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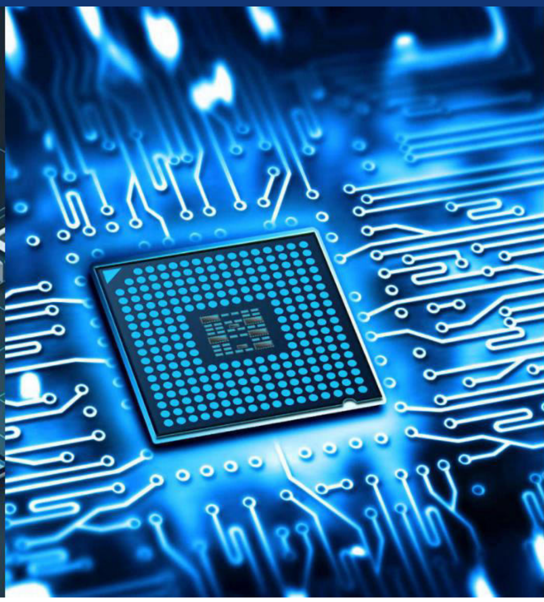


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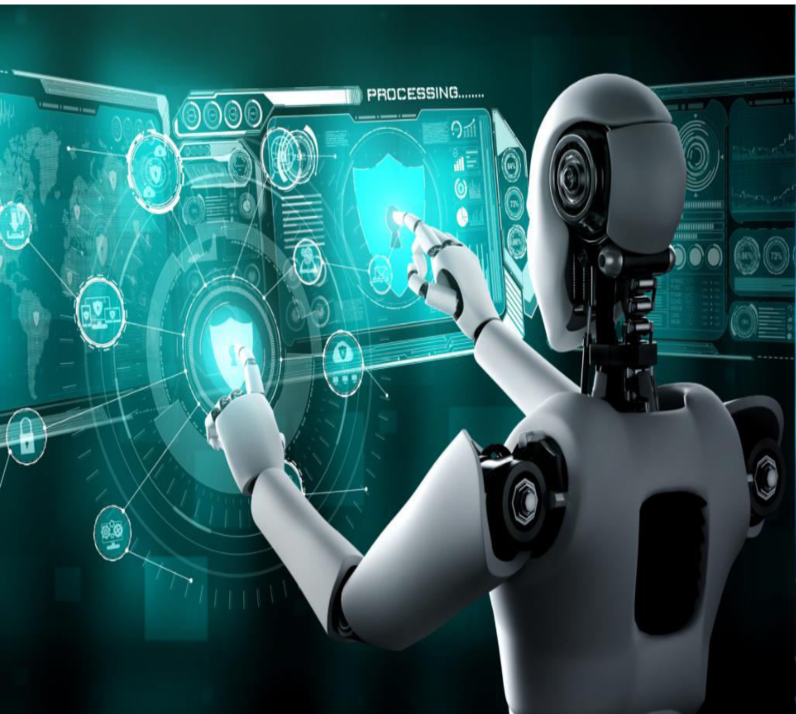

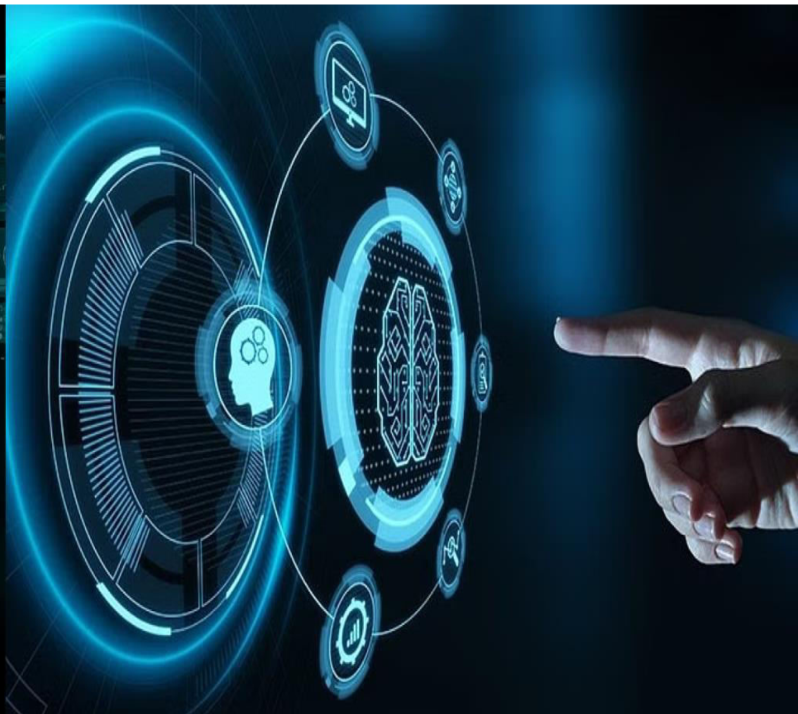

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Future Trends in Smart Green IoV

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ABSTRACT: An essential first step in guaranteeing the sustainability of our systems is the electrification of the transportation industry. This paradigm presents a viable way to address a number of issues, such as cutting back on oil use, lowering greenhouse gas (GHG) emissions, improving air quality, increasing the effectiveness of the transportation industry, and making it easier to incorporate renewable energy sources into the electrical grid. Despite its potential, a significant obstacle to car electrification is the requirement for a variety of charging infrastructure alternatives. Three innovative technologies have surfaced that have the potential to hasten the uptake of electric vehicles (EVs): battery swapping stations, fast charging stations (FCSs), and dynamic wireless charging (DWC). The key to maximizing the use of charging infrastructure is addressing issues with directing EVs to the closest FCS that can satisfy certain charging needs. These specifications cover things like waiting time, charging time, and cost. To achieve grid load balancing and avoid grid overload, coordinated control of EV charging demand becomes essential in addition to the integration of Vehicle to Everything (V2X) communications for improving EV routing to FCS. Presenting the vision and emerging trends of the Smart Green Internet of Vehicles (IoV) in the EV age is the goal of this study. Data security, grid integration, sustainable V2X connectivity, vehicle networking, and related services are all explored in addition to basic vehicle communication.

KEYWORDS: Internet of Vehicles, wireless charging, electric vehicles, battery swapping stations, V2X technology, power grids, sustainability

I. INTRODUCTION

Decarbonizing the transportation sector is a crucial piece of the climate action puzzle. As the world moves closer to a zero-emissions future, the need for developing sustainable transportation is more important than ever. The transportation sector bears a significant burden, contributing to approximately one-quarter of global greenhouse gas emissions [2] and accounting for approximately 62.3% of global fuel consumption [1]. Sustainable transport promises universal access, improved safety, reduced climate and environmental impacts, enhanced resilience, and significantly increased efficiency. Urgent steps must be taken to embrace advanced technologies, including EVs, and alternative fuels, while also encouraging greater reliance on public transportation. In our battle against climate change and to lessen our reliance on fossil fuels, EVs are crucial. They provide a more sustainable and clean form of transportation, which helps to lower air pollution and greenhouse gas emissions.

There are four developments in this field that are aimed at managing EV smart charging, improving EV charging infrastructure, and reaching net zero emissions. Furthermore, in order to meet the increasing demand for EVs and evaluate the overall environmental effect of their broad adoption, intelligent EV routing strategies that make use of V2X capabilities were investigated.Compared to internal combustion engine vehicles (ICEVs), electric vehicles (EVs) are cleaner and more efficient, which has led to their recent rise in popularity. An International Energy Agency estimate [2] projects that by 2025, there will be 70 million EVs on the road, and by 2030, they will account for 30% of the total transportation fleet. It is crucial to make sure that the infrastructure can support the growing number of EVs due to the growing demand for these vehicles. Furthermore, it is crucial to address the difficulties EV owners encounter in order to enable a smooth transition.Issues including battery deterioration, range anxiety, and energy availability call for targeted attention and solutions. The deployment of DWC systems infrastructure, which provides electricity to EVs while they are moving, is a viable way to increase EV driving range and also to reduce range anxiety [3]. It is anticipated that DWC adoption will significantly improve the drivers' convenience and overall Quality of Experience (QoE) while increasing EV adoption by at least 15% [4-6]. Battery swapping stations, which significantly cut down on EV owners' charging downtime, are becoming more and more popular in addition to DWC. Clear ownership guidelines for these stations must be set up, though. In addition to supporting utilities and acting as Distributed Generation (DG) sources, these stations have the ability to increase the amount of renewable energy that is integrated into the grid. It is

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critical to improve how EV charging demand is coordinated across energy supply points.Current research frequently makes simple assumptions, such as fixed distance thresholds for EVs, linear models, and constant energy consumption rates. The integration of coordinated Vehicle-to-Grid (V2G) energy transfer and the resolution of presumptions pertaining to the supply of electricity and communication infrastructure are essential for the advancement of this industry. Additionally, integrating renewable energy sources could result in cost savings and utility support. EV mobility patterns should serve as a guidance for charging management, and privacy issues need to be handled well. Future research should aim to generalize system settings, incorporate human mobility patterns,and leverage ML for prediction and optimization. Notable challenges include variable electricity prices, State of Charge (SOC) estimation for batteries, and the computational demands of machine learning model training. Additionally, expanding charging infrastructure in specific geographic areas presents ongoing challenges.

II. EVs IN THE ERA OF IoV

Effective computing and data interchange infrastructures are necessary to create the Internet of Vehicles (IoV) with capabilities in intelligence, learning, communication, storage, and decision-making. New Radio (NR) V2X was created by the 3rd Generation Partnership Project (3GPP) to facilitate IoV communication. Since 5G NR is not backward-compatible like earlier cellular technologies, it may integrate cutting-edge capabilities like autonomous navigation, expanded sensors, machine-type communications, the Internet of Things, vehicle platooning, and remote driving. In order to facilitate sustainable vehicle communication, the development of a green IoV inside developing 6G networks is accelerating.

In addition to vehicle-to-everything (V2X) communication, the Internet of Vehicles (IoV) also refers to the wider integration of automobiles into the internet ecosystem, which makes a range of intelligent services and applications possible. Autonomous driving is supported by IoV inside Intelligent Transportation Systems (ITS) to improve safety, decrease accidents, ease traffic congestion, optimize routing, save energy, and lessen environmental impact. In keeping with smart city ambitions, it also enhances vehicle control, safe navigation, traffic monitoring, and guiding.

The Smart Green IoV design for 6G that has been suggested encourages energy efficiency and sustainable resource use. Numerous end users are supported by this system, including as charging stations, utilities, power grids, EV fleets, infrastructure calculations, and connected persons. Intelligent traffic systems, green energy integration, secure data-driven services, and sustainable connectivity are the four primary areas of focus for the vision, which lays a strong basis for the development of intelligent, environmentally friendly mobility solutions in the future.

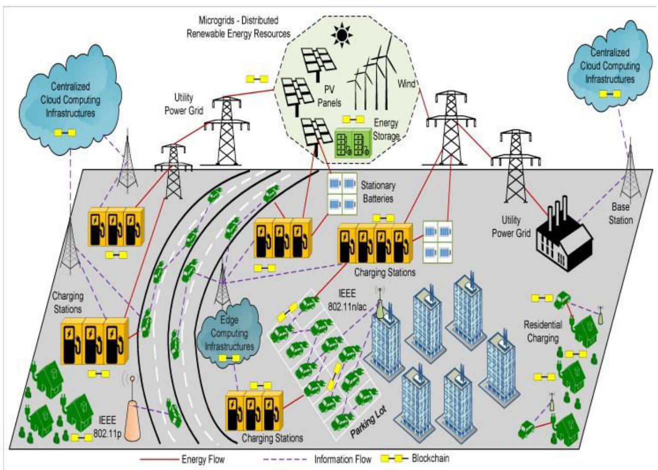

FIGURE1: Green IoV architecture for 6G era.

The figure 1 The Smart Green IoV architecture for the 6G age, which offers a new function for energy efficiency and sustainable resource use to meet the needs of its end users, including EV charging stations, power grids, utilities, infrastructure computations, EV fleets, and connecting people. The system overview and sample use cases mainly

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concentrate on the four major areas stated below in order to realize the goal of smart green technologies for the upcoming deployment of 6G networks.

III. LEVELS OF EV CHARGING SYSTEM

Charging stations are categorized into four levels of EV charging based on the type of current they deliver and their maximum power output [5]. We delve into each level: **Level 1**: The first level of charging employs a single-phase alternating current (AC) to generate a voltage of 120 V up to 2.4 kW and charge slowly. Countries like the US and Canada, where residential electrical systems normally supply a conventional household voltage of 120 V, are frequent users of this charger level. Here, the on-board converter is used to change the electric power's AC to DC format. These charging solutions are incredibly cost- effective, but because there is no communication control to the power system, they could have a detrimental effect on the grid when used extensively. Although there is currently no product on the market for such a device, it is technically possible to integrate an on-board converter (charger) for communication with the power grid.

Level 2: offers up to 22 kW of single- or three-phase charging. In order to prevent overheating and current, EV fleet customers prefer vehicle-to-charger connectors supplied by the supplier to charge EV batteries outside of their residences.

Level 3: DC charging produces a DC voltage of about 500 This charger charges the battery directly, avoiding the on- board converter. For the EV fleet, it offers FCSs that are accessible at gas stations, malls, airports, parks, and other public facilities. Although FCSs handle high power output and employ specialized electrical connectors, they have several drawbacks, such being heavy, thick, and expensive to install. They also require additional cooling setup for high power electronics and require costly maintenance to prevent unexpected overloads.

Level 4: charging may be connected to large goods vehicles (LGVs) for long-distance travel, has direct connection to the power grid, is a lightning-fast charger that uses DC, and can transport voltages beyond 1,000 volts. Only the Tesla manufacturer offers level 4 EV DC chargers at this time, and they demand a lot of power. The Level 3 and Level 4 charging options are more expensive for EV owners. The charging infrastructure in your location, your demands, and your vehicle's compatibility all influence the charge level you should use. Furthermore, increasing a battery's charge level can hasten its aging and destruction, leading to the production of unwanted chemical compounds, higher temperatures, and a higher chance of harmful side effects.

IV. BLOCK DIAGRAM OF ELECTRIC VEHICLE CHARGING STATION

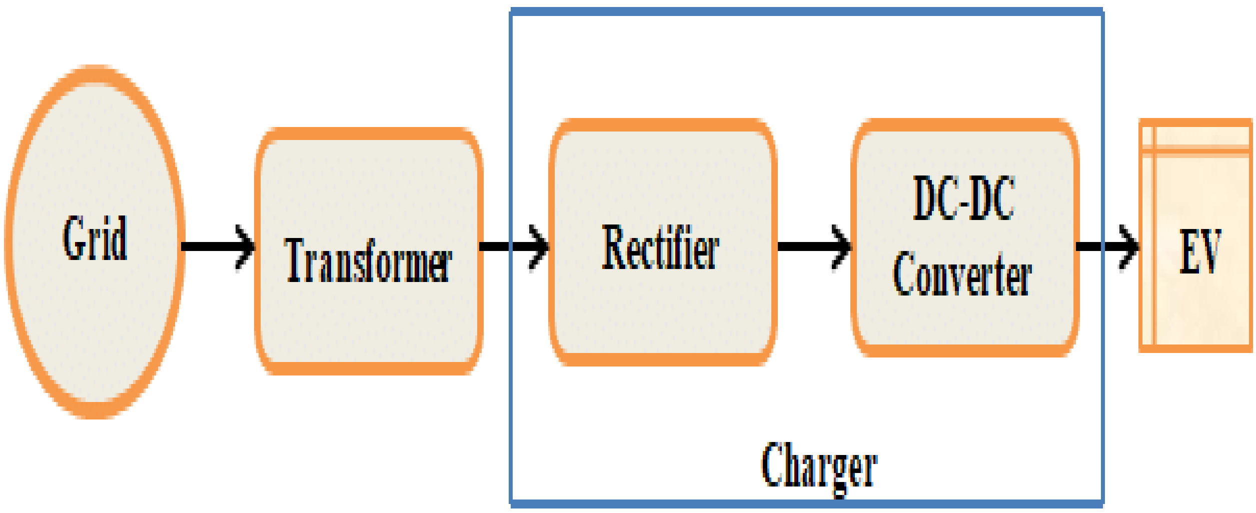

FIGURE 2: Block diagram of EV charging station.

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A. ELECTRIC GRID

It provides alternating current (AC) electricity, usually at a high voltage. It serves as the charging station's primary electrical energy source. may come from renewable energy sources (wind, solar, etc.) or traditional electricity sources. Electricity is delivered from power plants to residences, businesses, and EV charging stations via the electric grid, a system of power generating, transmission, and distribution networks. There are three primary components to it: Generation: Coal, natural gas, nuclear, hydro, wind, or solar energy are some of the methods used by power plants to produce electricity. Transmission: Electricity travels great distances on high-voltage wires. Distribution: Users, including EV chargers, get local voltage that has been stepped down. The Grid's Function in EV Charging Primary electricity Source: Unless they are exclusively powered by solar or wind backup systems, all public and private EV charging stations use electricity from the grid.
The grid ensures continuous and scalable power delivery.

B. TRANSFORMER

In order to control and modify power grid voltage levels to levels appropriate for EV chargers, a transformer is a crucial electrical component utilized in EV charging infrastructure.It reduces the grid's high voltage AC to a level that can be used. makes sure the voltage (for example, 400V to 230V) is appropriate for the charging apparatus. allows the charger and the grid to be electrically isolated. The transformer serves as a link between the lower-voltage EV charging system and the high-voltage electrical grid in EV infrastructure. It is an essential part of any EV charging network since it guarantees that the power supplied is secure, reliable, and compatible with charging devices.

C. AC-DC RECTIFIER

In systems for charging electric vehicles (EVs), an AC-DC rectifier is an essential power electronics component. It transforms grid-supplied Alternating Current (AC) into Direct Current (DC), which is necessary for EV battery charging. The majority of electric grids provide AC power, whereas EV batteries store energy in DC. For an EV to be charged effectively and safely, AC to DC conversion is necessary. Alternating current (AC) is converted to direct current (DC). In a rectifier, AC is converted to DC using diodes or controlled switches (such as IGBTs or MOSFETs).It could be: Using only diodes, the uncontrolled rectifier has a set output but is simpler. The output voltage and current of a controlled rectifier are managed by power electronics.

- Higher-power chargers (Level 3 DC fast chargers) employ three-phaserectifiers.
- Assures grid supply and EV battery compatibility.
- Provides accurate control over charging voltage and current
- For grid compliance, it can be combined with power factor correction (PFC).Rectification is required because the majority of EV batteries charge on DC.
-

D. DC-DC CONVERTER

An integral part of EVs and EV charging stations is the DC- DC converter. It modifies the direct current (DC) voltage to meet the needs of different systems, particularly the battery. The primary goal is that when charging, EV batteries require exact voltage and current, the DC-DC converter either increases or decreases voltage. According to the battery's specifications and State of Charge (SoC), it provides the appropriatevoltageandcurrent. In order to ensure safe and efficient charging, it communicates with the Battery Management System (BMS). TheEV'nterior(auxiliarysystems) High-voltage battery power (such as 400V or 800V) can be converted to 12V or 48V.Powers accessories such as power steering, infotainmandlights. Units of Electronic Control (ECUs) DC-DC Converter Types: **Isolated:** Input and output are electrically isolated. Used in rapid chargers or onboard charging, it is safer. **Non-Isolated:** More effective and straightforward. In internal auxiliary power systems, it is frequently utilized. It Enables fast and safe charging, allows multi-voltage operation inside EVs. Increases energy efficiency through precise regulation and Protects sensitive components from over/under-voltage. Regulates and adjusts the DC voltage to the specific voltage level required by the EV battery. It Can boost or buck (increase or decrease) voltage as needed. Ensures stable and safe charging current is delivered. It May include isolation transformers in some cases (especially in fast chargers).

E. Electric Vehicle (EV)

An **Electric Vehicle (EV)** is equipped with a **Battery Management System (BMS)** that plays a crucial role in monitoring and controlling the battery during charging and discharging. The BMS continuously tracks parameters such as cell voltage, current, temperature, and the state of charge (SoC) to ensure the battery operates safely and efficiently. It also manages cell balancing and protects the battery from conditions like overcharging or overheating. The **battery**

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pack itself is the main energy storage unit, typically composed of lithium-ion cells, and provides power for driving and auxiliary systems. During charging, the EV communicates with the charging station using standardized communication protocols such as **CCS** (Combined Charging System).These protocols ensure compatibility and safety by managing real-time data exchange for authentication, voltage/current negotiation, and fault detection. This smart communication between the EV and the charger allows for optimized and secure charging tailored to the vehicle's specific needs. As it contains a Battery Management System (BMS) that monitors and controls charging. he battery pack stores the energy for driving. Communication protocols (like CCS, CHAdeMO, or GB/T) manage safety, authentication, and control between the EV and the charger.

V. KEY PARAMETERS FOR SMART GREEN IOV

In the context of the Smart Green IoV system, this section gives a summary of the important parameter interdependencies between the infrastructure systems, EV parameter optimization and routing, predictive parameters, and machine learning. The interdependencies between factors in infrastructure, communication (packet data transfer), transportation, and energy resources are depicted in the diagram in Figure 5. The central controller manages EV charger coordination, taking demand-driven dynamic pricing and a variety of charging choices into account. Grid-to-Vehicle (G2V) and V2G services are also supported, but in order to increase efficiency, network integration and regulatory requirements are required. These crucial characteristics are explained in full below. Here's an explanation of Optimization of EV Parameters and Routing through Signal Controlling**,** Transmission Power Adjustment**,** and Routing Schedulingtime routing that takes into account: Current traffic circumstances

- EVs will plan environmentally friendly routes on their own that use the least amount of energy and maximize on-route rechargetimes.
- Collaborative routing and vehicle platooning will increase road capacity and lessen traffic.
- Route selection will become more ecologically friendly through integration with carbon footprint reduction algorithms.In the emerging Smart Green Internet of Vehicles, signal control, transmission power adjustment, and routing scheduling will become increasingly intelligent, adaptive, and eco-conscious**.** These optimizations will ensure that EVs operate efficiently in a connected environment, support low- carbon mobility, and contribute to smarter, greener cities. Technologies like AI**,** edge computing**,** 5G/6G, and V2X communication will be the backbone of these advancements.

VI. OPTIMIZATION OF EV PARAMETERS AND ROUTING IN THE SMART GREEN IOV ERA

The Smart Green Internet of Vehicles (SG-IoV) refers to a next-generation, eco-friendly vehicular network that integrates Electric Vehicles (EVs)**,** intelligent transportation systems**,** 5G/6G connectivity**,** and green computing. In this system, EV parameter optimization and routing strategies play a key role in enhancing energy efficiency, safety, and real-time communication. Below are the core methods for this optimization:
The definition of smart signal controlling is the dynamic management of traffic lights, vehicle speeds, and stop-start behavior using real-time data from EVs and traffic infrastructure.

- By reducing needless idling, AI-powered traffic signal optimization will save battery life and lessen gridlock in cities.
- Green Light Optimal Speed Advisory, or GLOSA, is a feature that EVs can use to modify their speed by integrating with Vehicle-to-Infrastructure (V2I) systems to obtain green- light time estimates.
- SG-IoV's signal control will give EVs or shared electric fleets priority, reducing emissions and improving route efficiency.

A). Transmission Power Adjustment

In order to communicate data with other vehicles (V2V), infrastructure (V2I), and cloud servers, EVs must have their wireless communication power level adjusted.

- Dynamic transmission power adjustment will balance network dependability and energy consumption in SG-IoV. While high-power signals are saved for high-speed or long- distance routing, low-power communication will be used in dense traffic zones to minimize interference. Future EVs will use edge computing and AI algorithms to predict the best transmission levels based on mobility, traffic density, and QoS requirements. Through the reduction of needless communication overheads, battery life is increased.

B). Routing Scheduling

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Definition: EV route planning and intelligent selection based on environmental impact, traffic, battery condition, and availability.
• Using cloud-based AI technologies,

VII. ENVIRONMENTAL & ECONOMIC IMPACT OF USING EVS FOR SMART GREEN IoVS

A Smart Green IoV system that uses EVs can have a number of important economic and environmental effects. In addition to providing financial benefits including cost savings, job development, and technology innovation, it can lessen the negative environmental effects of transportation. However, for implementation to be successful, governments, corporations, and communities must work together to support sustainable mobility practices and invest in EV infrastructure. Connectivity, sustainability, shared mobility, autonomous driving, and vehicle electrification are highlighted as key market themes for the mobility transformation of the future [90]. Thus, combining these two effects leads to a more sustainable and effective transportation ecosystem by leveraging clean energy, cutting-edge technology, and connectivity. Among them are:

ENVIRONMENTAL IMPACTS
REDUCED EMISSION AND SUSTAINABILITY
Making the switch to EVs charged via wireless systems improves air quality and public health by lowering greenhouse gas emissions and air pollution. This has a particularly significant effect when used in conjunction with renewable energy sources for charging, including solar or wind power. Because wireless charging supports sustainability objectives, it can further increase the allure of EVs. Since EVs have net-zero emissions, they don't contribute to the atmosphere by releasing dangerous pollutants including particulate matter, CO_2, and nitrogen oxides (NO_x). We can fight climate change and drastically cut air pollution by integrating EVs into the IoV infrastructure. This leads to better air quality, which can have major health advantages by lowering the prevalence of air pollution-related respiratory and cardiovascular disorders.

LOWER NOISE POLLUTION
EVs are quieter than traditional internal combustion engine vehicles. This can lead to a reduction in noise pollution, creating more pleasant and healthier urban environments.

ECONOMIC IMPACTS
REDUCED FUEL AND MAINTAINENCE
It expenses more compared to cars that run on gasoline or diesel, electric vehicles offer reduced running expenses. For
OPPORTUNITIES AND JOB CREATION
Manufacturing, technology, and transportation are just a few of the industries where new job opportunities may arise as a result of the transition to EV production, infrastructure development, and fleet maintenance.
ENERGY INDEPENDENCE A transition to EVs can reduce a country's dependence on imported fossil fuels, which can improve energy security and reduce the economic impact of fluctuating oil prices.

VIII. ADVANTAGES

Environmental Advantages
- **Reduced Emissions:** Electric and smart vehicles integrated with IoT can optimize routes and driving patterns, significantly lowering carbon emissions.
- **Energy Efficiency:** Smart IoV systems improve fuel and energy efficiency through intelligent traffic management and vehicle performance monitoring.
- **Support for Renewable Energy:** Integration with smart grids allows vehicles to charge during periods of surplus renewable energy generation.

Technological Advancements
- **Autonomous Driving:** Enhanced sensors and AI allow vehicles to drive safely with minimal human intervention.
- **Real-Time Communication:** V2X (Vehicle-to- Everything) technologies improve safety and navigation

through real-time data sharing.

- **Predictive Maintenance:** IoT-enabled vehicles can detect and report issues before breakdowns, reducing maintenance costs and accidents.

IX. APPLICATIONS

Intelligent Traffic Management Systems in a Smart Green IoV enable electric vehicles to respond in real time to traffic conditions through AI-powered traffic monitoring and dynamic traffic signals, optimizing flow and reducing energy consumption.

Autonomous and Connected Vehicles play a pivotal role as electric vehicles become self-driving, relying on AI and sensor technology. Through vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication, EVs nhance safety and efficiency on the road.

Electric Vehicle (EV) Ecosystems evolve with the integration of smart charging systems that interact with renewable energy grids, including wireless and ultra-fast charging stations, ensuring sustainable and user-friendly power solutions for EV users.

Vehicle-to-Everything (V2X) Communication is central to Smart Green IoV, with EVs exchanging data via V2V for collision avoidance, V2I for signal timing and road alerts, and V2G (Vehicle-to-Grid) to feed surplus energy back into the grid, promoting energy efficiency.

Smart Fleet and Logistics Management leverages IoT and cloud systems to monitor EV fleets in real time, optimize delivery routes, and minimize fuel (or battery) usage and carbon emissions through intelligent scheduling and analytics.

Predictive Maintenance and Diagnostics enhance the reliability of EVs by using embedded sensors to monitor ystem health, predict failures, and schedule maintenance based on usage trends, thereby extending vehicle lifespan and improving safety.

Mobility-as-a-Service (MaaS) integrates EVs into shared mobility solutions such as ride-hailing, car-sharing, e-scooters, and public transport, promoting low-emission, convenient, and cost-effective travel across urban areas.

Smart City Integration ensures EVs communicate seamlessly with urban infrastructure—traffic lights, parking systems, and environmental monitoring—using real-time data to guide urban planning and reduce congestion and pollution.

Cybersecurity and Data Privacy are critical as EVs become increasingly connected. Robust security frameworks are needed to protect vehicle data, ensure secure V2X communications, and prevent cyber threats within the IoV network.

Insurance and Regulatory Innovations are emerging with usage-based insurance models for EVs, which use real-time driving behavior and telematics data, along with automated systems for accident detection and compliance with evolving EV regulations. delivery routes, and minimize fuel (or battery) usage and carbon emissions through intelligent scheduling and analytics.

X. CONCLUSION

The future of the Smart Green Internet of Vehicles (IoV) is poised to revolutionize transportation by blending sustainability, connectivity, and intelligence. With electric vehicles at the core, future trends indicate a shift toward autonomous driving, real-time communication, and seamless integration with urban infrastructure. Advancements in AI, IoT, and V2X technologies will empower vehicles to interact intelligently with each other and the environment, enhancing safety, efficiency, and energy management. The development of smart charging networks, predictive maintenance, and data-driven fleet management will further drive the adoption of eco-friendly mobility. As cybersecurity and regulatory frameworks evolve alongside these technologies, the Smart Green IoV promises not only a cleaner and smarter transportation system but also a foundation for resilient, sustainable, and intelligent future cities.By combining edge computing, sustainability, intelligence, and V2X connectivity, a unique viewpoint on the Smart Green IoV system is shown. The goal of this integration is to transform our attitude to transportation systems and create a transportation ecosystem that is safer, more effective, and more ecologically friendly. We want to lower energy usage, improve safety protocols, streamline traffic management, and increase EV routing by utilizing real-time communication between automobiles and their environment, ultimately leading to a more environmentally friendly future. Furthermore, by offering wireless charging choices and reducing strain on the power grid, the integration of renewable energy sources into EVs and the use of a dynamic wireless charging technique can significantly improve the

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user experience. Collaboration amongst stakeholders, the adoption of cutting-edge technologies, and a strong dedication to resolving related issues are essential.

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