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# Wireless Charging Pathway for RFID-Authenticated Electric Vehicles

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***Abstract: -*** In the upcoming times, transitioning to electric vehicles from traditional diesel-powered ones will be crucial for achieving a more sustainable and efficient transportation future. This paper introduces the concept of Wireless Charging Pathway (WCP) specifically designed for RFID-authenticated vehicles. The paper also describes the implementation of a routing algorithm to guide electric vehicles to the nearest available charging lane based on lane occupancy and traffic conditions. Moreover, the paper incorporates a prototype demonstration of wireless charging through mutual inductance. Once an EV is verified and authenticated for charging, it is guided to the designated charging lane where wireless charging occurs through mutual inductance between the vehicle and the charging infrastructure present on the road. In this paper, we explore how this technology could transform the way we charge electric vehicles, making transportation more sustainable and efficient.

***Keywords:*** Electric vehicle, wireless power transfer, RFID- authentication, wireless pathway, inductive coupling.

## I. INTRODUCTION

As the world embraces sustainability, electric vehicles (EVs) are becoming more popular globally. However, the widespread use of EVs brings challenges, especially the need for efficient and easily accessible charging infrastructure. To address this issue, this paper introduces the idea of Wireless Charging Path- way (WCP) for electric vehicles. The WCP system represents an advancement in electric vehicle (EV) technology, offering a seamless and efficient method to power EVs without the need for physical connectors. By integrating these pathways into road infrastructure, vehicles can be charged dynamically while in motion eliminating the downtime typically associated with conventional charging stations.

To further enhance the security and efficiency of this technology, RFID-enabled authentication systems are employed. These systems ensure that only authorized vehicles can access the charging pathways, preventing unauthorized usage. This integration of wireless charging and RFID authentication paves the way for a smarter, more connected infrastructure that supports the widespread adoption of electric vehicles, ultimately advancing the goals of sustainable transportation.

Routing electric vehicles to charging lanes is crucial for optimizing the use of wireless charging infrastructure. By implementing routing algorithms, cities can ensure that EVs are directed to the nearest available charging lane based on factors such as traffic conditions and proximity to their destination, as described by the author Zhou et al [1]. This proactive approach to routing not only minimizes congestion at charging lanes but also maximizes the efficiency of the charging process, reducing overall travel times and enhancing the user experience for EV owners.

The Dynamic Charging Lane (DCL) for authenticated Electric Vehicles emerges as a promising answer to this question as described by the author [2] M. R. R. Razu et al. It represents a paradigm shift in the way we think about EV charging infrastructure. Instead of static charging stations, DCL envisions a dynamic wireless and integrated system within the existing road network that provides electric vehicles with a continuous and seamless source of power. This concept, while still in its early stages, carries the potential to revolutionize how we charge EVs by making it as straightforward as driving on the road.

## II. RELATED WORKS

The research conducted by ElGhanam et al. [3] illuminates the escalating significance of Dynamic Wireless Charging (DWC) systems in propelling electric vehicles (EVs) while in motion. This innovation offers a promising remedy to address concerns regarding range limitations and charging infrastructure. Their study introduces a pioneering online, mobility- aware EV allocation algorithm within the realm of DWC coordination. This algorithm

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adeptly guides EVs seeking a charge to the most suitable DWC lanes, emphasizing the criticality of maximizing cost optimization, integrating renewable energy sources, and bolstering the overall sustainability of the electric vehicle ecosystem. DWC can be visualized with the help of a simulation tool as described in the research conducted by M. Muralidharan et al. [4].

This paper gives an in-depth exploration of the technical aspects of the DWC system, which is demonstrated with the help of SUMO (Simulation of Urban Mobility), which is a simulation tool utilized to understand urban mobility context.

The research conducted by Ushkewar et al. [5] addresses the emerging technology of wireless charging for electric vehicles (EVs) in dynamic environments, focusing on the challenges and solutions associated with ensuring efficient energy transfer while the vehicle is in motion. It explores various aspects of dynamic wireless power transfer (DWPT) systems, including design considerations, power transfer efficiency, infrastructure requirements, and real-world implementation challenges. Beyond the scope of charging technologies, traffic density emerges as a pivotal concern, notably in urban settings. The crowded lanes directly affect the way people travel, especially in the field of logistics distribution. To find an optimal urban distribution route that satisfies electric vehicle limitation, a mixed planning model is developed as mentioned by Li et al. [6] for the routing of EVs.

The study conducted by Bhargavi et al. [7] provides a comprehensive examination of wireless power transmission for electric vehicles, covering the underlying principles, design considerations, efficiency optimization, safety issues, and real- world applications. The paper underscores the transformative potential of WPT technology in making EV charging more convenient and accessible, while also addressing the technical and economic challenges that need to be resolved to facilitate widespread adoption.

This paper by Mehar et al. (8) explores the concept of wireless power charging systems for electric vehicles using the inductive coupling method. It covers the theoretical principles, system design, implementation, efficiency valuation, and safety considerations. By presenting case studies and discussing the advantages and limitations, the paper underscores the potential of inductive coupling to offer a convenient and efficient charging solution.

## III. PROPOSED WORK

The flowchart proposes a system to optimize electric vehicle (EV) charging efficiency by regulating access to a designated lane. As a vehicle enters the lane, a sensor system identifies it. Electric vehicles are then differentiated from non-electric ones, potentially through vehicle markers or emissions data. Authorized EVs undergo a further check, likely using RFID tags, to confirm their permission to use the lane. Authenticated EVs are granted access to proceed and charge, while unauthorized vehicles, which could be electric vehicles without proper credentials or non-electric vehicles altogether, are redirected elsewhere. This system aims to streamline charging access for authorized EVs while preventing misuse of the lane by non- compliant vehicles as shown in Fig. 1.

Electric cars (EVs) and traditional vehicles can be differentiated based on various primary factors such as maximum battery capacity, peak power output, consistent power consumption, energy recovery efficiency, and braking thresholds.

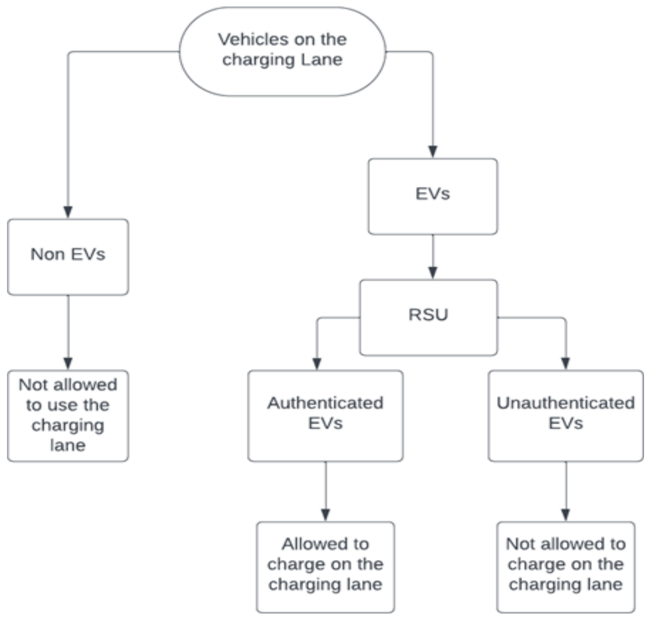


**Fig. 1. Flowchart of Vehicle Access to Charging Lane**

*A. Inductive WPT*

Inductive wireless power transfer (WPT) in electric vehicles (EVs) operates through electromagnetic fields to charge the vehicle's battery without physical cables. The process involves two main components: a transmitting coil, typically installed on the ground, and a receiving coil located on the underside of the EV. When the EV moves over the transmitting coil, an electromagnetic field is generated by the transmitting coil, inducing a current in the receiving coil on the vehicle. This current is then directed to the vehicle's onboard power management system to charge the battery. Inductive wireless power transfer (WPT) simplifies the charging procedure, providing ease and eliminating the requirement for manual cable connections. [9]

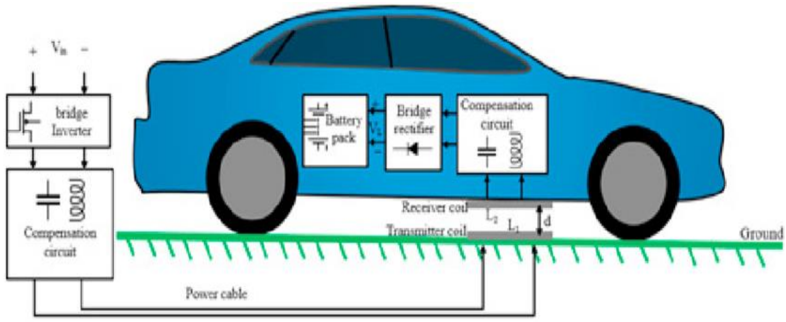


**Fig. 2. Generic Diagram of Inductive WPT [ 9]**

*B. Radio-Frequency Identification (RFID)*

Radio Frequency Identification (RFID) technology employs radio waves for the identification and tracking of objects, consisting of three primary components. Upon entering the reader's electromagnetic field, the tag is activated and transmits its data through modulated radio waves. The reader then captures this data and relays it to a central computer system for further processing. RFID systems operate across various frequency ranges, including Low Frequency (LF), High Frequency (HF), Ultra-High Frequency (UHF), and Microwave. RFID readers emit radio waves to initiate and establish communication with RFID tags. When a RFID reader emits an interrogating signal, it triggers the activation of nearby RFID tags, prompting them to transmit the data they store. This transmitted data can encompass a variety of information, such as unique identifiers, sensor data, or other pertinent details. Subsequently, readers capture this transmitted data and relay it to a computer system for further processing and analysis. This is described in the research conducted by Ching-Yen Chung et al. [10]. The working of RFID [15]is illustrated in the Fig 3.

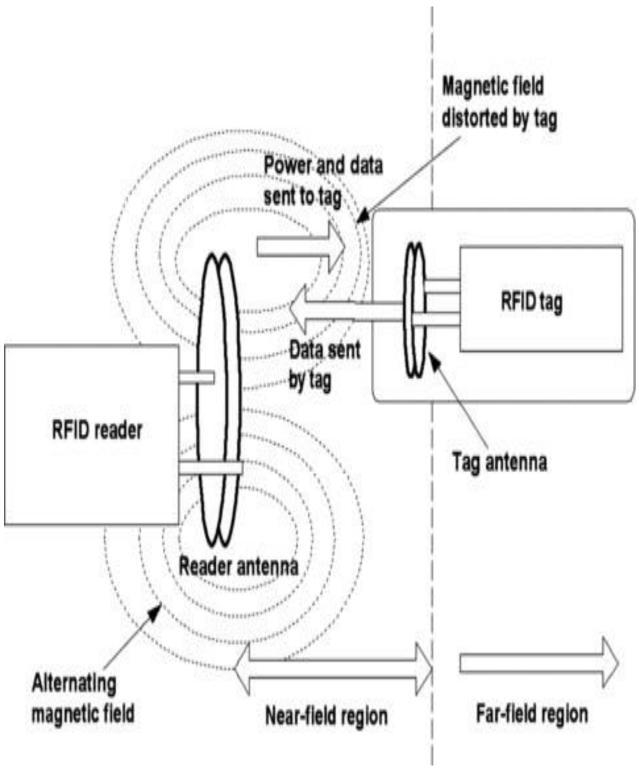


**Fig. 3. Working of RFID [15]**

### C. *Electric Vehicle Routing Algorithm "ElectraTrail"*

The Electric Vehicle Routing Algorithm "ElectraTrail" determines the most efficient routes for electric vehicles, considering factors such as charging lane locations, traffic conditions, and electric vehicle traffic. The ElectraTrail algorithm leverages OpenStreetMap data, which provides detailed information about road networks, including the locations of charging lanes. By using the OR-Tools library, the algorithm is equipped with optimization techniques to efficiently compute optimal routes for EVs. To make the results of the algorithm more accessible and understandable, we visualize them using interactive Folium maps.

The dataset for live traffic conditions and EV (electric vehicle) traffic conditions in the city of Ulldecona as shown in Fig.4, serves as a crucial resource for the ElectraTrail algorithm. This dataset of 500 data points contains information such as normal traffic conditions and EV traffic conditions across Ulldecona's road network. Leveraging this dataset, the algorithm can make informed decisions regarding optimal routes for electric vehicles, considering both traffic dynamics and EV- specific considerations, thereby enhancing mobility efficiency and sustainability within Ulldecona.

| | A | B | C | D | E | F | G | H | I |
|---|---|---|---|---|---|---|---|---|---|
| 1 | city | normtraf | evtraf | name | province | street | | | |
| 2 | Alcanar | 40.59315 | 0.561053 | Bar Monts | Tarragona | Carrer Tarongina, 2 | | | |
| 3 | Alcanar | 40.54211 | 0.481537 | Bar Paella | Tarragona | Carrer del Canonge Matamoros, 7 | | | |
| 4 | Alcanar | 40.54388 | 0.477914 | Restauran | Tarragona | Carrer de l'Arquitecte GaudÃ-, 26 | | | |
| 5 | Alcanar | 40.52865 | 0.509533 | Citrus del | Tarragona | C N-340 Km 1059 (Sol de Riu | | | |
| 6 | Alcanar | 40.56906 | 0.5384 | Bar km.10 | Tarragona | Carrer a Platja Daurada, 2 | | | |
| 7 | Alcanar | 40.59704 | 0.568667 | Restauran | Tarragona | Av. Mar, 9 | | | |
| 8 | Alcanar | 40.54211 | 0.4817 | SofÃ-a Alc | Tarragona | Carrer Miquel Figueres, 6 | | | |
| 9 | Alcanar | 40.54394 | 0.476781 | Restauran | Tarragona | TP-3318, 54 | | | |
| 10 | Alcanar | 40.54514 | 0.476673 | Juan Pedr | Tarragona | Rda. del Remei, 73 | | | |
| 11 | Alcanar | 40.54302 | 0.481086 | Bar Morer | Tarragona | PlaÃ§a Major, 2 | | | |
| 12 | Alcanar | 40.54328 | 0.480656 | Casa Keba | Tarragona | PlaÃ§a Major, 7 | | | |
| 13 | Alcanar | 40.54325 | 0.482237 | Serra Mar | Tarragona | Avenida Mar, 0 S/N | | | |
| 14 | Alcanar | 40.54097 | 0.481524 | Restauran | Tarragona | Carrer de Ramon i Cajal, 37 | | | |
| 15 | Alcanar | 40.54103 | 0.478198 | Andreu | Tarragona | Avinguda de Catalunya, 4 | | | |
| 16 | Alcanar | 40.54172 | 0.48054 | Bar Abril | Tarragona | Av. d'Abril, 9 | | | |
| 17 | Alcanar | 40.54516 | 0.476688 | Bar Migue | Tarragona | Rda. del Remei, 75 | | | |
| 18 | Alcanar | 40.54498 | 0.483026 | La Llaunet | Tarragona | Carrer de les Eres, 21 | | | |
| 19 | Alcanar | 40.54597 | 0.476567 | Bar Lloren | Tarragona | Carrer Rafel Casanova, 11 | | | |
| 20 | Alcanar | 40.59205 | 0.559392 | Anna | Tarragona | Av. MontsiÃ , 23 | | | |
| 21 | Alcanar | 40.54058 | 0.475722 | Bar Miracl | Tarragona | Ctra. Nova, 77, 81 | | | |

**Fig. 4. Dataset of Ulldecona City**

## IV. RESULTS

### *A. Prototype Result*

The prototype developed for wireless charging of electric vehicles (EVs) via mutual inductance between two coils represents a cutting-edge solution to the evolving needs of sustainable transportation infrastructure. At its core, the system comprises a primary coil embedded in the road surface and a secondary coil installed beneath the EV. These coils are configured to achieve optimal mutual inductance, enabling efficient power transfer without the need for physical contact. A fundamental aspect of the prototype is the creation of dedicated charging lanes equipped with primary coils. These lanes are strategically positioned within roadways, allowing EVs to access charging infrastructure seamlessly as they travel over them. As an EV enters the designated charging lane, the secondary coil underneath the vehicle aligns with the primary coil in the road, initiating the wireless charging process automatically. This innovative approach eliminates the need for manual intervention, streamlining the charging experience for EV owners.

Integral to the functionality of the prototype is the integration of a sophisticated motion sensor system. These sensors are strategically deployed along the charging lanes to detect the approach of vehicles. Upon detecting motion, the sensors trigger a relay switch, facilitating the activation of the charging process. This automated mechanism ensures that charging begins promptly as the EV enters the charging lane, enhancing convenience and efficiency.

In addition to automation, the prototype prioritizes security through the implementation of RFID authentication technology. Each EV is equipped with an RFID tag or chip, which serves as a unique identifier. Before the charging process commences, the system verifies the authenticity of the vehicle by scanning its RFID tag. Only authenticated EVs are granted access to the wireless charging infrastructure, mitigating the risk of unauthorized usage and ensuring the integrity of the system.

This prototype represents a significant advancement in wireless charging technology for EVs, offering a comprehensive solution that integrates automation, security, efficiency, and safety. With its potential for scalability and seamless integration with existing EVs, the system holds promise for widespread adoption of electric vehicles.

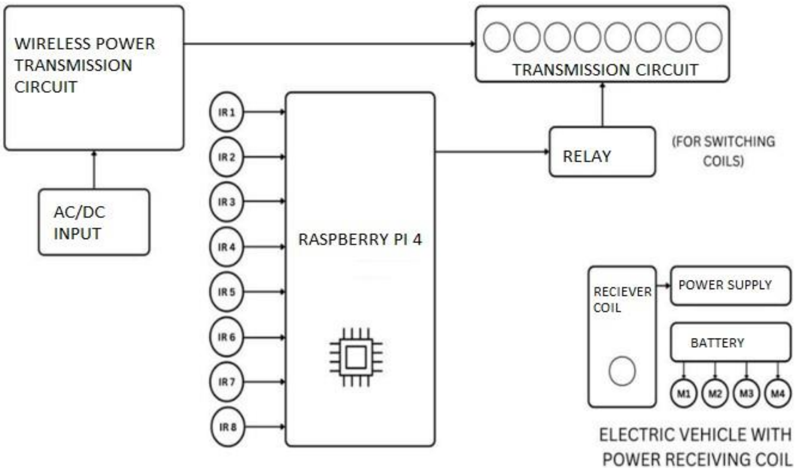


**Fig. 5. Block diagram of the prototype [16]**

This wireless charging method is based on the Inductive coupling technique. The circuit consists of two parts: Transmitter and Receiver [16] as shown in Fig.5.

In the transmitter section, the primary coil is placed on the charging lane as shown in Fig.6. This coil being powered up generates a magnetic field around it. As the coil is center tapped, the two sides of the coil start to charge up. One side of the coil is connected to the resistor and another side is connected to the collector terminal of the NPN transistor. During the charging condition, the base resistor starts to conduct which eventually turns on the transistor.

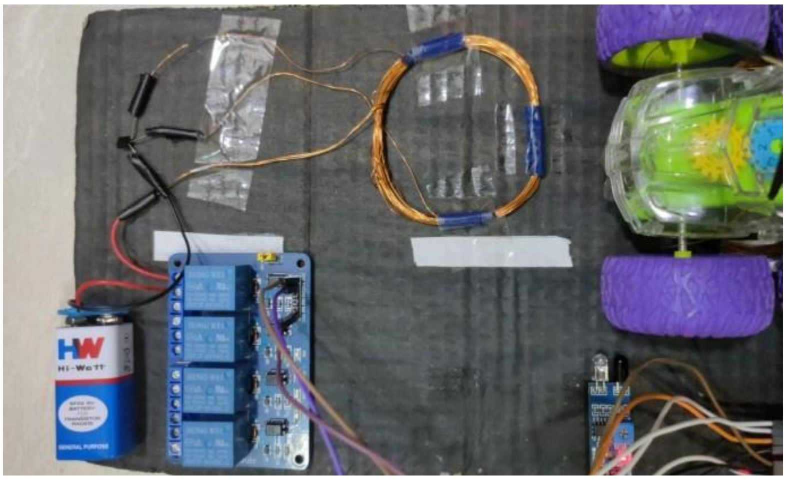

**Fig. 6. Primary coil placed on the charging lane.**

On the receiver side, that magnetic field is transferred into the secondary coil placed beneath the car as shown in Fig.7, and by Faraday's law of induction, the receiver coil starts producing EMF voltage which is further used to light up the LED.

**Fig. 7. Secondary coil placed beneath the car.**

The MFRC522 RFID reader, connected to a Raspberry Pi as shown in Fig. 8, facilitates authentication by exchanging encrypted data with RFID tags. This interaction verifies the identity of the tag, enabling secure access control and authentication systems

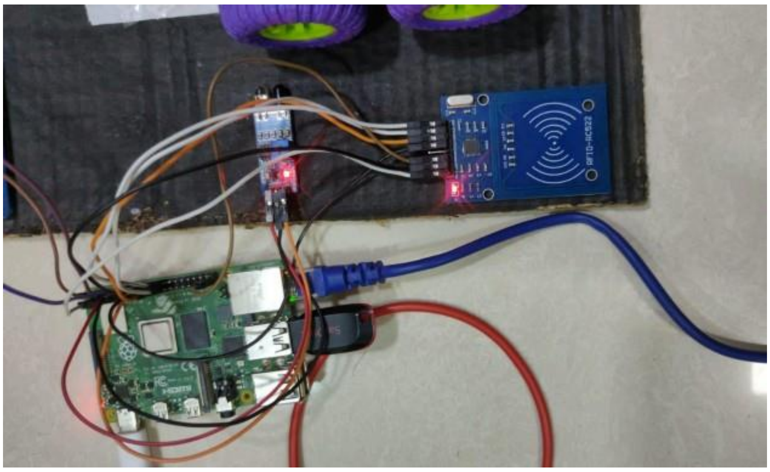

**Fig. 8. RFID reader connected to Raspberry Pi.**

When motion is sensed by an IR sensor, it triggers a relay switch, closing its contacts and activating the charging process as shown in Fig.9. The relay switch provides power to the transmitter section, creating a high-frequency oscillation signal.

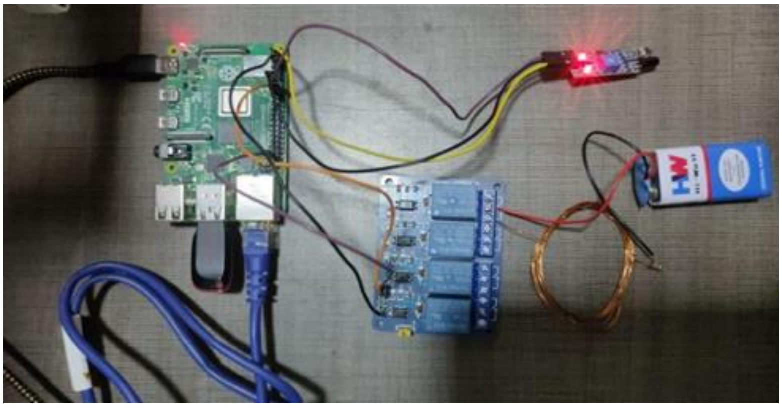

**Fig. 9. IR sensor and relay connected to Raspberry Pi**

The RFID reader first verifies if the vehicle is authenticated. Upon authentication and subsequent detection of motion by the IR sensor, a relay connected to the battery triggers, activating the primary coil on the charging lane. This coil induces a current in the secondary coil through mutual induction, facilitating charging. Charging completion is signaled by the illumination of an LED. This is depicted in Fig.10.

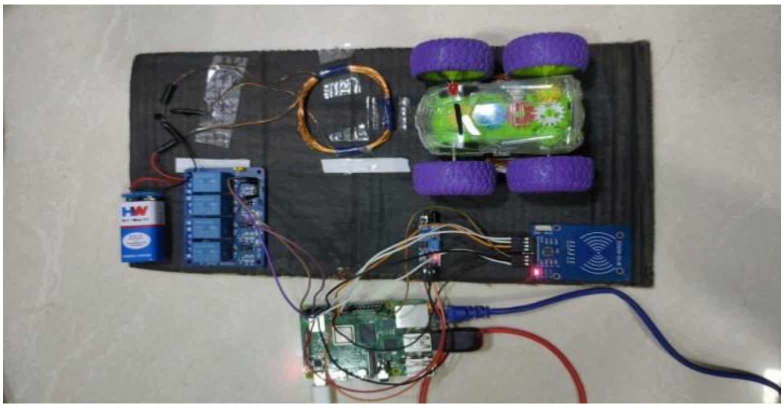

**Fig. 10. Setup connections**

Fig.11 illustrates the outcome when an authenticated RFID tag is scanned by the reader, initiating the relay to commence the charging process.

```
Run

Scan RFID: 4123456745
Authenticated vehicle detected.
Triggering relay...
Relay triggered.
Vehicle charging...
Charging complete.
```

**Fig. 11. Code output for authenticated vehicle**

Fig.12 illustrates the outcome when an unauthenticated RFID tag is scanned by the reader, thus not allowing the charging process to begin.

```
Run

Scan RFID: 234367856
Unauthenticated vehicle.
```

**Fig. 12. Code output for unauthenticated vehicle**

*B. Simulation Result*

The ElectraTrail algorithm is designed to optimize travel routes for electric vehicles by analyzing various factors such as charging lane placements, traffic conditions, and electric vehicle flow. Through careful consideration of these variables, the algorithm aims to improve overall efficiency and reduce energy consumption in electric vehicle transportation. One significant finding of ElectraTrail is its identification of the “Amposta” route as the most optimal path for electric vehicles utilizing the charging lane. Spanning 4.7 kilometers, this route stands out for its efficiency in relation to charging infrastructure and favorable traffic conditions. The selection of the Amposta route underscores the algorithm’s ability to pinpoint routes that offer the greatest efficiency as shown in Fig.13.

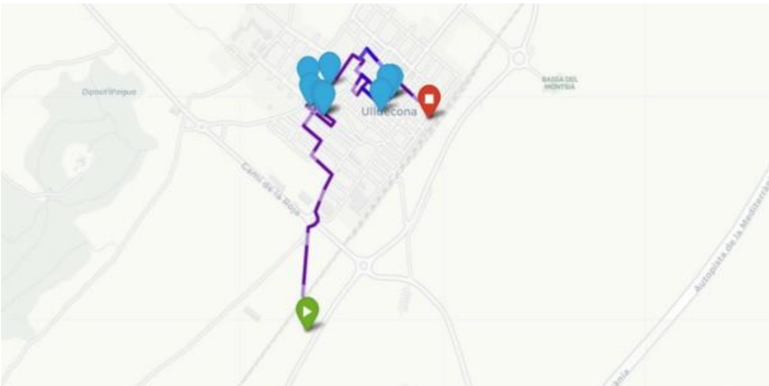


**Fig. 13. Map indicating the source and destination along with charging lane**

Fig.14 shows all the routes present and the ElectraTrail algorithm gives the optimized route for the EV considering all the parameters given.

```
Planning route for Alcanar
Route for vehicle:
 Restaurante Club de Tenis Serramar -> Bar Montsia Mar -> Bar km.1065 -> Restaurante L'Estona -> Juan Pedro Lara Márquez -> Restaurant l'Esquella D'en
Route distance: 27.7km

Planning route for Amposta
Route for vehicle:
 Bar Residència L'Ullal Apasa -> Bar Restaurant Bon Gust -> Basar Amposta -> Prince Doner Kebab | Soylent Green -> Les Palmeres -> Bar Simpatica -> Amo
Route distance: 4.7km

Planning route for Deltebre
Route for vehicle:
 Cafeteria Bar Restaurante Lo Mirador -> Restaurant l'Arròs -> Restaurant Lo Transbordador -> Ristorante La Dolce Vita -> Cafeteria Restaurant Casa Nic
Route distance: 16.2km

Planning route for L'Aldea
Route for vehicle:
 Caravan food -> Restaurante Exit l'Aldea -> Restaurant Español -> Bar Societat -> Bar Al Punt -> La Llar Hector Roda -> Restaurant Pizzeria Les Xiques
Route distance: 28.2km

Planning route for La Ràpita
Route for vehicle:
 RESTAURANT EL BAR DEL CLUB -> Lo Faro -> J Chalé Escrihuela -> Freddy, caliu familiar -> Restaurante Ancora -> Restaurant Casa Asmundo -> Bar-Ça Marin
Route distance: 5.9km
...
Route for vehicle:
 Perpebrots_ulldecona -> El Rebost -> Bar lo negre -> Cafetria-Bar Phoenix -> Mont-Mar -> El Mosset d'Exequiel -> Kebab Ulldecona -> Bar La Plaça -> La
Route distance: 5.0km
```

**Fig. 14. Output of the algorithm showing the optimized route**

## V. Conclusion

In this paper a prototype is developed to illustrate the concept of wireless charging for EVs while in motion on the road. Leveraging the principle of mutual inductance, the prototype demonstrates how EVs can replenish their energy reserves as they traverse designated charging lanes. The authentication mechanism integrated into the wireless charging process ensures security and authenticity.

By developing the "ElectraTrail" routing algorithm, the project further demonstrated the practicality of directing EVs to the nearest available charging lane based on real-time traffic data and the demand for charging services.

Ultimately, the paper not only promotes the adoption of electric vehicles but also drives forward the transition towards a more sustainable system.

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