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A Review of Emerging Trends in Smart Green IoV: Advancing Vehicle-to-Everything (V2X) Communication in the Electric Vehicle Era

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Abstract- *The advent of the electric vehicle (EV) era has accelerated the evolution of the Internet of Vehicles (IoV), transforming it into a dynamic and sustainable ecosystem. Among its most promising developments is Vehicle-to-Everything (V2X) communication, which facilitates seamless interaction between vehicles, infrastructure, pedestrians, and networks. Emerging trends in Smart Green IoV are reshaping mobility by integrating cutting-edge technologies such as 5G/6G connectivity, artificial intelligence (AI), edge computing, and blockchain to enable real-time, efficient, and eco-friendly vehicular operations. This review explores the convergence of these technologies, emphasizing their role in optimizing energy management, reducing greenhouse gas emissions, and enhancing road safety. It also highlights challenges such as cybersecurity, interoperability, and scalability that need addressing to fully realize the potential of V2X in a sustainable smart transportation framework. By analyzing current advancements and identifying future research directions, this paper provides a comprehensive overview of the transformative impact of Smart Green IoV in the EV era, paving the way for a greener, smarter, and safer transportation ecosystem..*

Keyword: Smart Green IoV, Vehicle-to-Everything (V2X), Electric Vehicles (EV), Sustainable Transportation, 5G/6G Connectivity, Artificial Intelligence (AI), Edge Computing, Blockchain

1. INTRODUCTION

The The rapid electrification of the automotive industry is revolutionizing traditional transportation systems, paving the way for sustainable and intelligent mobility solutions. Central to this transformation is the Internet of Vehicles (IoV), a networked ecosystem where vehicles communicate not only with each other but also with infrastructure, pedestrians, and external networks. Within the IoV paradigm, Vehicle-to-Everything (V2X) communication has emerged as a cornerstone, enabling seamless interaction across multiple domains, including Vehicle-to-Vehicle (V2V), Vehicle-to-Infrastructure (V2I), Vehicle-to-Network (V2N), and Vehicle-to-Pedestrian (V2P) interfaces.

In the context of the electric vehicle (EV) era, V2X is evolving into a "Smart Green IoV" framework. This framework integrates advanced technologies such as 5G/6G connectivity, artificial intelligence (AI), edge computing, and blockchain to enhance communication efficiency, optimize energy utilization, and promote environmental sustainability. Smart Green IoV facilitates real-time decision-making, predictive maintenance, and energy management, contributing to reduced greenhouse gas emissions and improved urban mobility.

Despite its promising potential, the implementation of V2X in Smart Green IoV faces significant challenges, including cybersecurity risks, data interoperability issues, and the need for scalable infrastructure. This paper examines the emerging trends shaping V2X in the EV era, discussing its technological enablers, potential applications, and associated challenges. It also identifies future research directions to bridge existing gaps and accelerate the adoption of sustainable, smart vehicular ecosystems. By fostering a deeper understanding of these trends, this study aims to support the development of a greener and safer transportation landscape for the modern world.

The Internet of Vehicles (IoV) represents a significant leap in intelligent transportation by connecting vehicles to a digital ecosystem. Extending beyond traditional vehicular technology, IoV combines advanced computing, data analytics, and connectivity to transform how vehicles interact with their surroundings.

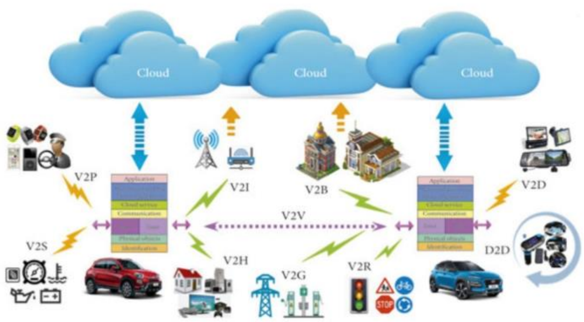

Figure 1.Internet of Vehicles (IoV)

Unlike isolated, stand-alone cars, IoV-enabled vehicles become active elements within a broader network, communicating with various systems to optimize driving safety, traffic management, and energy use.

As a specialized application within the Internet of Things (IoT), IoV involves equipping vehicles with smart sensors, computing systems, and network capabilities that enable data sharing and interaction with other connected devices. Vehicles today generate vast amounts of data on speed, location, environmental conditions, and more. IoV leverages this information to make real-time, data-driven decisions. In turn, this interconnectivity allows for smarter routing, reduced congestion, and better use of transportation resources.

II. LITERATURE SURVEY

The literature indicates that the future of smart green IoV in the era of electric vehicles is poised for significant advancements. The integration of connected technologies, renewable energy sources, and intelligent transportation systems presents opportunities for sustainable urban mobility. Continued research and collaboration among stakeholders will be essential to overcome challenges and fully realize the potential of smart green IoV. Overview of future trends in smart green IoV within the context of electric vehicles, addressing key technologies, impacts, challenges, and directions for future research.

Tasneim Aldhanhani et al. (2024) is proposed electrification of transportation is key to sustainability, reducing oil consumption, GHG emissions, and enhancing air quality while integrating renewable energy into the grid. However, challenges. Technologies such as Dynamic Wireless Charging, Battery Swapping, and Fast Charging Stations (FCS) address issues like range anxiety and downtime. This work focuses on FCS optimization, emphasizing EV routing based on wait time, duration, and cost. Vehicle-to-Everything (V2X) and the Internet of Vehicles (IoV) play pivotal roles in routing and grid load management, highlighting future trends in Smart Green IoV for sustainable V2X, networking, and grid integration[1].

Junhua Wang et al. (2022) studied on the future of the IoT, the IoV is recognized as a core technology for advancing Intelligent Transportation Systems (ITS) in smart city environments. With the advent of sixth-generation (6G) communication technologies, extensive network infrastructures will be densely deployed, significantly increasing the number of network nodes. This expansion will drive a substantial rise in energy consumption. Consequently, there is growing interest in developing green IoV systems that prioritize sustainable vehicular communication and networking within the 6G era. However, IoV operates as a unique mobile ad-hoc network, where energy expenditure includes not only communication and computational energy but also fuel consumption and the electricity required by vehicles. Additionally, the likely widespread adoption of energy harvesting technologies in 6G systems presents further complexity in optimizing overall system energy efficiency. Current research has largely addressed isolated aspects of energy consumption in IoV systems, lacking a comprehensive review of state-of-the-art approaches for energy efficiency and the impact of 6G advancements on green IoV. In this author examine the primary considerations for green IoV across five key scenarios: communication, computation, traffic management, electric vehicles (EVs), and energy harvesting. Author compare relevant literature in each of these areas from an energy optimization perspective, covering aspects such as resource allocation, workload scheduling, routing design, traffic control, EV charging management, and energy harvesting and sharing. Furthermore, we discuss factors influencing energy efficiency, including resource limitations, channel conditions, network topology, and traffic flow. In addition, this paper explores potential challenges and emerging 6G technologies that support green IoV development. Finally, we outline current research trends focused on designing energy-efficient IoV systems, paving the way for future innovations. [2]

Bhaskar P. Rimal et al. (2022) represents a significant advancement in the integration of various systems, connecting individuals, fleets of electric vehicles (EVs), utilities, power grids, distributed renewable energy sources, and communication and computing infrastructures. This development is pivotal for creating sustainable societies within the context of smart grids and urban environments. However, the decentralized and complex nature of grid edge systems presents numerous challenges in the planning, operation, and management of power systems. Thus, establishing a reliable communication infrastructure is essential. The fourth industrial revolution, characterized by the emergence of cyber-physical systems alongside the Internet of Things (IoT), as well as the integration of edge (fog) and cloud computing, offers innovative solutions to these challenges, maximizing the advantages of power grids. In this light, we propose a cloud-based EV charging framework as a specific application of IoV to address the high demand for charging stations during peak periods. This framework includes a pricing incentive scheme and an electricity supply expansion strategy, both of which are evaluated against a baseline model. The results indicate that these hierarchical models enhance system performance and improve the QoS for EV customers. The proposed approaches can effectively assist system operators in optimizing system design and ensuring grid stability. Additionally, to highlight emerging technologies for smart and interconnected EVs, we identify seven key trends: decentralized energy trading using blockchain and distributed ledger technology, insights from behavioral science and behavioral economics, applications of artificial and computational intelligence, the development of digital twins for IoV, software-defined IoVs, intelligent EV charging through information-centric networking, and the establishment of parking lot microgrids with EV-based virtual storage solutions. We also address several potential research areas within IoV to encourage further exploration of this field. The successful integration of communication technologies, modern power system management, EV control systems, and computing solutions is critical for maintaining grid stability and supporting large-scale EV charging networks. [3]

Baofeng Ji et al. (2020) provides a comprehensive literature review on the fundamental aspects of IoV, including foundational VANET technologies, various network architectures, and typical IoV applications. By synthesizing existing research and proposing a robust architectural framework, this work aims to contribute valuable insights that will drive advancements in IoV and its applications in intelligent transportation systems. The VANET has become a prominent application within the realm of mobile ad hoc networking, particularly in the automotive sector. However, as we enter the 5G and beyond (B5G) era, the IoT is emerging as a transformative technology that is reshaping the current Internet into a fully integrated future Internet. This transformation is not only enhancing existing domains but also steering research into new directions, including smart homes, smart communities, smart health, and intelligent transportation systems. To effectively meet the evolving demands of intelligent transportation systems, vehicle automation, and intelligent road information services, VANET must accelerate its technological advancement. This necessity has given rise to the IoV, which aims to facilitate information exchange between vehicles and all entities connected to them. The primary objectives of IoV include reducing accidents, alleviating traffic congestion, and providing various information services to enhance the driving experience. Currently, IoV has garnered significant attention from both academic researchers and industry practitioners. In support of relevant research in this field, this article presents a novel network architecture designed for future networks, emphasizing features such as increased data throughput, reduced latency, enhanced security, and massive connectivity capabilities. [4]

Y. Wang et al. (2021) introduce a novel IoV block-streaming service that emphasizes awareness and trusted verification within a 6G context. In our proposed framework, edge nodes upload microservices along with their associated calling diagrams to the blockchain network. This blockchain network acts as an intermediary verification platform, effectively recording interactions between edge nodes and IoV devices, thereby providing a reliable evidence trail. Additionally, we have integrated identity-based blind signature technology into our security scheme, allowing IoV devices to anonymously request services from edge nodes. This mechanism facilitates mutual authentication between IoV devices and edge servers while preserving the confidentiality of users' real identity information. To further enhance system performance, we propose an edge caching mechanism that is responsive to user requests and service awareness. This mechanism enables the pre-compilation of services at edge nodes, thereby improving the cache hit rate for service requests from vehicle users on the edge servers. This approach not only streamlines the processing of resource requests from users but also optimizes the overall efficiency of the IoV system. By leveraging blockchain and edge computing technologies, our framework aims to bolster the security, privacy, and efficiency of IoV operations in the forthcoming 6G landscape. [5].

III. METHODOLOGY

The proposed research will follow a structured approach to design, implement, and validate a secure and efficient framework for data sharing in mobile cloud platforms. The study will begin with a comprehensive analysis of existing challenges, focusing on issues such as unauthorized access, data breaches, and performance inefficiencies. Based on this analysis, the objectives and scope of the framework will be defined to address these critical gaps. The design phase will involve creating an architectural blueprint that integrates advanced encryption algorithms, robust multi-factor authentication mechanisms, and dynamic resource optimization strategies. The framework will be implemented using suitable tools and technologies to ensure compatibility with mobile cloud environments. Diverse datasets will be collected or generated to simulate real-world scenarios, including high-traffic conditions and potential security threats, enabling rigorous testing of the framework’s adaptability and effectiveness. Performance evaluation will focus on metrics such as data security, scalability, computational efficiency, and response time, with results compared against existing solutions to highlight the proposed framework’s improvements. Iterative validation and refinement will be conducted to ensure the framework’s reliability and robustness under varied conditions, incorporating expert feedback to enhance its overall efficacy. This methodology aims to deliver a comprehensive solution that addresses the pressing needs of secure data sharing in mobile cloud ecosystems.

IV. CONCLUSION

This review highlights the critical challenges and advancements in secure data sharing within mobile cloud platforms. The analysis reveals that while significant progress has been made in developing encryption techniques, authentication mechanisms, and resource optimization strategies, existing solutions often fall short in addressing the dynamic and heterogeneous nature of mobile cloud environments. The need for frameworks that balance robust security with efficient system performance remains paramount.

Future research should focus on integrating adaptive and intelligent mechanisms capable of responding to evolving threats and diverse user requirements. Additionally, leveraging emerging technologies such as artificial intelligence, blockchain, and quantum cryptography can pave the way for innovative solutions that enhance data protection and system scalability. By addressing these gaps, researchers and practitioners can contribute to the development of resilient mobile cloud ecosystems that prioritize both security and user experience, ultimately fostering greater trust and adoption in this transformative domain.

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