing valuable insights for the evolving landscape of electric vehicle charging infrastructure. [13] investigates OCPP's impact on enhancing interoperability and standardization within the charging infrastructure, contributing to the industry's growth. [14] explores the landscape of Electric Vehicle Charging Infrastructure, delving into its current state, prevalent challenges, and prospective advancements.[15] comprehensively reviews electric vehicle (EV) battery charging infrastructure, encompassing topologies, power control strategies, and future trends.

II. METHODOLOGY

A. System architecture and design

Open Charge Point protocol (OCPP) use WebSocket as a communication protocol between the individual charging stations and the central control system. The system developed, shown in Fig. 1, consists of the Charging Station Management System, the OCPP Gateway, the Solar Panel, the Grid Devices, the Energy Management System, the Mobile Application, the AWS Cloud, the Charging Station and the Electric Vehicle (EV)..

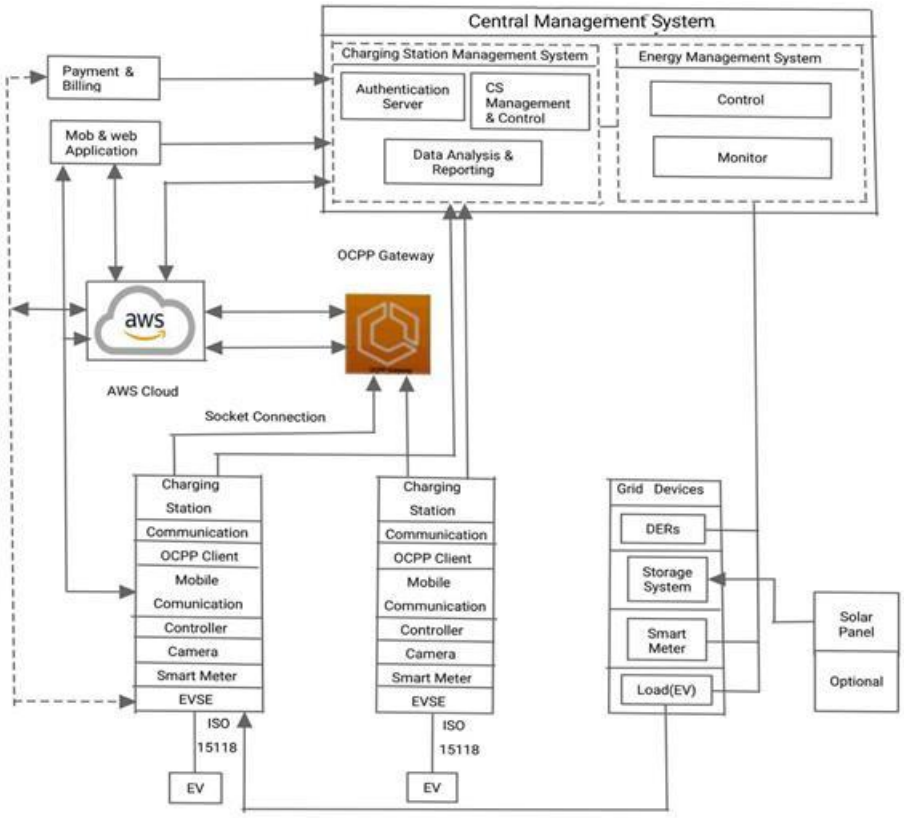


Fig. 1. Architecture of Open Charge Point Protocol compliant EV charging station in AWS cloud

The charging station is equipped with an OCPP stack, which is a software component responsible for handling OCPP communication and also responsible for responding to commands from a central management system (CMS). The charging station connected to an AWS cloud, to establish communication with the CMS

B. Open charge point protocol

The Open Charge Point Protocol (OCPP) is an open-source protocol that facilitates smooth communication and operation of EV charging structure. It enables interoperability between colorful EV charging outfit and central operation systems. The OCPP's part is to make any EV charging station work in a compatible way with any bowl operation software.

Fig. 2. Open charge point protocol versions

Charge points calculate on OCPP compliance to enable charging sessions, manage remote diagnostics, and insure a secure exchange of data. OCPP defines the messaging format, commands, and data structures for communication between charging stations and central management systems.

The emergence of new technologies and the growing demand for advanced monitoring and increased stability have led to the development of OCPP 2.0.1. OCPP2.0.1 provides advanced smart charging capabilities and control features for serviceability, Charge Point Drivers (CPO), and EV possessors.This interpretation includes several advancements, similar as the support of the ISO 15118 standard for secure communication between the charging point and the electric vehicle. OCPP 2.0.1 provides advanced smart charging capabilities and control features forutilities, Charge Point Operators (CPO), and EV owners. This version includes several enhancements, such as the support of the ISO 15118 standard for secure communication between the charging point and the electric vehicle.

C. Amazon web service cloud

Amazon Web Services pall enables ever cover and manage charging stations, including firmware updates, status monitoring and fault discovery, throughcustom operations or services. AWS offers integration options, making it easier to connect charging station structure to other systems, similar as billing etc. AWS Lambda can admit data from OCPP charging stations, similar as Status updates, Charging session data, or metering information. It can validate incoming data and also further it to other AWS services for storehouse and analysis. It can interact with AWS services like Amazon DynamoDB and Amazon SNS.

API Gateway provides robust security features. DynamoDB is used to store and manage structured data from OCPP- biddable charging stations. It can make it suitable for storing charging session data, station status updates, stoner information, and other affiliated data.DynamoDB integrates with AWS CloudWatch and AWS CloudTrail for monitoring and auditing. Amazon S3 can be used to store a wide range of data generated by EV charging stations, including session records. Charging station data can be periodically backed up to Amazon S3. It can be used for charging station operation,

reporting, and monitoring. AWS Cloud trail captures events generated by various AWS services, such as AWS Lambda, Amazon S3, AWS API Gateway, and more. Cloud Trail logs can be stored in Amazon S3 buckets. This is valuable for monitoring interactions between charging station and AWSservices.

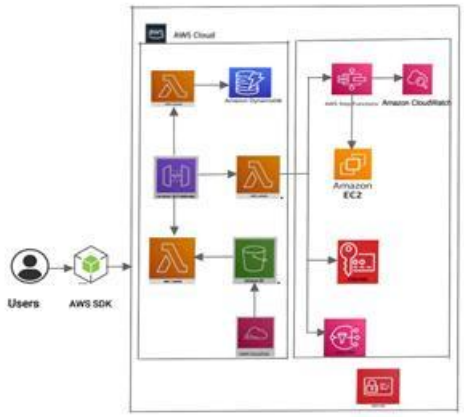


Fig. 3. Amazon Web Service Cloud

CloudTrail logs provide valuable information for identifying and investigating security incidents. Amazon EC2 instances can integrate with various AWS services, such as AWS Lambda for serverless computing, and Amazon S3 for object storage, enabling a comprehensive charging station management system. It can be monitored using AWS CloudWatch, allowing to collect performance metrics, set up alarms, and troubleshoot issues and used to host the software components and services required for charging stations.AWS Step Function for EV charging stations, this can include orchestrating tasks like starting and stopping charging sessions, handling user authentication, and updating billing records. AWS CloudWatch can collect and track various metrics from EV charging stations, such as power consumption, charging rates, and station status. CloudWatch Logs allows to capture, store, and analyze log data generated by charging stations and related AWS services and can create custom dashboards in CloudWatch to visualize the performance and status of EV charging stations.AWSKey Management Service (KMS) allows to create, manage, and control cryptographic keys used forencrypting and decrypting data. This is crucial for protecting and sensitive information stored and transmitted by EV charging station infrastructure.AWS Simple Notification Service (SNS) enables infrastructure. AWS Simple Notification Service (SNS) enables to send real-time notifications and alerts for EV charging stations. SNS can be used to notify about the health and performance of charging stations and can set up alarms and notifications based on metrics collected by AWS CloudWatch or other monitoring systems. The AWS SDK provide language specific support for the Message Queueing Telemetry Transport (MQTT) and WebSocket Secure (WSS) protocols. AWS Mobile SDKs also provide support for MQTT device communications and the APIs of other AWS services on mobile devices.

C. Central management system

The Central Management System (CMS) serves as the linchpin, orchestrating seamless collaboration between the Charging Station Management System (CSMS) and Energy Management System (EMS) in EV charging stations. Functioning as a nexus, the CMS oversees user authentication, payment processing, and real-time monitoring through CSMS, while coordinating with EMS to optimize energy consumption and demand response.

Fig. 4. Integrated central management system under OCPP protocol

D. Surveillance and enforcement system

A comprehensive Surveillance and Enforcement System for Electric Vehicle (EV) Charging Stations, along with a Charging Station Management System (CSMS) and Mobile Application, ensures efficient operation and user compliance..The core of this system is a network of cameras strategically positioned at charging stations. These cameras continuously monitor and recognize license plates of EVs that enter the station. When an EV is detected, the CSMS starts a timer to monitor the time it stays connected to the charger.

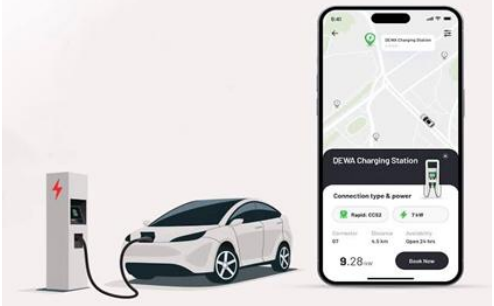


Fig. 5. License Plate detection and monitoring system

If an EV exceed the allowed charging time, the CSMS generates a penalty notification. This notification is instantly relayed to the owner mobile application , utilizing the details from the license plate recognition, the mobile app serves as a direct channel for communication between the CSMS and EV owners ,offering real-time updates and alerts. This system promotes fair use of charging infrastructure and enforces these limits, preventing EVs from overstaying at charging stations.

E. Mobile application development

The development of a Mobile Application for Charging Station Management System, designed to support the OCPP 2.0.1 protocol and seamlessly integrated with the AWS Cloud network, is a pivotal innovation in the realm of electric vehicle charging infrastructure.

ISSN : 2277-1581
29 Dec. 2023

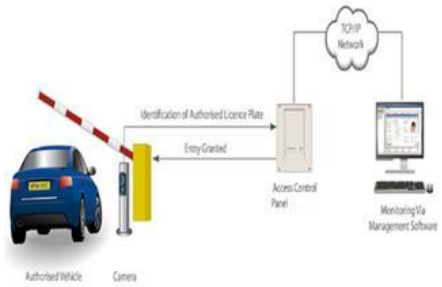


Fig. 6. EV charging visualization in mobile app

The Mobile Application primarily serves EV users, offering an intuitive interface for locating, reserving, and accessing charging stations. Users can effortlessly view real-time station availability, plan routes, and initiate charging sessions. Furthermore, the application provides transaction history, payment options, and user profiles for a seamless experience.

F. V2G and solar panel integration

Grid devices and solar panels, when integrated with an Energy Management System (EMS) and Charging Station, offer an efficient solution for power management. The EMS optimally distributes energy, reliance on the grid during peak demand. Solar panels serve as a supplementary power source when sunlight is available, reducing grid dependence. Whengrid power is interrupted or overloaded, solar panels can function independently, providing a resilient backup.This integrated system enhances energy efficiency, reduces costs, and minimizes environmental impact.

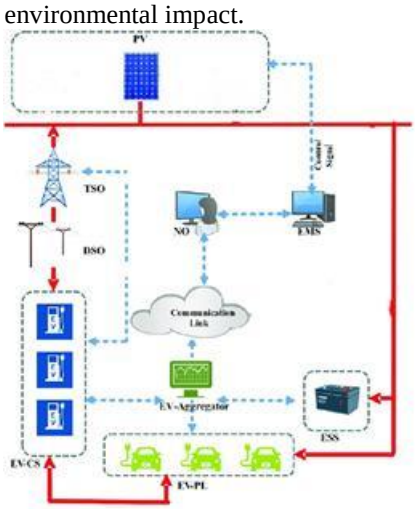


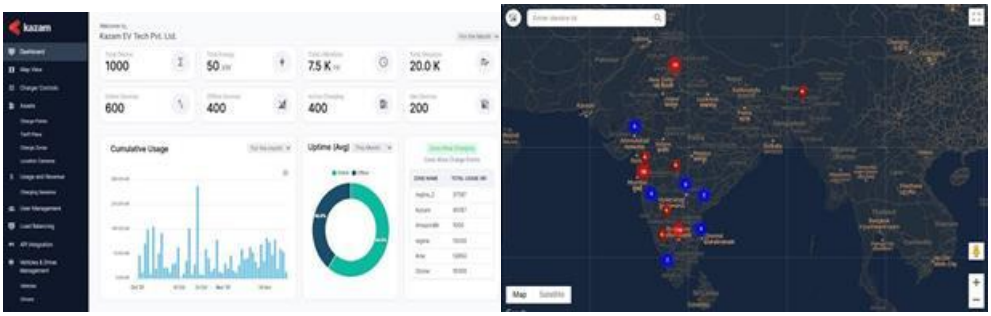
Fig. 7. V2G and solar panel integration and monitoring system

When a user approaches the charging station, to start a charging session, the user may need to tap a card or a smartphone, or insert a payment method (e.g., credit card). The LCD display will guide the user through this process, showing prompts and instructions. Once the session begins, the display shows relevant information, such as the current charging rate (in kWh), the estimated time remaining for a full charge, and the current battery state of charge. This helps users monitor the progress of their charging session. If the charging station requires payment, the display will show the cost of the charging session in real-time, updating as the session progresses.

Fig. 8. EV charging performance at LCD

At Charging Station Management System(CSMS), charging station managementsoftware communicates with the charging station hardware to start the charging process.Throughout the session, the software collects real-time data on charging status, including power consumption, time, and energy transferred. It integrates with payment gateways and allows usersto link their payment methods to their accounts.Users are billed based on the duration of the charging session or the amount of energy consumed, depending on the pricing structure set by the charging station operator.Billing details are generated and stored by the platform for user access and management. It allows users to create accounts, manage their profiles, and track their charging history.It also offers features like reservation capabilities, enabling users to reserve charging stations in advance.

III. RESULT DISCUSSION



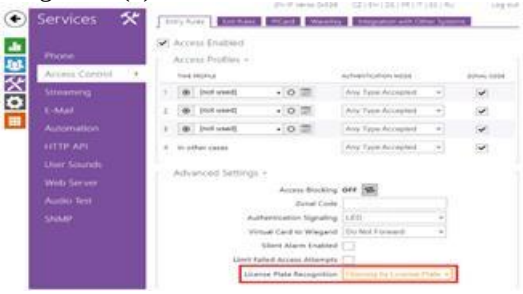
(a) Charging session analysis (b) Charging station location

ISSN : 2277-1581
29 Dec. 2023

(c) Energy performance analysis

Fig. 9. EV Charging station performance web dashboard/Software

(a) Access control for EV license Platerecognition (b) Service authentication for EV license Plate

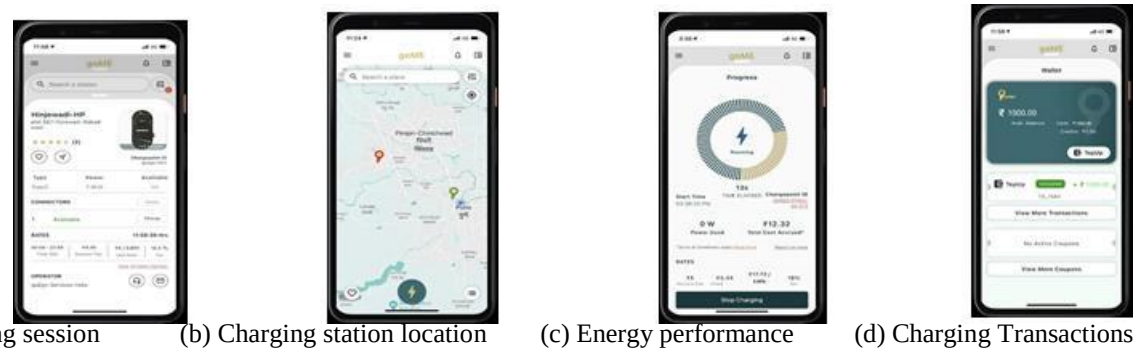


(c) Access enable for license plate recognition

Fig. 10. EV license plate recognition and logging dashboard/software

The click of the button will start the number plates' recognition process. The system, by using IP video cameras settings data, will start separate processes for each camera settings, where the used processes will recognize the vehicle data that control the barriers and other devices, will be activated. Pressing the button will display a list of vehicles allowed to access the secure zone. Clicking the button will show a list of vehicles that, when detected, will activate a sound alert, a pop-up window, and more e-mail message. Pressing the button will display a list of either accepted or rejected vehicles. The click of the button will open the configuration window. Clicking the button will open the configuration window for IP cameras, license plate recognition, relays, and other settings. The click of the button will stop the program and the current logged in user will be logged off, so that another user is able to login. The click of the button will bring up the main program, mail server and registration settings window. The click of the button will bring up the software information window. The click of the button will stop all number plates' recognition processes and the ANPR/LPR server will be shut down. The system can also show messages in a monitor's window about a blacklisted number and excess limit or send e-mails to set e-mail addresses

Users can use the app to locate nearby chargingstations. The app usually provides a map with station locations, details, andavailability.Once a user selects a charging station, they can initiate acharging session through the app. This involves selecting the charger, confirming the vehicle's details, and starting the charging process. Users often need to register and link their payment methods to the app. Some apps may use QR codes, RFID cards, or Bluetooth for authentication at the charging station. The app allows users to monitor and control the charging session. They can start, stop, or adjust the charging rate if supported by the station. During or after the charging session, the app calculates the energy consumed and calculates the cost based on the user's pricing plan. The app typically uses the linked payment method to process the payment



(a) Charging session (b) Charging station location (c) Energy performance (d) Charging Transactions

Fig. 11. EV charging monitoring by mobile application

IV. CONCLUSION

This paper has delved into the comprehensive design and implementation of an OCPP-compliant smart EV charging station integrated with a sophisticated Charging Station Management System (CSMS), Energy Management System (EMS), mobile application, and seamless integration with grid devices. The incorporation of optional solar panels further enhances the sustainability of the system, ensuring uninterrupted charging even during grid overloads or interferences. Leveraging the power of AWS Cloud network infrastructure, this solution offers scalability, security, and real-time data management, making it a robust and future-proof choice for the electric vehicle ecosystem. The inclusion of a camera and penalty system enhances security and accountability. This research bridges the gap between advanced EV infrastructure and the growing demand for sustainable energy solutions. It not only provides a detailed blueprint for the implementation of a state-of-the-art smart charging station but also underscores its significance in advancing the adoption of electric vehicles and renewable energy sources. As the world transitions toward sustainable transportation results, this design paves the way for a future where EV charging is both environmentally friendly and technologically advanced.

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