ElectroCap Project Proposal

Optimizing EV Charging in Residential Buildings: Efficient Usage and Power Management

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1. Advisors and Mentor

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2. Problem definition (I)

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As **electric vehicles** (EVs) become **more popular**, the **demand** for charging infrastructure has **increased** significantly, particularly in urban **residential buildings.**

Fig. 1 –Electric vehicle charging [1]

2. Problem definition (II)

The existing charging points are **often underutilized or inefficiently distributed** due to limited infrastructure and unclear policies on how to allocate these resources among residents.

Fig.2 – Electric vehicles charging at same time [1]

2. Problem definition (III)

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This can **overload** the building's electrical system, resulting in **power constraints** that may affect the overall electricity supply. This situation may lead to **safety concerns and poor user experiences.**

Current solutions tend to be **rudimentary**, without the ability to dynamically adjust to usage patterns or predict demand spikes, leading to underutilization or overloading of available resources.

Fig. 3 – Shared EV charging station [2]

3. Solution beneficiaries (I)

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- Residents of multi-family housing who own electric vehicles and rely on shared building electric grids.

- Building administrators responsible for managing the building's energy resources and maintaining a safe and reliable power supply.

Fig. 4 – Residencial charging station for EV

3. Solution beneficiaries (II)

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- EV owners who require convenient, accessible, and efficient charging options in urban residential settings.

- Electricity companies that benefit from a more efficient management of energy, allowing them to concede a constant amount of energy

Fig. 5 – Residencial charging station for EV

4. Technological solution (I)

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Smart Grid Controller: Our advanced controller solution is designed to enhance the efficiency of the electrical grid by optimizing energy distribution. It constantly monitors power demand and adjusts the charging process to prevent grid overload. This not only improves energy efficiency but also helps reduce energy bills while promoting a balanced and sustainable energy use in buildings.

Fig. 6 – Technological solution

4. Technological solution (II)

For instance, when two electric vehicles (EVs) are charging, the controller prioritizes the vehicle with the lower energy level, ensuring it receives more power. This approach helps achieve a better overall energy balance for both vehicles.

5. Competitors and previous work(I)

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Existing solutions for managing EV charging in residential buildings include basic installations with dedicated chargers for each resident or shared systems that require manual slot selection.

Fig. 7 – Basic installations

Fig. 8 – Dynamic charging system

However, they often overlook power management and do not provide dynamic charging schedules based on demand. Though some buildings use time-of-use pricing, this is frequently not integrated with the power management system.

5. Competitors and previous work (II)

Recently, E-Redes introduced the FlexC project, a smart charging solution for shared garages. It dynamically adjusts charging power according to the building's total energy consumption, eliminating the need for costly electrical upgrades and enabling more efficient vehicle charging within existing capacity.

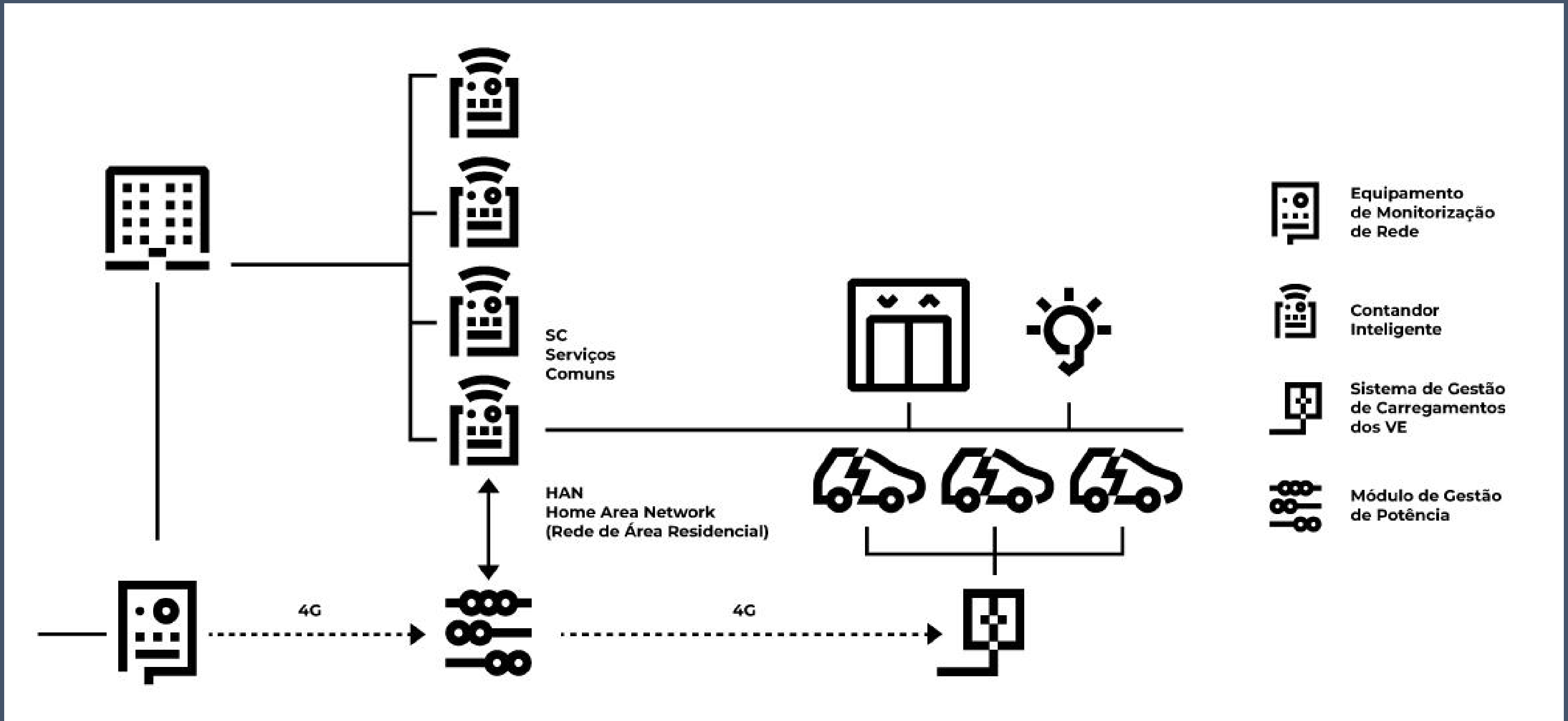

Fig. 9 – FiFlexC Project by E-Redes

6. Solution requirements

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1. Monitor and dynamically adjust energy allocation, prioritizing a branch
   that requires more energy to charge electric vehicles without overloading the grid.

2. Autonomy with no regular need for human interaction.

3. Real-time data analysis of grid performance.

4. This technology can make EV charging faster during high-peak hours.

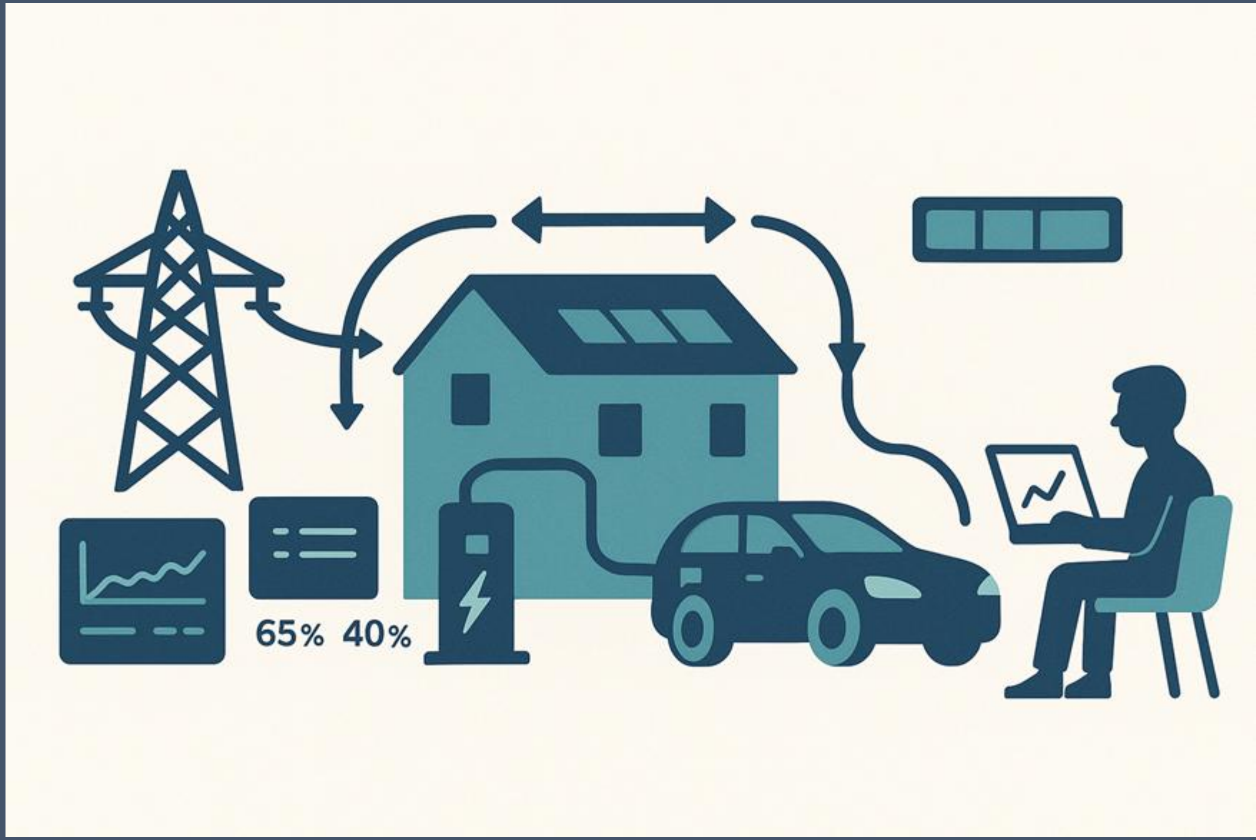

Fig. 10 – Solution Requirements

7. Technical challenges

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Creating a controlling system that manages the energy distribution between home facilities and EV charging points can have the following complications:

1. **Energy demand forecasting** – Predicting usage patterns to optimize energy allocation.

2. **Infrastructure integration** - Ensuring compatibility with existing systems and IoT devices.

3. **Real-time control** - Monitoring and adjusting energy flow dynamically.

4. **Safety compliance** - Adhering to standards and minimizing risks like surges or fires.

5. **Cybersecurity** - Protecting against cyber threats and data breaches.

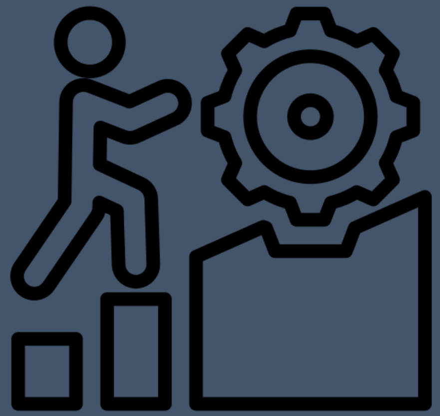
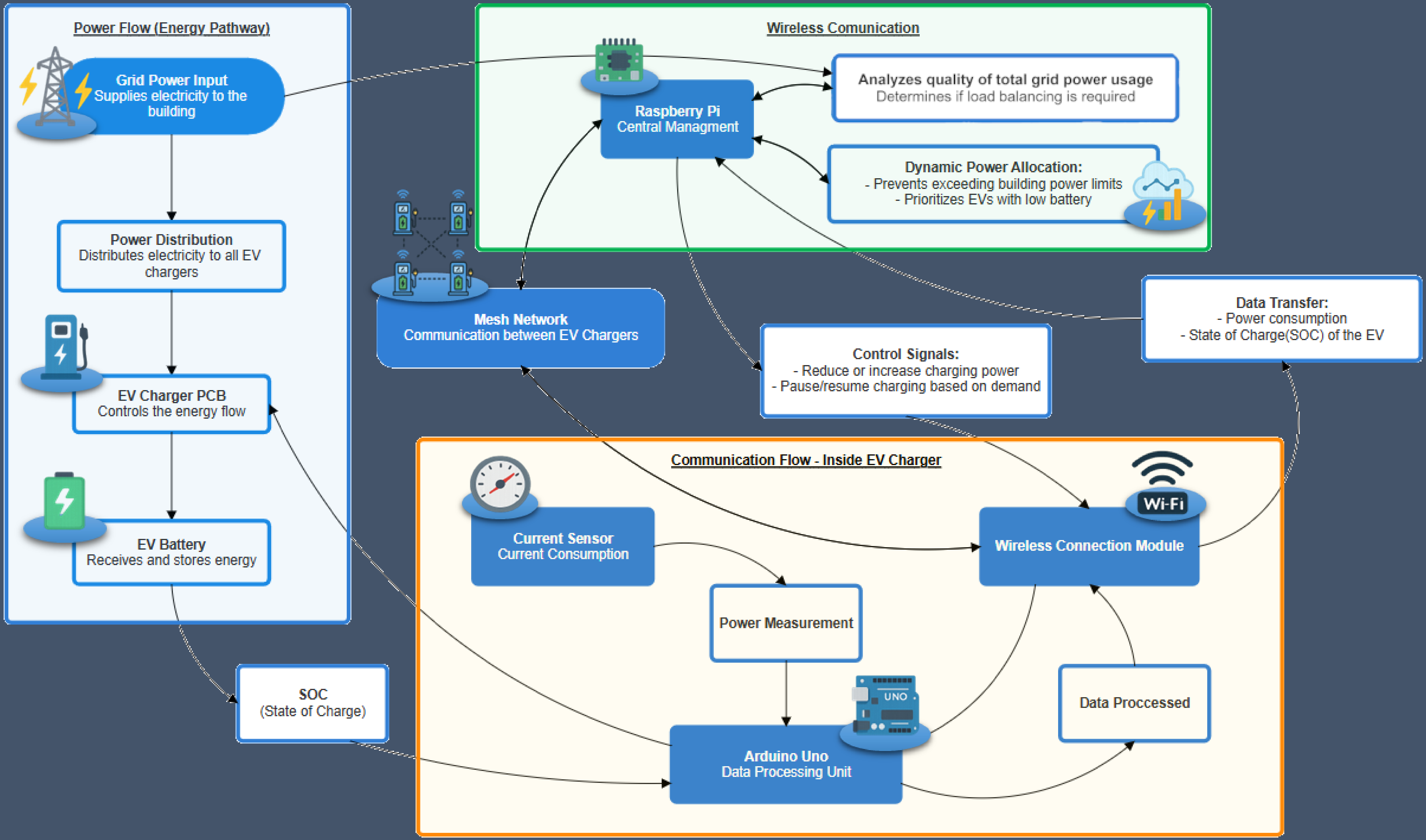


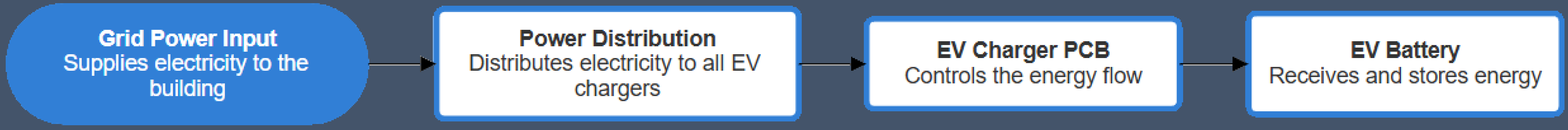
Fig. 11 – Technical challenges

8. Project Structure



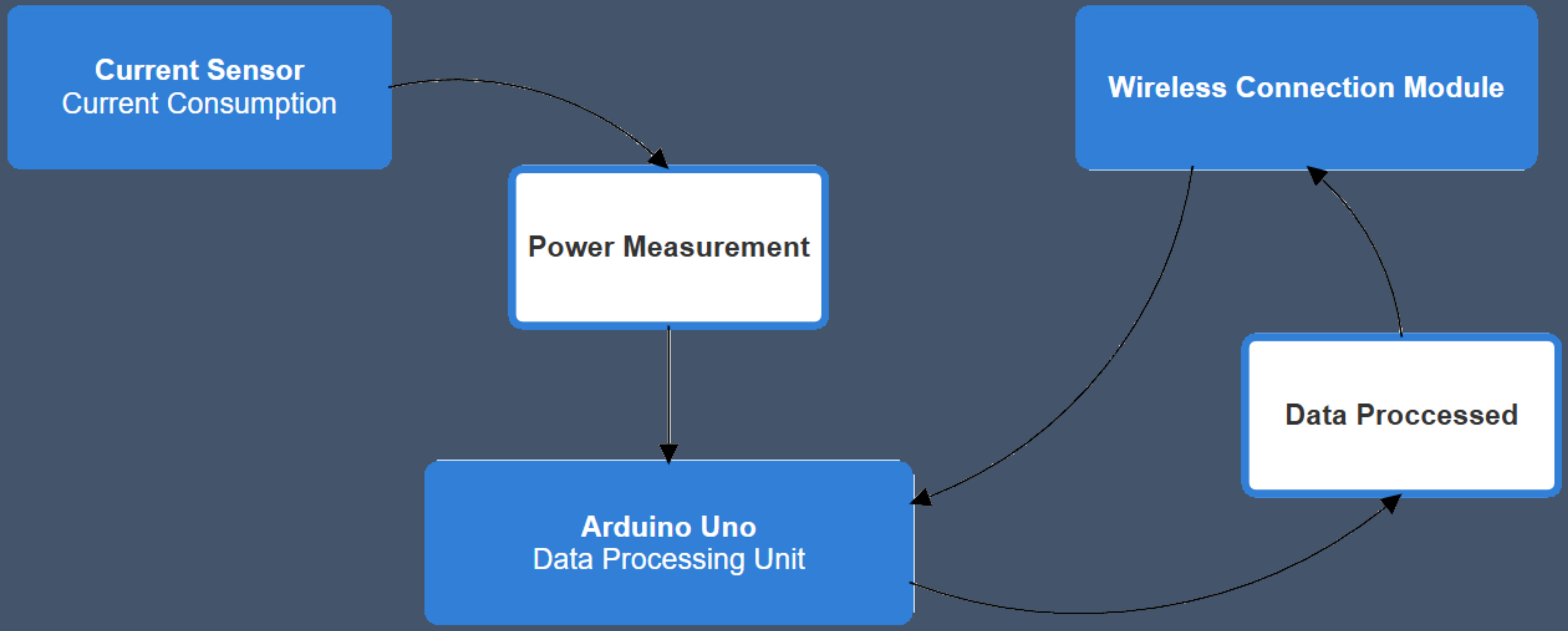
Power Flow (Energy Pathway)
Grid Power Input
Supplies electricity to the building
Power Distribution
Distributes electricity to all EV chargers
EV Charger PCB
Controls the energy flow
EV Battery
Receives and stores energy
SOC
(State of Charge)
Wireless Comunication
Raspberry Pi
Central Managment
Analyzes quality of total grid power usage
Determines if load balancing is required
Dynamic Power Allocation:
- Prevents exceeding building power limits
- Prioritizes EVs with low battery
Mesh Network
Communication between EV Chargers
Control Signals:
- Reduce or increase charging power
- Pause/resume charging based on demand
Data Transfer:
- Power consumption
- State of Charge(SOC) of the EV
Communication Flow - Inside EV Charger
Current Sensor
Current Consumption
Power Measurement
Arduino Uno
Data Processing Unit
UNO
Wireless Connection Module
Wi-Fi
Data Proccessed

8. Project Structure (I)



- **The EV Charger PCB** is installed in each car charger, this circuit will **control the energy flow** based on decisions made by the central computer, received via **wireless communication**. It acts as an actuator, **dynamically regulating the amount of energy delivered to the car battery**.
- The **non-EV charger loads** on the grid are also monitored and sent to the central computer to assess overall load balance.
- In this module, the **State of Charge (SoC) of the EV battery** is also acquired and sent for further processing in the local Arduino, which is situated in each of the EV chargers.

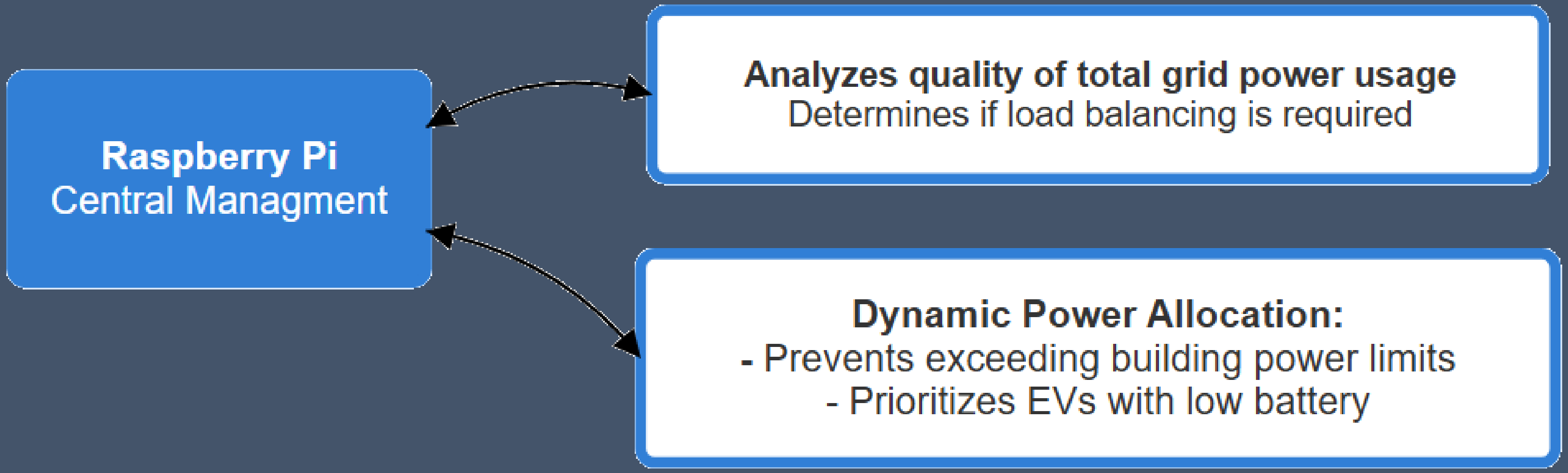
8. Project Structure (II)



- This part will be used to **read battery information** like battery status, current and max charging speed, etc via SoC.
- It will also read Power Measurement and limit what current will be used for charging.
- After reading all data it will **send to the central computer** and receive the current that can be used, using the wireless connection module.

8. Project Structure (III)

- **The central computer (Raspberry Pi)** in the system **receives information wirelessly** about total grid power usage and the status of multiple EV chargers.
- Using algorithms and battery physics limitations, this central management system **process this information to ensure optimal energy distribution**. This data includes power consumption levels and battery charge states.
- It determines if load balancing is necessary to prevent overloading the building’s power limits.
- Additionally, it dynamically allocates power by prioritizing electric vehicles (EVs) with the lowest battery levels while ensuring efficient energy use across all chargers.



9. Partners

- Currently, we do not have partners; however, we have the support of our Mentor, who will assist us in identifying potential partnerships throughout the ElectroCap Project.

Fig. 12 – Partners

- Considering the challenges that we may face, we plan to structure the problem and actively explore companies that can help us. This could involve seeking support for materials, identifying devices like what already exists, and collaborating with organizations that would allow us to test our prototype in their facilities and improve out research.

10. Testing and validation metrics

- **Charging Efficiency**: The percentage of available charging time that is used productively.

- **Power Utilization Rate**: The proportion of the building's electrical capacity allocated to EV charging versus other uses. Efficient systems should avoid exceeding the building's total power limit.

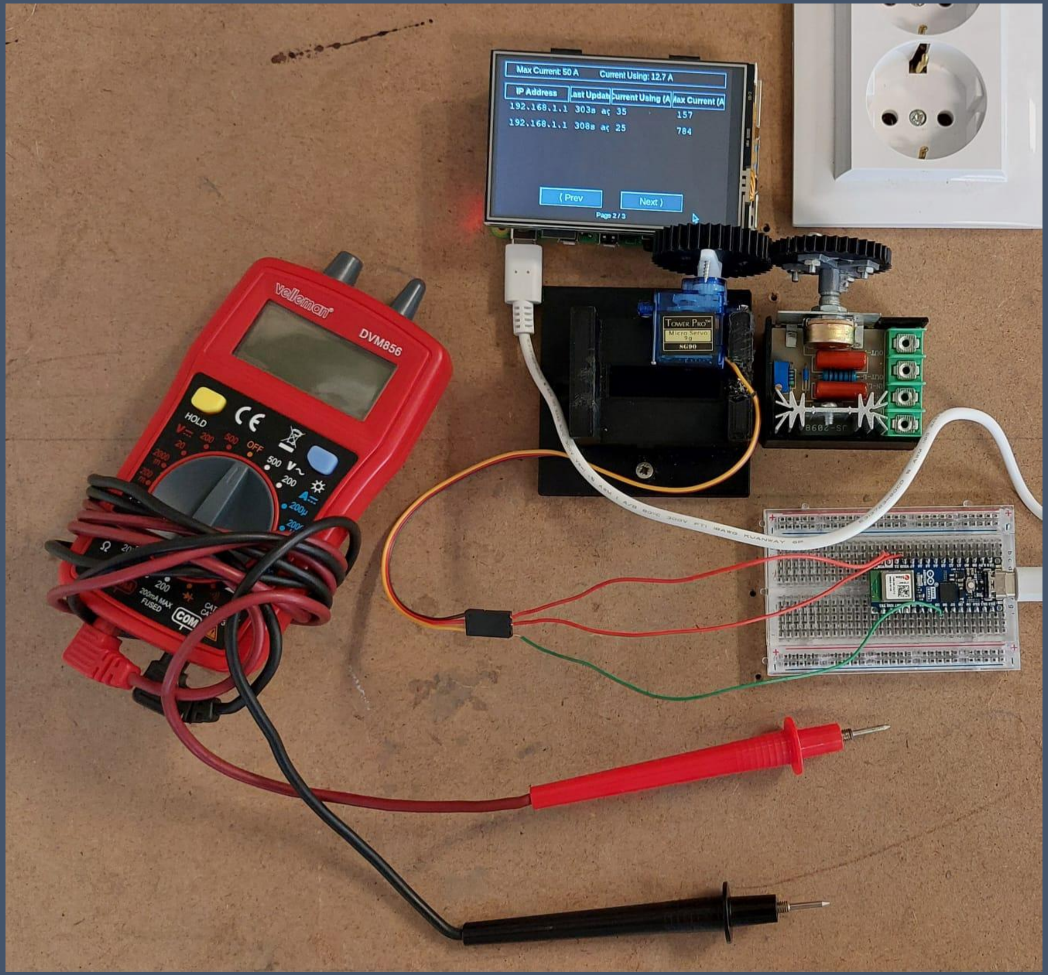


Fig. 13 – Used Material

11. Achieved Results

- A communication system has been successfully established between the central computer and all ESP32 microcontrollers installed at each EV charger. Each ESP32 is currently responsible for monitoring and transmitting key metrics such as the **charging speed** and **charging percentage** (i.e., the current state of charge of the battery) to the central dashboard. The central computer aggregates this data and provides a real-time overview of the charging infrastructure through a custom-built dashboard.
- To our surprise, our servo motor burned out. While we aren't entirely sure what caused this, the most likely explanation is that the current passing through the motor was too high when connected to a power supply.
- This setback was particularly frustrating since we received the materials only two weeks before the deadline, and we certainly didn't expect something like this to happen at such a crucial moment. Without the servo motor, we weren't unable to gather data on the current flowing into the chargers. This was a huge backstep for us since we only got the material 2 weeks before the deadline, we couldn't have something like this happening at the finish line. Without the servo motor, we didn't get data from the current that flows into the chargers.

12. References

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- Fig. 1, 2 - by Michael Fousert on Unsplash

- Fig. 3 - Image generated using ChatGPT-4 (by OpenAI) from the prompt: “Imagem de um edifício residencial com carregadores para EVs”.

- https://learnius.com

13. Website

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QR code to website - SmartFlowEV