RESEARCH

Design of Data Management Service Platform for Intelligent Electric Vehicle Charging Controller - Multi-charger Model

Pedro Baptista[1], José Rosado[2,4], Filipe Caldeira[1,3] and Filipe Cardoso[1,4*]

*Correspondence:
fcardoso@estgv.ipv.pt
[1]Viseu Polytechnic - ESTGV, Viseu, Portugal
[4]INESC Coimbra, Coimbra, Portugal
Full list of author information is available at the end of the article

Abstract

The electric charging solutions for the residential market imply, in many situations, an increase in the contracted power in order to allow to perform an efficient charging cycle that starts when the charger is connected and ends when the VE battery is fully charged. However, the increase in contracted power is not always the best solution for faster and more efficient charging. With a focus on the residential market, the presented architecture is suitable for single-use and shared connection points, which are becoming common in apartment buildings without a closed garage, allowing for sharing the available electrical connections to the grid. The multi-charger architecture allows using one or several common charging points by applying a mesh network of intelligent chargers orchestrated by a residential gateway. Managing the generated data load involves enabling data flow between several independent data producers and consumers. The data stream ingestion system must be scalable, resilient, and extendable.

Keywords: EVSE, Electric Vehicles, Intelligent Charging, Load Management, Mobility, Mesh, Data Management, Fog Computing

Introduction

Electric vehicles (EV) are environmentally friendly since they do not emit any gas directly into the atmosphere, have fewer maintenance needs and operating expenses, and offer a quieter driving experience. These are the primary advantages of EV, which are becoming more and more attractive as the technology evolves. Even though they presently represent only 2.7% of global sales, according to the Bloomberg report by [1], the tendency is for them to grow. It is predicted that by 2025, EV will account for 10% of worldwide passenger vehicle sales, growing to 28% in 2030 and 58% in 2040, respectively. According to an analysis conducted by the Association of Electric Vehicles Users (UVE) for Portugal, the sale of EV increased by 80% in November 2020 when compared to the same month in 2019 [2].

In many situations, the EV charging solutions for the home market implies an increase in the contracted power to allow for an efficient charging cycle that begins when the charger is connected and stops when the EV battery's maximum charge is reached. Increased contracted power is not necessarily the most effective approach for charging faster and more efficiently. A limited power grid connection shared among a large number of tenants makes it difficult to implement electric charging solutions able to solve challenges such as, controlling expenses by user, optimizing charging time, and even balancing the load based on the energy available at a given time [3] [4].

The authors in [5] present two distinct IEVCC system configurations. This work focus on the Mesh version intended for use in condominiums where tenants do not have access to a portion-powered parking spot. With the difficulties identified when designing and implementing multi-client solutions in mind, this work proposes a technical architecture capable of managing high data loads. The solution must be resilient and scalable to address the mesh installation problems and optimize grid usage. These aspects will benefit the end consumers and also assist the electricity distributors.

The planned solution is considered a streaming analytics system, typically consisting of three layers: ingestion, processing, and storage. The ingestion layer is the gateway to streaming. Data flow from inputs to processing and storage levels is decoupled, automated and managed. The processing layer receives the ingestion layer's data streams and transfers the output or intermediate results to storage. The storage layer keeps data in memory for iterative calculations or in databases for long-term storage. The analytics findings are given to a range of display and decision-assistance tools [6] [7].

This paper is organized as follows: after this introduction, the different data stages are presented in Section II. In Section III the full architecture diagram is presented and discussed, finally, the Conclusions are presented in Section IV.

Charging data stages

According to [8], on the Internet of Things, there are five primary data processing architectures, fog-based processing, middleware-based processing, cloud-based processing, cloudlet computing, and mobile-edge computing.

The current data load comes from chargers, electrical counters, and message handling devices (broker). While systems operate, it is vital to log and store not only charging data, but also device status and usage metrics. To minimise damage in the event of network or device failures, the local setup (device layer) must be able to store and recover from failures. The final architecture proposal will take that into consideration.

The next natural step is to store data in the cloud, but once again, due to the sensitive nature of data and the significant load caused by each local instance, transmitting gathered data straight to cloud servers has proven to be challenging [9]. The same article discusses how fog computing may help minimize cloud reliance while improving performance. Nevertheless, the paper concludes that cloud and fog are complementary and can help deliver better and more complete services.

Fog Architecture

Cloud computing and fog computing infrastructures do not compete with each other, and they're complementary architectural solutions. IoT applications connect across fog nodes, and devices must be linked to at least one of these fog nodes (Fig. 1). Any device part of the IEVCC solution may connect to fog nodes which may be used in specific geographical cloud areas [10].

Because each fog node is a single point of failure, its spread and replication across regions should be considered for failure recovery and redundancy.

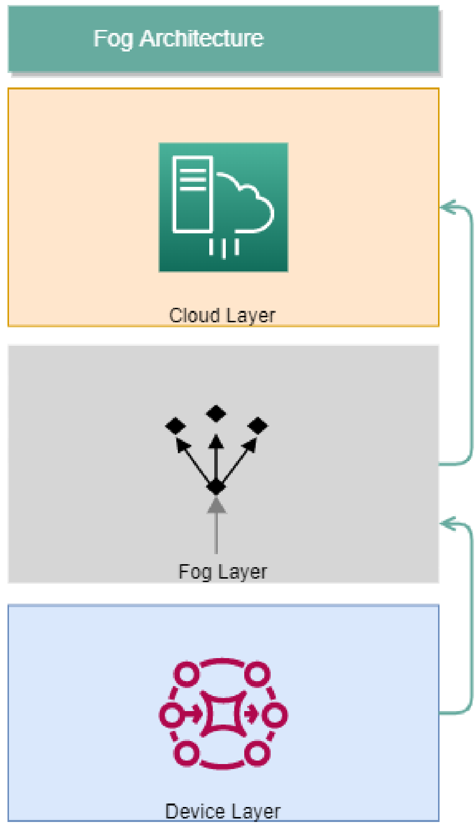

Figure 1 Fog Architecture.

Multi-Charger Model

The multi-charger installation includes multiple chargers and may also include multiple electrical counters. Fig. 2 illustrates how each device connects to the "heart" of the device layer (Device Manager). This device is responsible for message handling and forwarding. At the same time, it manages authorized devices and clients during charges.

Each instance can be configured with custom load balancing rules, charger priority, and energy source selection when more than one source is available or when the provider shares the current source through an API endpoint.

All data is stored locally and forwarded to remote instances for data cleansing and transformation. Electrical communication usage, system logs, and client usage are then available for access by clients and providers.

Design of Data Management Service Platform

In order to allow data flow between several independent data producers and consumers, a data stream ingestion system must be scalable, resilient, and extendable. Chargers and electrical counters are the primary focus of the current configuration. However, the Device Manager design ensures that more Internet of Things devices will be able to connect and integrate into the solution in the future.

In order to demonstrate how to integrate the Fog Architecture into the Multi-Charger Model, the Fig. 3 depicts the position of each entity within the three Fog

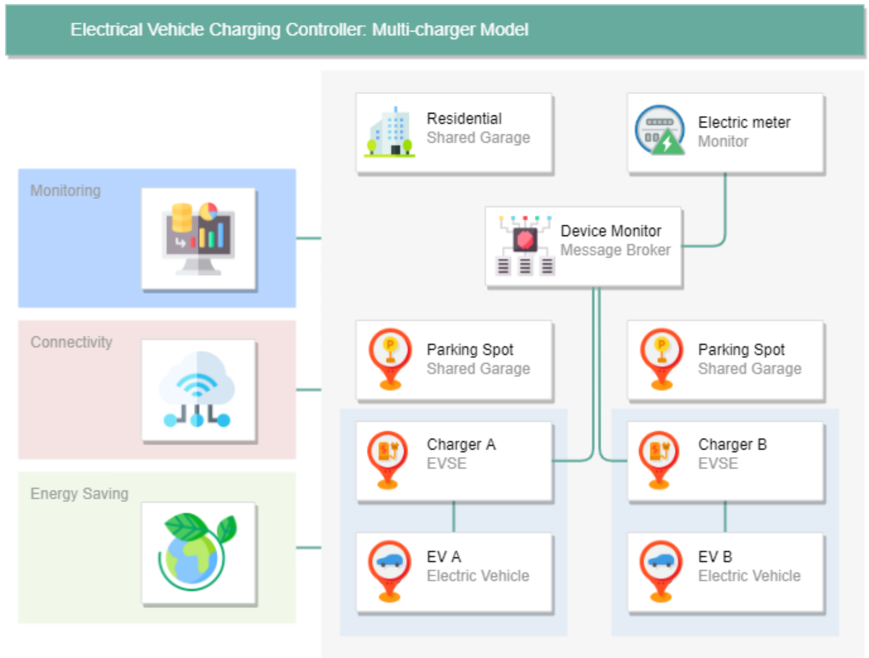

Figure 2 Multi-Charger Model.

Architecture levels.
Each colored section maps the three distinct layers (Device, Fog and Cloud layers), where generated data is saved and then forwarded to the subsequent layer instances. It is crucial to clean and aggregate each record to be stored in the database during this process. It is also important to note that while generated data flow in one direction only, it is mandatory to authenticate users, devices, charging sessions, and others. This responsibility is taken care of by the Device Manager through the API instance in the cloud layer.

Device Layer

The device layer includes all the devices that support the local area network, like routers, switches, wireless access points or extenders, and all the smart devices connected locally. The smart ESP32-based devices are chargers and electricity meters for the current solution. Multiple other IoT devices may be integrated into the solution in the future.
The solution's heart is the Device Manager. Raspberry Pi version 3 boards were tested during development with no performance issues while handling device auth, messages, local storage, and data forwarding to the fog layer.
For the Manager role, it is clear that power consumption and price will affect the board choice. Given that architecture compatibility is not an issue, the minimum requirements must meet the Raspberry Pi 3 specifications, as well as the ability to run Docker.

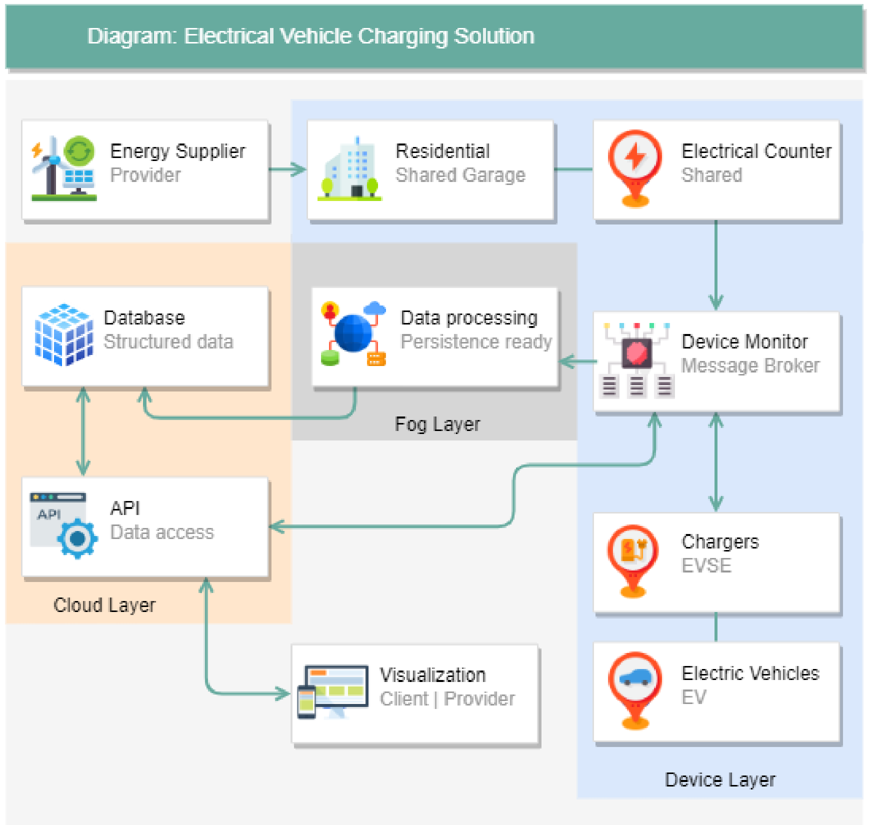

Figure 3 Mesh-Model Diagram.

Fog Layer

The Fog Layer comprises devices in an intermediate layer between the cloud and the Device Layer. In this case, data is transferred to and processed by a computer or data center regionally located. Splitting this processing power across multiple regions decreases the total load each fog node will handle while increasing redundancy, a significant concern when dealing with critical data.
Fog node hardware must meet the minimum system requirements set for the distributed event streaming platform and the applications for cleansing and transforming data. Our prediction suggests each node has 8GB of RAM, 4 CPU cores, 1TB of storage, and 1GbE connection.

Cloud Layer

The cloud computing infrastructure builds on top of large-scale clusters that run various applications and pursue the core foundation that enables computing resources to be used to their full potential.
Cloud customers expect the entire system to be reliable, with redundant network and hardware. These cloud solutions allow companies to access data storage, resources, and on-demand services over the internet. Although cloud providers offer a variety of solutions for several operations, based on the presented Mesh-Model (Fig. 3), the core business activities in the Cloud Layer include database services

and API web applications.
The Cloud Layer is sub-layered into 3 layers: Infrastructure as a Service (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS). Choosing the best cloud layer depends on the budget, resources, the size of the operations, and multiple other factors.

Tech Stack

A tech stack is a company's choice of technologies to develop and manage an app or project. A tech stack often includes programming languages, frameworks, databases, front-end and back-end tools, and apps linked through APIs [11].
In a top-to-bottom analysis of Fig. 4, in the Device Layer, the current charger and electricity meter devices are programmed in C++, while the Device Manager is currently being developed in Python 3.8, with a tested compatible version range from Python 3.6 to Python 3.10. MQTT message broker (Mosquitto MQTT) and InfluxDB, an open source Time Series Database, both run on the same hardware.
Each fog node in the Fog Layer will provide one or more Apache Kafka instances, an open-source distributed event streaming platform. Apache Kafka advertises necessary core capabilities like high throughput with low latency (2 ms), being prepared to scale, and delivering high availability. It's also important to mention the built-in stream processing that enables the processing of event streams using joins, aggregations, filters, transformations, and exactly-once processing. It is also worth mentioning that the Kafka Connect interface is pre-integrated with hundreds of event sources and sinks, including Postgres, JMS, Elasticsearch, and AWS S3.
As previously stated, in the Cloud Layer, our solution's core depends on a PostgreSQL database instance and the possibility to host web applications like client portals or APIs to access and store information.
The best cloud solution for PostgreSQL service is still open for further analysis, howsoever it is mandatory to have scalability possibilities, backups, and snapshots. Multi-region availability and synchronization will be decisive when dealing with thousands of clients.
Region and response time are essential factors in web application hosting, but so are high availability with load balancing, security, and scalability.

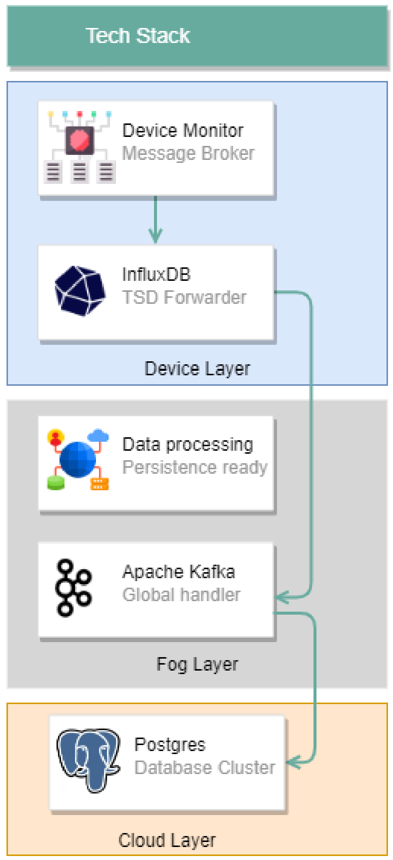

Figure 4 Tech Stack.

Conclusions

Ingestion of data is critical for businesses and organizations that gather and analyze massive amounts of data. Continuous data streams are often ingested into big data processing and management systems from external sources. They are either processed incrementally or utilized to create a persistent dataset and related indexes. In order to keep up with vast amounts of rapidly changing data, stream processing systems must be able to ingest, analyze, and persist data continuously.

This work presents an architecture and the corresponding tech stack designed to handle massive time-critical data while performing cleansing and transforming operations, then storing it in a cloud database service. The innumerable options for each entity in the tech stack open new paths to different approaches and benchmarks. This will also help choose the best-tailored cloud provider for the solution's specific needs.

DECLARATIONS

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Author details
[1]Viseu Polytechnic - ESTGV, Viseu, Portugal. [2]Coimbra Polytechnic - ISEC, Coimbra, Portugal. [3]CISeD IPV, Viseu, Portugal. [4]INESC Coimbra, Coimbra, Portugal.

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