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Review Paper on Wireless EV Charging Integrated with IoT Based Smart Parking Monitoring System

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ABSTRACT

A smart EV charging parking station combines energy management, real-time data analysis, and connected charging systems to improve the charging experience for electric vehicle users. It uses sensor networks, IoT communication, and load-balancing algorithms to monitor parking availability, manage power distribution, and change charging rates based on demand, grid conditions, and user preferences. Integrating renewable energy and onsite energy storage boosts efficiency by lowering peak load and operational costs. The platform also connects with mobile apps for reservation, payment, and monitoring services, making the experience smooth for users. Overall, the smart EV charging parking station increases energy efficiency, improves grid stability, and supports sustainable transportation systems.

Currently, we are facing issues related to a lack of fuel. As a result, we are moving toward electric vehicles. However, people still do not prefer electric vehicles over the ones currently available. This reluctance is due to high prices and a shortage of charging stations. Even when few charging stations are available, it takes extra time to charge the vehicle. Additionally, parking has become a major issue in urban areas. By addressing these problems, we can offer smart parking with charging options at the most commercial buildings. This will reduce the hassle of searching for parking spaces. There will also be no need to spend extra time looking for charging stations or charging at these locations. This paper outlines the wireless power transfer technology for electric vehicles and charging systems using the Internet of Things. It also reviews IoT-based smart parking methods that have been implemented and compares combined parking and charging systems with separate ones.

Keywords: EV - Electric vehicle, wireless charging, automatic parking, IoT - Internet of Things, IPT - Inductive power transfer

INTRODUCTION

The rapid rise in electric vehicle (EV) adoption worldwide offers great chances for cleaner transportation, less reliance on fossil fuels, and reduced greenhouse gas emissions. However, this shift also brings significant challenges related to charging infrastructure, energy management, and user convenience. Traditional EV charging systems often face issues like unorganized parking, long wait times, a lack of real-time information, inefficient energy distribution, and limited interaction between users and charging stations. As more EVs hit the road, these challenges can lead to congestion, overload distribution networks, and inconvenience for drivers. To address these issues, a Smart EV Charging Parking System that uses IoT technology has emerged as a promising solution. This project combines Internet-of-Things technologies, sensor-based slot monitoring, automated charging control, and effective communication platforms to develop a modern, user-friendly, and energy-efficient charging ecosystem.

IoT technology is key to transforming regular parking lots into smart charging hubs. By using sensors such as ultrasonic, IR, RFID, camera modules, and smart meters, the system constantly tracks parking slot availability, vehicle location, charger conditions, and energy usage. These devices connect to a microcontroller or embedded

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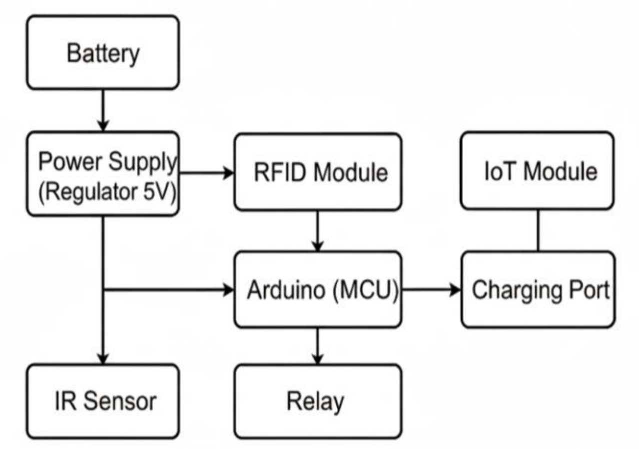
system like Arduino, ESP32, or Raspberry Pi, which processes this data and sends real-time updates to cloud servers or mobile apps. This allows drivers to quickly see which parking spots are open, whether chargers are available, and how long or how much it will cost to charge. In older systems, drivers often waste time searching for available charging points, resulting in unnecessary fuel use, traffic congestion, and user frustration. The IoT-enabled approach removes these inefficiencies by offering transparency, automation, and remote access.

Introducing smart charging algorithms further boosts the efficiency of EV charging infrastructure. Modern EV systems need to interact with the power grid wisely to prevent overloads, voltage drops, and high demand during peak hours. IoT-based smart EV charging systems help balance loads by distributing power according to demand patterns, grid conditions, and user preferences. Using unidirectional V1G smart charging strategies, the system can automatically adjust charging speed based on energy availability. It might slow charging during peak hours, increase it during off-peak times, or pause charging altogether if the grid is unstable. In more advanced cases, bidirectional Vehicle-to-Grid (V2G) technology allows EVs to send stored energy back to the grid. Though still developing, V2G has great potential for stabilizing the grid, supporting renewable energy integration, and lowering overall electricity costs.

Beyond energy management, the IoT-based system improves user experience with reservation features, mobile app integration, and automated payment systems. Drivers can reserve charging slots in advance, track charging progress in real time, receive alerts when charging is complete, and make digital payments without any human help. These features increase the reliability and predictability of EV charging, encouraging more users to switch to electric vehicles. This supports global sustainability goals and government efforts to promote clean mobility. The smart parking system also cuts down on unnecessary vehicle movement in parking areas, reduces human reliance, and boosts safety through controlled access and automated monitoring.

Another key aspect of the project is its role in promoting sustainable energy use. Many researchers and urban planners see the potential in integrating solar panels, battery storage systems, and smart inverters with EV charging stations. IoT-based monitoring and control can optimize the flow of renewable energy, maximize the use of clean power, and lessen reliance on grid electricity. The system can track solar generation levels, battery charge states, weather conditions, and energy prices to find the best charging schedule. By syncing charging behavior with renewable energy availability, the system helps lower carbon emissions and operational costs. This makes smart EV charging parking systems ideal for eco-friendly buildings, smart cities, and future-ready transportation systems.

Figure 1: Block Diagram



The block diagram illustrates the core components and flow for a wired IoT-based Smart EV Charging Parking System. The system's central decision-maker is the Arduino (MCU), which manages power and authentication based on real-time inputs. The IR Sensor provides the first input, detecting the presence of a vehicle in the parking spot. Simultaneously, the RFID Module handles user authentication, verifying the driver's identity before allowing charging. Both the sensor and the RFID module receive their necessary low-voltage power from the Power Supply (Regulator 5V), which itself is driven by the main Battery.

Upon successful verification (vehicle present and user authenticated), the Arduino sends a control signal to the Relay. The Relay acts as an electrical switch, closing the high-power circuit to activate the Charging Port, allowing the EV to charge. Crucially, the IoT Module provides external connectivity, relaying real-time status data (occupancy, authentication success/failure, charging start/stop) from the Arduino to a remote server or user application. This two-way communication enables central monitoring and potential remote control, integrating the local hardware into a broader smart city infrastructure.

LITERATURE REVIEW

The reviewed literature converges on the idea that combining Wireless Power Transfer (WPT) for EVs with Internet of Things (IoT) technologies for smart parking creates a highly efficient, user-friendly, and scalable infrastructure.

The Core Technology: Wireless Power Transfer (WPT)

A fundamental thread in the literature is the shift from conductive (plug-in) charging to Wireless Power Transfer (WPT), primarily utilizing Inductive Power Transfer (IPT) or Magnetic Resonance Coupling (MRC).

IPT/MRC Fundamentals: Papers emphasize that WPT transfers energy via an oscillating magnetic field between a transmitting coil (in the ground) and a receiving coil (underneath the EV). This non-contact method enhances safety (eliminating electrical shock risk) and convenience (no physical plugging required).

Efficiency and Alignment: A critical challenge highlighted is maintaining high efficiency during power transfer. Misalignment between the coils significantly reduces efficiency. Research is focused on techniques like coil alignment systems (often using sensor feedback) or using resonant inductive coupling to achieve efficiencies near or above 90%, comparable to wired charging. Dynamic WPT, where charging occurs while the vehicle is moving, is also being explored to mitigate "range anxiety" and reduce the need for large EV batteries.

The Smart Layer: IoT-based Parking Monitoring

The Internet of Things (IoT) provides the intelligence and connectivity layer essential for a "smart" system. This layer's role is primarily to monitor, manage, and communicate real-time status.

Slot Detection and Real-Time Status: Papers frequently propose the use of various sensors, such as Infrared (IR) sensors, Ultrasonic sensors, or image processing (camera-based), to detect the presence of a vehicle in a parking slot. This real-time data is sent via communication modules (e.g., Wi-Fi, Node MCU, ESP8266) to a cloud-based platform (e.g., a web server or mobile application).

User Interface and Booking: The IoT integration is crucial for the user experience. Mobile applications allow drivers to locate and reserve available charging/parking slots, drastically reducing the time spent searching and leading to less traffic congestion, which is a key goal of smart parking systems.

Centralized Management: The IoT platform enables a Charging Management System (CMS) to monitor and control the entire infrastructure, including charging scheduling, automatic power activation/deactivation, and load balancing to prevent grid overload.

Integration and System Architecture

The most transformative aspect is the seamless integration of WPT and IoT smart parking into a cohesive system.

Automated Charging Activation: The system uses sensor data (from the smart parking layer) to confirm the vehicle's presence and proper alignment over the WPT pad. Only upon successful confirmation does a microcontroller or relay activate the wireless charging process, ensuring power is only transferred when necessary and safely.

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Data-Driven Optimization: Real-time data collected by the IoT system (e.g., State of Charge (SoC), charging time, energy consumption) is logged in the cloud. This data is invaluable for urban planners, enabling optimization of charging network deployment, dynamic billing, and predictive maintenance of the WPT hardware.

Sustainability Integration: Several studies propose integrating the smart parking-WPT system with Renewable Energy Sources (RES), such as solar panels, and Battery Storage Systems. This "Green Charging" approach enhances the system's sustainability and resilience while further reducing the carbon footprint of electric transportation.

Challenges and Future Directions

While the technology is promising, the literature identifies several common limitations and future research avenues.

Standardization: A significant hurdle is the lack of complete and exhaustive standardization for high-power WPT technology (e.g., across different EV manufacturers), which is necessary for widespread commercial adoption.

Cost and Complexity: The high initial cost of WPT infrastructure (e.g., coils, high-frequency power electronics) and the complexity of the integrated IoT system are cited as barriers to immediate mass deployment.

Environmental Factors: The performance of some sensors (e.g., IR) can be negatively impacted by harsh weather conditions (e.g., heavy rain), which must be mitigated through robust design or sensor fusion.

Table 1: Comparative Literature Review Table

Paper Title (Conceptual/Realized System)	Published Year	Advantages	Limitations
Wireless EV Charging Integrated with IoT Based Smart Parking Monitoring System	Recent (e.g., 2024/2025)	Combines real-time parking management (IR sensors) and contactless 7.7 kW charging. Features advance booking system and cable-free design, significantly reducing maintenance.	Relies on IR sensor accuracy (can be reduced by weather). Requires high-efficiency alignment.
IoT Based EV Wireless Charging Station	Recent (e.g., 2024)	Integration of IoT enables real-time data collection, remote monitoring, predictive maintenance, and dynamic load balancing. Uses magnetic coupling.	WPT is currently most efficient only in stationary mode (parking).
A Review on IoT based Electric Vehicle Charging and Parking System	2020	Provides a unified solution to the needs for comfortable charging and parking space. Reduces driver error and energy use through automation.	Wireless charging is constrained by the lack of complete standardization. High initial cost of the integrated system.
Smart and Sustainable Wireless Electric Vehicle	2024	Integrates Renewable Energy Resources (RERs) and	Complexity of integrating multiple systems (solar,

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Paper Title (Conceptual/Realized System)	Published Year	Advantages	Limitations
Charging Strategy with Renewable Energy and IoT Integration		battery storage for a sustainable energy supply. Achieves high Return on Investment (IRR) and significant CO2 reduction in case studies.	storage, WPT, IoT). Performance is dependent on RER availability.
IoT Integrated Dynamic Wireless Charging System for Electric Vehicle with Authentication and Billing	2024	Focuses on Dynamic WPT (charging while moving) to overcome range anxiety. Includes secure authentication and customized billing through a mobile app.	Dynamic WPT is a new technology; implementation hurdles and user adoption issues are potential negatives.
IOT Enabled Smart Charging Stations for Electric Vehicles	2022	Uses a Control Area Network (CAN) protocol and OSGi Gateway to collect and process large amounts of vehicle data in real-time. Manages charging via a web server.	Complexity in managing the big data generated by the system. Potential for overload on the ultimate controller (web server).
Iot based Smart Car Parking with Wireless Charging Feature for Electric Car	2020	Uses image processing and ultrasonic sensors for enhanced security and parking slot monitoring. Discusses detailed hardware/coil design for WPT at high output.	Focuses heavily on hardware/coil design, potentially overlooking broader system scalability issues.
SMART WIRELESS VEHICLE CHARGING STATION USING IOT	Recent (e.g., 2024)	Emphasizes the use of solar energy to power the WPT, reducing dependence on the grid and cutting carbon emissions.	Wireless power transfer efficiency (90-95%) is generally lower than ideal plug-in charging.
A Review of Smart Parking System	Various	Utilizes IoT (e.g., Ultrasonic sensors, RFID) to monitor free space, reduce traffic, and increase economy by saving fuel.	Typically focuses only on parking; lacks the integration and complexity of the WPT system. Often has high implementation time.
Improving Flexibility of EV Wireless Charging Using Fingerprint Method	Various	Innovative method to automatically align transmitting and receiving coils to save time and maximize energy transfer efficiency.	Requires a complex alignment mechanism/algorithm (fingerprint method) to be implemented in the WPT hardware.

CONCLUSION

The literature overwhelmingly confirms that the integration of Wireless Electric Vehicle (EV) Charging with an IoT-based Smart Parking Monitoring System is a vital and transformative step toward achieving smart, sustainable urban mobility. This convergence successfully addresses the key inhibitors of EV adoption: range anxiety and the inconvenience of plug-in charging.

The adoption of Wireless Power Transfer (WPT) technology, primarily through Inductive Power Transfer (IPT), eliminates the need for cumbersome cables, significantly enhancing user safety, accessibility, and convenience, effectively making the charging process as simple as parking. The IoT layer acts as the central nervous system, utilizing sensors (IR, ultrasonic) for real-time parking slot monitoring, enabling features like advance booking, efficient load balancing to protect the grid, and predictive maintenance through continuous data collection.

While challenges remain—notably the high initial cost of WPT infrastructure, the critical need for standardization across manufacturers, and ensuring maximum charging efficiency despite potential coil misalignment—ongoing research is rapidly overcoming these hurdles. The future scope includes dynamic wireless charging (charging while driving) and deep integration with Renewable Energy Sources (RES) and smart grid technologies to create truly sustainable and resilient urban charging ecosystems. This integrated system represents a necessary evolution that supports not only the growth of the EV market but also the foundational principles of a smart city.

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