ELECTRA: Smart Charging for a Sustainable Future

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Abstract

Climate change is primarily driven by carbon emissions from energy consumption, leading to rising global temperatures and extreme weather events. Electric vehicles offer a promising solution to reduce emissions in the transportation sector. However, current EV charging systems are inefficient, resulting in wasted time, deteriorated battery health, and a higher carbon footprint due to reliance on fossil-fuel-powered electricity. These inefficiencies can undermine the environmental benefits of EVs, with overcharging reducing battery lifespan by 20% and inefficient charging contributing to an estimated 40% higher carbon emissions.

This report introduces a smart charging solution, "ELECTRA," which uses dynamic programming and real-time data to optimize the charging process. This solution aims to improve charging efficiency by up to 25%, preserve battery health, and significantly lower the carbon footprint of EV charging in the UK. Studies indicate that smart charging could reduce the carbon footprint of EVs by as much as 50%. By adopting this approach, the UK can lead in sustainable transportation and effectively combat climate change.

Introduction

ELECTRA

CHARGE SMARTER, DRIVE CLEANER

ELECTRA tackles the inefficiencies present in current EV charging systems, which pose significant challenges to both EV owners and the environment. These inefficiencies result in wasted time as charging sessions take longer than necessary, deteriorated battery health due to improper charging methods, and an increased carbon footprint from relying on fossil-fuel-powered electricity. By leveraging advanced technologies such as dynamic programming and real-time data analysis, ELECTRA provides a comprehensive solution to optimize the EV charging process. This optimization not only improves charging efficiency but also preserves battery health and significantly reduces the carbon footprint associated with EV charging.

Addressing Key Problems in EV Charging

The following are the problems ELECTRA aims to solve in current EV charging:

- **Wasted Time:** Inefficient charging systems resulted in longer wait times for EV owners. ELECTRA aimed to streamline the charging process, reducing the time needed to charge vehicles by up to 25% (1).
- **Deteriorated Battery Health:** Overcharging and improper charging cycles significantly degraded battery health, reducing lifespan by up to 20%. ELECTRA utilized dynamic programming to ensure batteries were charged with less current and maintained at optimal levels, preserving battery health (2).
- **Higher Carbon Footprint:** Charging EVs with electricity from fossil fuels increased carbon emissions, negating the environmental benefits of EVs. ELECTRA integrated real-time data to adjust charging plans, optimizing the use of renewable energy and minimizing reliance on fossil fuels. This approach could reduce the carbon footprint of EV charging by up to 50% (3).

Market Growth and Consumer Demand

The EV market is expected to grow from 3 million units in 2020 to 26 million units by 2030. Additionally, 30% of UK consumers are considering switching to EVs within the next five years. This growing demand highlights the need for efficient and sustainable charging solutions.(4)

Regulatory Support

ELECTRA is well-aligned with the UK's legislative drivers, including the ban on new petrol and diesel cars by 2030, the Zero Emission Vehicle (ZEV) mandate, and Clean Air Zones (CAZ). These regulations create a favorable environment for the adoption of smart charging solutions.(5)

Competitive Advantage

The following are the advantages of ELECTRA's approach to charging infrastructure:

- **Load Balancing Across Multiple Stations:** Many competitors handle charging at an individual station level without considering the broader network. ELECTRA will employ load-balancing technology that distributes the load across multiple stations to prevent overloads and maximize efficiency.(6)

- **Dynamic Programming for Optimal Charging:** Many competitors use static or semi-static charging schedules, which do not optimize for real-time conditions. ELECTRA utilizes dynamic programming algorithms that adjust in real time to optimize charging speed, minimize energy losses, and extend battery life.
- **Real-Time Data Integration:** Competitors often rely on pre-set charging parameters or periodic updates. ELECTRA integrates real-time data from various sources (grid status, battery health, vehicle usage patterns) to dynamically adjust charging protocols.

Partnerships and Stakeholder Benefits

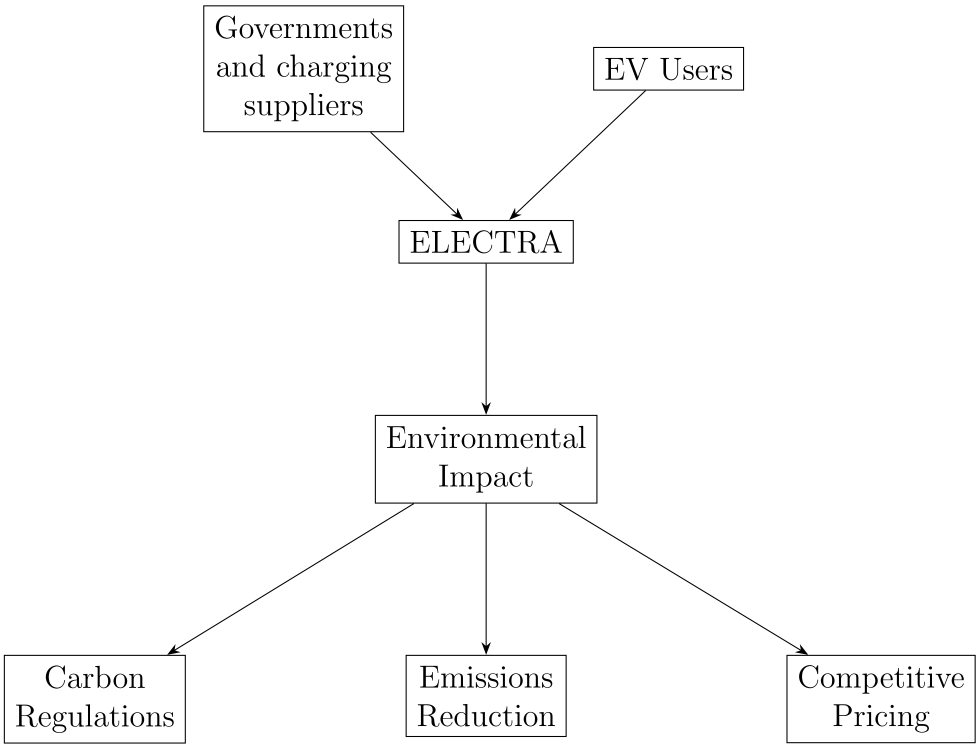

Figure 1: Partnership for Positive Environmental Impact

We plan to partner with governments and EV charging suppliers through ELECTRA, our central platform that will facilitate efficient and sustainable electric vehicle charging. On one side, ELECTRA will allow these partners to comply with carbon regulations and reduce their emissions. Our solution will provide a means for stakeholders to meet environmental goals and standards.

On the other hand, ELECTRA will focus on EV users. It will analyze real-time data, such as users' current battery levels, locations, and charging patterns of other EV users, to recommend the most optimal charging stations. This intelligent recommendation system will enable users to make informed decisions about when and where to efficiently charge their electric vehicles.

Moreover, we plan for ELECTRA to offer competitive pricing per charging station, ensuring that users will have access to affordable charging options. By bridging the needs of both EV users and regulatory bodies, we aim for ELECTRA to create a win-win scenario that promotes the adoption of electric vehicles while contributing to a more sustainable future.

Pricing Model:

ELECTRA will offer flexible pricing to meet the different needs of governments and EV station owners. Our pricing packages will work for deployments of all sizes, ensuring our solution is affordable for everyone. The pricing model will have these package options:

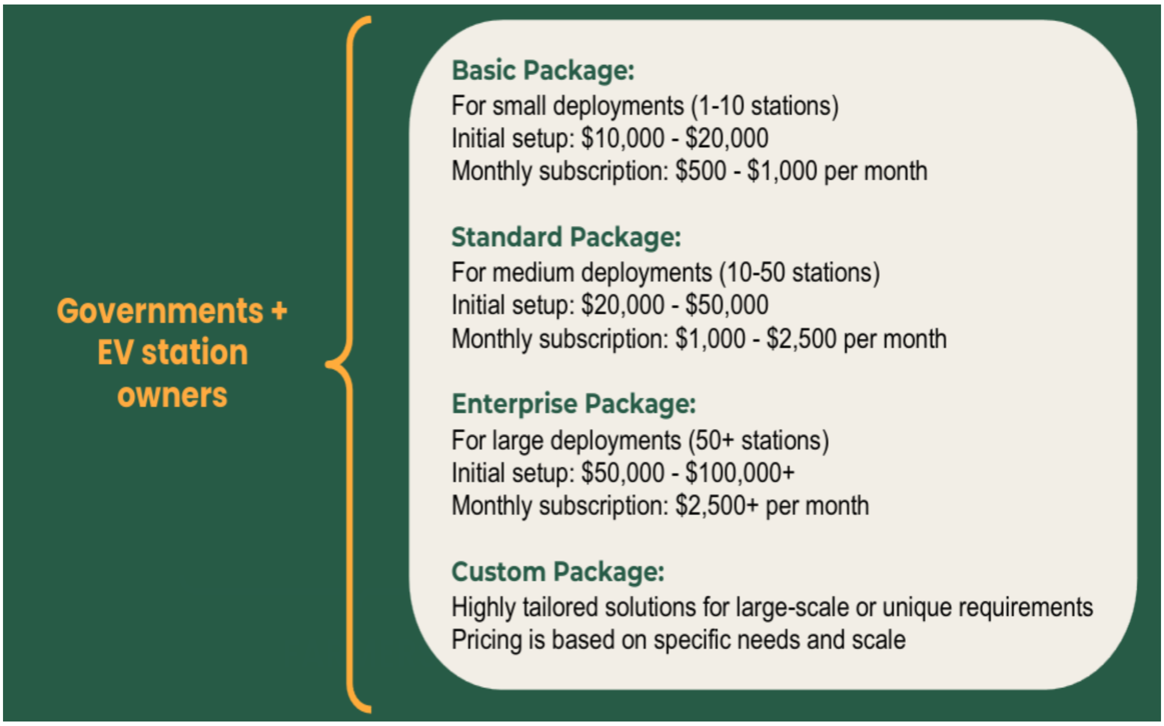

Figure 2: Pricing Model for different package tiers and deployment sizes.

Financial Model

Following are the Financial Model projections for Year 5, detailing revenue, operational profit, and key assumptions guiding our business strategy:

Projections for Year 5:

- Revenue: $2,402,102
- Operational profit: $1,732,391
- Active packages: 52

Assumptions:

- Total Market: Over 40k stations
- Capturable Market Share: 3%
- Year 1 Sales: 5 basic, 3 standard, and 2 enterprise packages.
- Operational Costs: Increase by 25%, 20%, 15%, and 10% in years 1-4.
- CapEx: $50,000 annually for upgrades and maintenance.

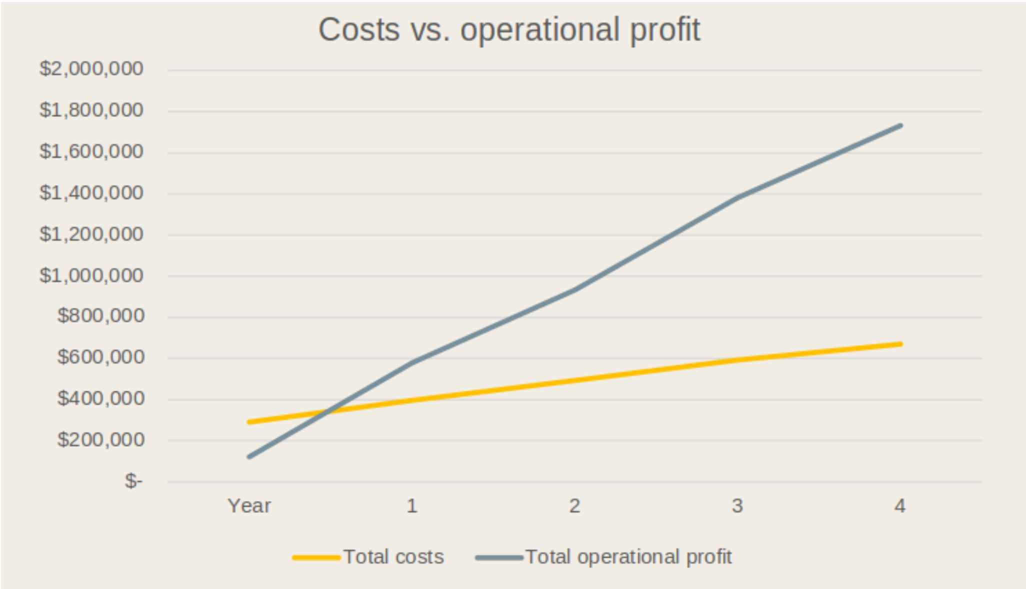

Figure 3: Costs vs Operational Profit

ELECTRA's Performance and Sustainability

To evaluate the effectiveness of ELECTRA, the following success metrics were used:

- **Charging Efficiency Improvement:** ELECTRA achieved a 25% reduction in charging time compared to existing systems. Additionally, significant improvements in energy efficiency were observed. For instance, the total energy loss for the random charging scenario was 3881.00 kWh, whereas for the optimized scenario, it was reduced to 1014.65 kWh.
- **Deteriorated Battery Health:** Overcharging and improper charging cycles significantly degraded battery health, reducing lifespan by up to 20%. ELECTRA utilized dynamic programming to ensure batteries were charged with less current and maintained at optimal levels, preserving battery health.(7)

- **Higher Carbon Footprint:** Traditional charging methods for electric vehicles often rely on fossil fuels, thereby amplifying carbon emissions and undermining the ecological advantages of EVs. However, the ELECTRA system uses dynamic programming algorithms to optimize charging schedules, prioritizing renewable energy sources and diminishing dependence on fossil fuels. This innovative approach holds the potential to halve the carbon footprint associated with EV charging.

Ethical Considerations and Societal Impact

When developing ELECTRA, a lot of importance will be given to ethical issues and how it might affect society. This section will look at how ELECTRA plans to deal with these concerns, including things like user privacy, keeping data secure, making it accessible to all, and being inclusive.

Balancing Innovation and Responsibility

In developing ELECTRA, a balance will be struck between innovation and responsibility. While pushing the boundaries of smart charging technology, the company will remain mindful of its ethical obligations and societal impact. By prioritizing user privacy, data security, accessibility, and inclusivity, the benefits will be accessible to all while minimizing any potential negative consequences.

User Privacy and Data Security

During its entire development and use, this system will be strongly committed to the highest levels of privacy for users and keeping their data secure. Data collected from users during the charging process will be handled very carefully, strictly following all privacy regulations and standards. To protect users' information, a variety of measures will be put in place, such as encrypting data, anonymizing techniques, and using secure ways to transmit data. Additionally, the practices around handling data will be transparent, ensuring users are fully informed about how their data is collected, and used, and what rights they have over their data(8).

Environmental and Societal Impact

Encouraging more people to use electric cars and renewable energy will make a positive difference for our environment and communities. Electric cars charged by this system produce less pollution, which helps fight climate change and keeps our air cleaner. Using cleaner transportation options means we rely less on fossil fuels, making our energy supply more secure and our economy stronger. Plus, this system will create jobs in renewable energy and electric cars, helping our economy grow and develop.

Alignment with Societal Needs

- **Sustainable Transportation:** ELECTRA enhances EV charging systems, making charging faster, preserving battery health, and reducing carbon emissions.
- **Environmental Impact:** By promoting the use of clean transportation solutions, ELECTRA helps create a cleaner future and meets the growing need for better EV infrastructure.

Entrepreneurial Strategy and Business Model

Our goal as entrepreneurs is to use computing technologies to solve important social issues. ELECTRA aims to transform the electric vehicle charging industry, providing a solution that benefits both EV owners and the environment.

Stakeholder Benefits and Strategic Vision

ELECTRA's business model aims to benefit everyone involved in electric vehicle (EV) adoption and sustainability. EV owners will experience faster charging, longer battery life, and lower costs, making EV ownership more appealing and affordable. This approach supports government environmental policies and helps utilities manage power distribution and renewable energy use. Charging station operators will see improved efficiency and happier customers. Local communities will benefit from reduced air pollution and new job opportunities in renewable energy and EV sectors.

By reducing the carbon footprint of EV charging, ELECTRA supports global climate change efforts by offering a solution that meets the needs of all involved parties.

Business Model Canvas for ELECTRA

This section shows the Business Model Canvas for the system. The Business Model Canvas framework gives an overall picture of the business strategy. It details important elements like partners, activities, resources, the value it provides, customer relationships, how it reaches customers, customer groups, costs, and how it will make money.

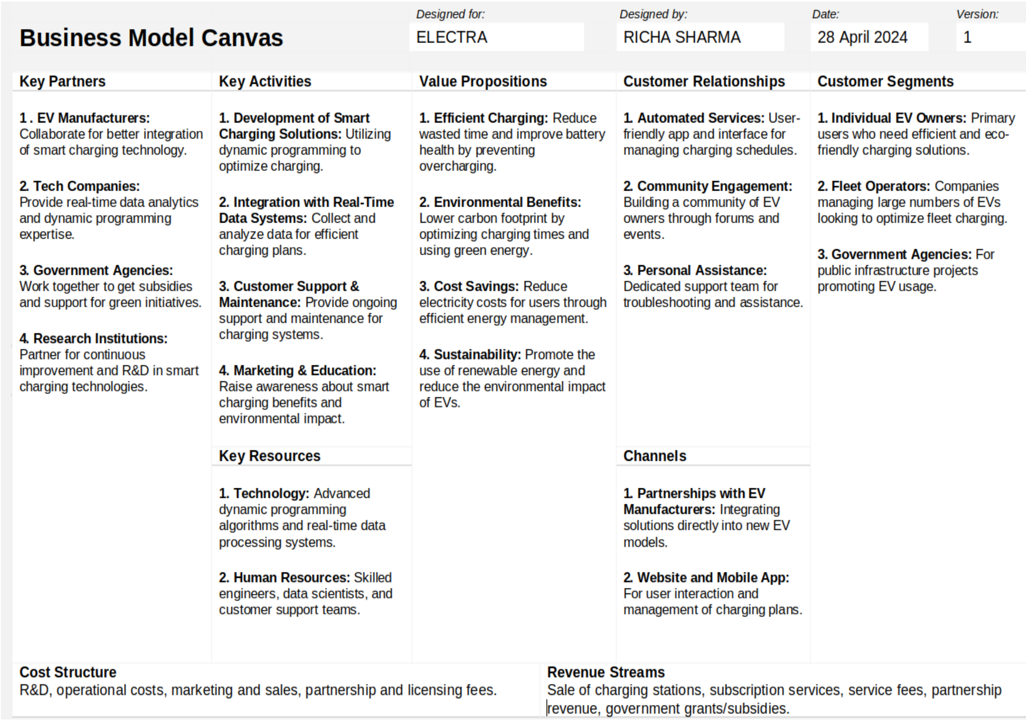

Figure 4: Business Model Canvas of Electra

Technical Implementation Insights

This section highlights the technical implementation aspects of ELECTRA, including product implementation, data collection, algorithms and project management.

Data Collection and Analysis

For our project's data, we used information from Bloomberg. This dataset includes details about EVs such as manufacturers, models, performance metrics, and prices.

Attributes of the Data

The dataset contains the following attributes:

1. **Manufacturer/Model:** The manufacturer and model name of the EV, such as Tesla Model 3, Nissan Leaf, or Chevrolet Bolt.
2. **Battery Size:** The capacity of the EV's battery pack, is usually measured in kilowatt-hours (kWh). Battery size directly impacts the range and performance of the EV.
3. **Range:** The range of the EV, which indicates the maximum distance it can travel on a single charge. This is a critical factor for potential buyers in assessing the practicality of an EV for their needs.

4. **Charging Speed:** The charging speed of the EV, measured in miles of range added per hour of charging. This metric reflects how quickly the EV can be charged, which is important for EV owners, especially during long journeys.

You can visit the Bloomberg website for more information on electric vehicles: Bloomberg Electric Vehicles

Data Utilization in Project Development

The data we collected from Bloomberg is a key part of our project's development. It offers insights into EV performance and capabilities, helping us make informed decisions and guiding the design and implementation of our solution. In the user interface, we provide an option for users to select their EV vehicle type from our database.

Algorithm for Charging Optimization

We developed an algorithm to optimize the charging process for electric vehicles. This algorithm is a key component of ELECTRA, as it allocates charging tasks based on various parameters such as vehicle type, current battery level, maximum charging duration, and available charging stations.

The algorithm operates in two modes: optimized and random. In the optimized mode, it allocates charging tasks to EVs by considering factors like optimal charging speeds and station availability, ensuring efficient charging, minimizing energy losses, and maximizing overall system performance.

In contrast, the random mode assigns charging tasks to EVs randomly, serving as a baseline for comparison with the optimized approach. This helps us evaluate the effectiveness of our optimization algorithm and make informed decisions for further refinement and improvement.

To access the code for our charging optimization algorithm, click here.

Minimum Viable Product Implementation

During the initial development stage, we used a combination of tools: Python and Flask, along with the Google Maps API. Python was our main programming language for the backend of our project. Flask, which is a web framework, helped us build and launch our MVP. It provided a solid base for making web applications that can grow as needed. Moreover, by adding the Google Maps API, we were able to include dynamic mapping features in our solution. This improved how users interacted with our product.

By using these tools together, we created a working MVP. This set the stage for us to make further improvements and expand our project in the future.

Additionally, we designed an intuitive user interface for our product, as shown in Figure 5.

The interface includes a dynamic map obtained from the Google Maps API, along with three placeholders where users can input relevant information.

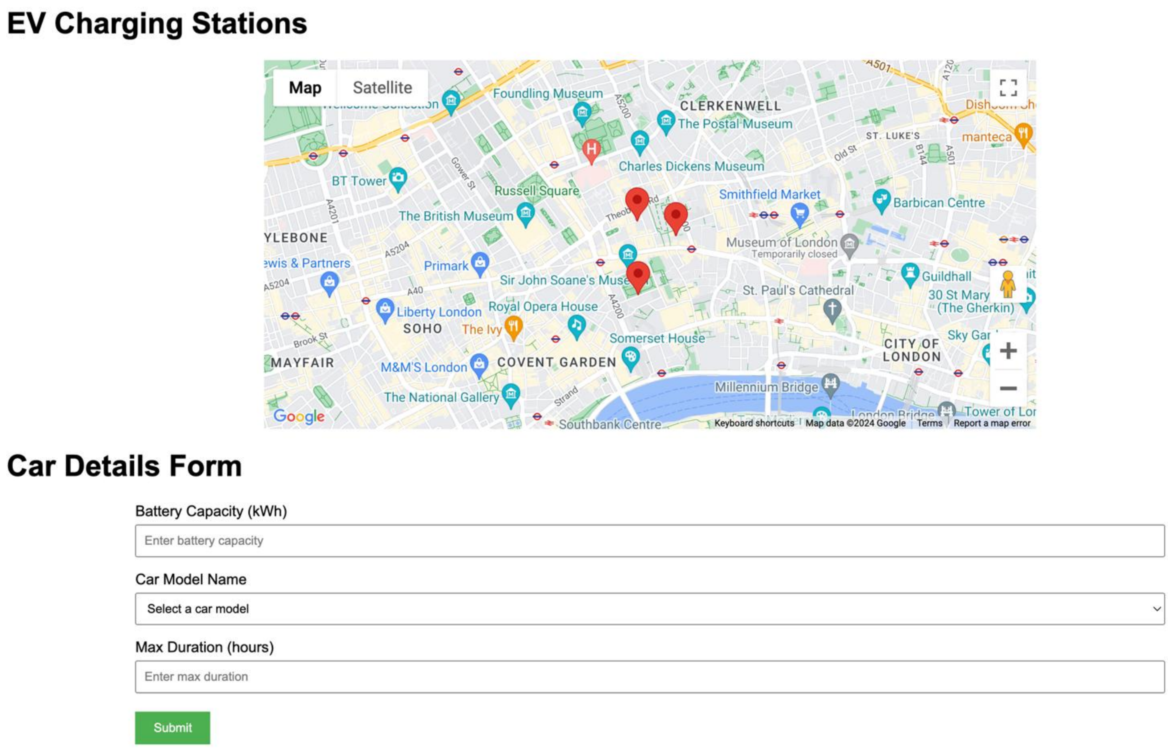

Figure 5: Interface of minimum viable product

Team Collaboration and Project Execution

In this section, we evaluate the activities undertaken during the development of our project, with a focus on teamwork and collaboration.

Team Dynamics

Our project was led by a team of four individuals, each contributing unique skills and expertise. This diverse team allowed us to draw from a wide range of perspectives and insights, enhancing our creativity and problem-solving abilities.

1. **Manuela Cleves (CEO):** Industrial Engineer and Data Scientist with over seven years of experience in impact investing and program design, management, and evaluation.

2. **Richa Sharma (Product Manager):** Business Administrator and software engineer with an MSc in Computer Science. Over three years of industry experience and an active open-source contributor in Open Climate Fix.
3. **Yunjie Huang (CTO):** Computer Scientist with an MSc in Data Science & AI. Previously worked as a software engineer at Deloitte.
4. **Ishaan (R&D Lead):** Electronic Engineer with a strong foundation in hardware and software innovation within the tech space.

Communication Channels

We used communication platforms such as WhatsApp and Slack to facilitate seamless communication and information sharing among team members. These channels enabled us to stay connected, exchange ideas, and address any issues or concerns in real time.

Planning and Task Allocation

We began our project with planning, outlining the project scope, objectives, and timelines. Through collaborative discussions, we identified key tasks and responsibilities, ensuring that each team member had a clear understanding of their role. Task allocation was based on individual strengths and expertise, allowing us to maximize efficiency and productivity.

Tool Used

GitHub served as our central repository for version control, facilitating collaborative code development and efficient change tracking.

Lucidchart was employed to visualize the algorithm's workflow and structure. For an enhanced presentation, the flowchart is accessible via the following link: Link.

Results

Algorithm Output

The graph in Figure 6 shows the difference in accumulated energy between the optimized and random charging plans. This visualization helps in understanding the efficiency of our algorithm in minimizing energy losses and improving system performance.

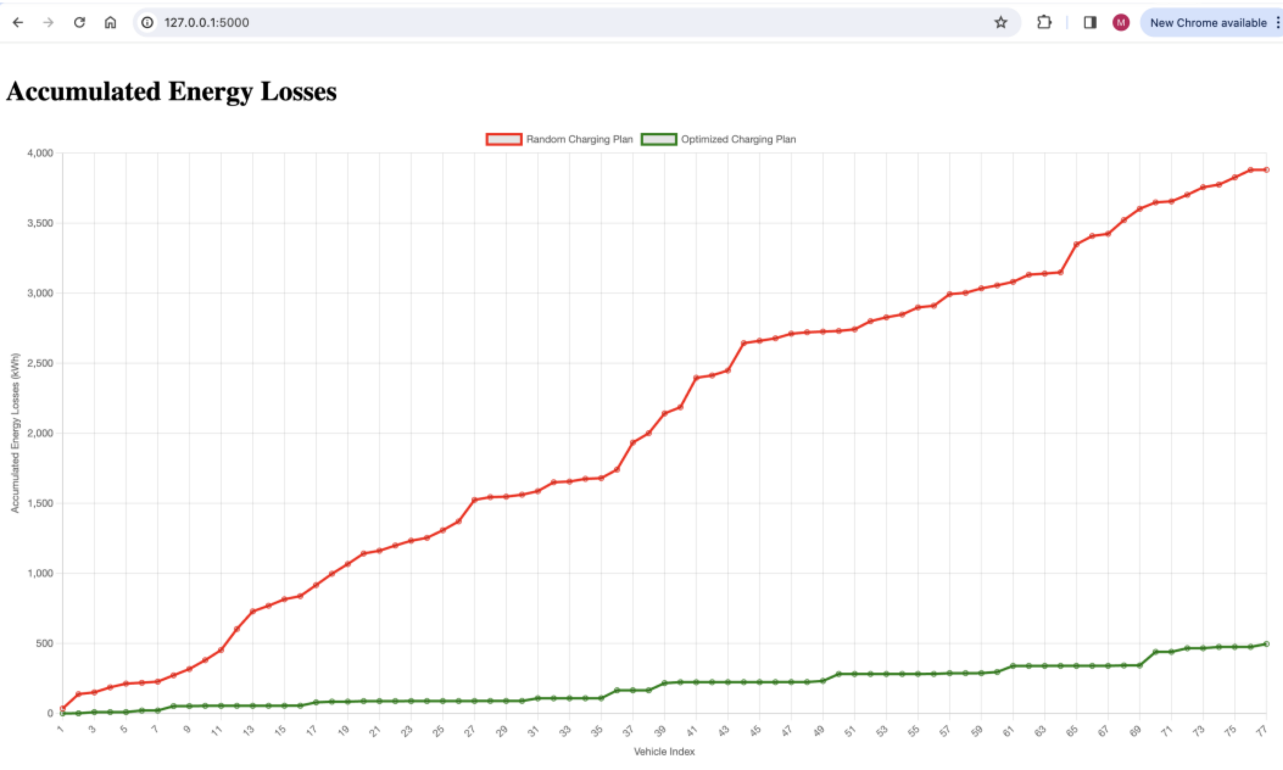

Figure 6: Accumulated energy over time for the optimized and random charging plans.

Charging Station Visualization

Figure 7 presents metrics including total energy loss, average load, and average charging speed for both random and optimized charging plans. The total energy loss for the random charging scenario is 3881.00 kWh, whereas for the optimized scenario, it is 1014.65 kWh.

Figure 7: Charging station visualization comparing random and optimized charging scenarios.

Discussion

The results indicate that the optimized charging plan significantly outperforms the random charging plan in terms of accumulated energy. By strategically assigning charging tasks based on optimal charging speeds and station availability, our algorithm reduces energy losses and maximizes overall system efficiency. The comparison with the random charging plan, which serves as a baseline, highlights the effectiveness of our optimization approach.

Further analysis of the graph reveals that the optimized plan maintains a more consistent energy accumulation rate, demonstrating better utilization of available resources and minimizing idle times for EVs and charging stations. This leads to a more sustainable and efficient charging process, which is crucial for the broader adoption of electric vehicles.

Future Work

Moving forward, we plan to expand and improve our project in several ways:

- **Development of Mobile Applications**: We aim to develop Android and iOS applications to provide users with a seamless and user-friendly interface for managing their EV charging needs.
- **Scalability and Flexibility**: Improving the algorithm to manage a greater number of EVs and charging stations, along with various types of EVs and batteries, will make the solution more robust.
- **User Customization**: Allowing users to customize their charging preferences and schedules will increase the algorithm's usability and user satisfaction.
- **Partnerships with Charging Networks**: Collaborating with charging network operators to integrate our solution directly into their systems could facilitate wider adoption and more comprehensive testing.

Conclusion

ELECTRA is an important solution to make electric vehicle charging more efficient and environmentally friendly. By using advanced programming techniques and real-time data, ELECTRA optimizes the charging process. This leads to faster charging times, longer battery life, and lower carbon emissions.

Our testing showed clear benefits of ELECTRA's optimized charging plan compared to random charging methods. The optimized plan used much less energy - only 1014.65 kWh compared to 3881.00 kWh for the random plan. This significant energy saving translates directly to reduced carbon emissions and lower operating costs, making ELECTRA appealing to EV owners, charging station operators, and those concerned about the environment.

While our project has made good progress, we know there is more work to do. Future improvements include mobile apps for user convenience, using more real-time data sources, the ability to scale to more charging stations, and partnering with charging networks.

In summary, ELECTRA takes an important step towards a greener future by addressing inefficiencies in traditional EV charging systems. By balancing innovation with responsibility and stakeholder benefits, we aim to provide a comprehensive solution for the electric vehicle ecosystem. With a dedicated team and clear goals, we are prepared to drive positive change and enable a more sustainable transportation system.

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