AI-Driven Edge-Integrated Central Management System for Intelligent Monitoring and Automation of Large-Scale OCPP EV Charging Network

The large-scale deployment of both public and private EV charging infrastructure accompanies the rapid adoption of electric vehicles. Contemporary charging networks feature hundreds to thousands of distributed chargers, each connected to a CMS via OCPP 1.6. These chargers continuously communicate with the backend regarding operational messages such as heartbeats, meter values, charging transactions, and diagnostic information. This communication gives a wealth of operational data, and yet existing CMS platforms are little more than monitoring dashboards and data repositories, which do much to provide visibility but nothing towards intelligent interpretation and proactive operational control.

In practice, most of the charging networks still rely on manual supervision. Charger failures are usually detected only when users report charging failures. It includes customer support teams checking system logs manually, calling maintenance personnel, and coordinating with field engineers. It resulted in delayed service restoration, longer downtime, and lesser customer satisfaction. Operation management becomes much more complex as the network scales up. Engineers have to track the health of individual chargers, manually assign maintenance tasks, and repeat follow-ups. Since the traditional systems rely on analytics based on stored backend logs, instead of real-time communication behavior, early detection of communication issues, intermittent hardware failures, or unstable charging sessions is difficult.

Another major challenge in the operational front concerns the coordination with the Original Equipment Manufacturers (OEMs). In general practice, hardware problems are identified only after repeated instances of complaints are recognized. Similarly, the maintenance activities are reactive rather than preventive, which results in higher operation expenses. In the absence of intelligent automation, the CMS acts like a passive monitoring tool rather than an operational management system.

To deal with these challenges, the proposed idea for a project includes an AI-based CMS monitoring platform and a communication analysis device at the edge. This entails the development of an IoT-compatible hardware engine that is placed in the middle of the EV chargers and the CMS server. This engine serves as a gateway and monitors all communication protocol messages using the OCPP. This device does not need to parse the logs through the backend server to analyze the patterns of messages. It observes the

patterns of messages in real time, such as the pattern of the status, the sequence of transactions, the pattern of heartbeat signals, and the pattern of error codes.

The hardware engine has an embedded AI module that identifies communication abnormalities such as irregular heartbeat intervals, transaction interruptions, unstable charging sessions, repeating issues, and communication timeouts. This identification of abnormalities occurs before the charging session goes wrong. This means that when an issue is recognized, alert messages are sent automatically to the CMS for maintenance. This system has transformed the method of running the networks from a reactive approach to a predictive approach.

Moreover, the centralized CMS is further enhanced using elements of intelligent automation. This includes an AI-enhanced customer support module, which is capable of correlating customer complaints with the real-time statuses of the chargers. In the event that a customer reports a complaint via a mobile application, call center, or customer service portal, the system would be able to immediately analyze the statuses of the chargers and determine the possible reason for the faulty operation, such as the hardware fault, connectivity issue, or operation error.

Additionally, the CMS has automated maintenance workflow management. In this regard, whenever there is an issue with the charger, a service request will be generated immediately and allocated to a field engineer based on location, availability, and expertise. Tasks will also be prioritized considering charger occupancy rate, location grade, and severity grades. This process greatly enhances efficiency in the maintenance of the chargers.

In OEM collaborative work, the platform aggregates recurring hardware problems, which are then used for the creation of a report. This report would include communication, errors, and program operation, thus helping the manufacturers solve problems relating to firmware and hardware.

Apart from fault management, operational intelligence is provided by the system. The AI models monitor the usage and effectiveness of chargers, peak usage times, trends in energy consumption, and demand distribution by region. Each charger is given an operational score

in terms of its uptime, stability, and successful transactions. Operational teams and management teams are provided with periodic reports on the requirements of adding more infrastructure, improving usage, and improving effectiveness.

As the charging infrastructure grows into the thousands of charging points, the system acts like an autonomous operational management system. Most of the activities, such as monitoring, ticketing, work assignment, tracking, responding to customers, and reporting, are fully automated. AI technology is used for the automation. Human intervention takes place only for major repairs and planning activities. This solution minimizes operational efforts, makes services more reliable, and provides a better end-user experience.

Through the implementation of real-time communication monitoring at the edge and AI-based automation at the central level, the proposed system can transform raw data obtained from the OCPP communication protocol into valuable operational intelligence. This study demonstrates the possibility of using artificial intelligence and edge computing to transform electric vehicle charging infrastructure into an intelligent and “self-monitoring” system for reliable and efficient operation.