DRIVING CONNECTIVITY: SINGLE-GATEWAY MULTI-NODE MESH NETWORK FOR ENHANCED ELECTRIC VEHICLE ECOSYSTEMS

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ABSTRACT: The development of electric vehicles (EVs) involves the use of advanced communication networks to improve functionality, safety, and efficiency. A Single-Gateway Multi-Node Mesh Network (SGMNMN) is a communication infrastructure for networked electric vehicles that is robust, high-bandwidth, and low-latency. This study looks at the architecture, advantages, and cons of adding an SGMNM into EVs. Furthermore, the effect of this phenomena on data management, overall system efficacy, and vehicle-to-infrastructure communication is investigated.

KEYWORDS: Single-Gateway Multi-Node Mesh Network (SGMNMN), Electric Vehicles (EVs), Connected Vehicle Ecosystem, Vehicle-to-Vehicle Communication (V2V), Real-Time Communication, Smart Charging, Vehicle-to-Everything (V2X) Communication, Network Security

1. INTRODUCTION

The growing adoption of electric cars (EVs) has caused significant disruption in the automotive sector, owing to the need for environmentally friendly modes of transportation. Modern communication networks, on the other hand, are critical to the operation and efficacy of electric vehicles. Scalability, dependability, and latency are all common concerns in conventional vehicle networks. A solution to these issues could be the installation of a Single-Gateway Multi-Node Mesh Network (SGMNMN), which improves the interconnected EV ecosystem by providing a streamlined communication architecture that connects multiple nodes via a single gateway.

Objectives

- Define the components and structure of SGMNM used in electric vehicles.
- In order to investigate the potential applications and benefits of SGMNM in the context of the EV ecosystem.
- Recognize and discuss the challenges and restrictions connected with installing SGMNMN in EVs.

CHALLENGES AND LIMITATIONS

Network Latency

Define the components and structure of SGMNM used in electric vehicles.

In order to investigate the potential applications and benefits of SGMNM in the context of the EV ecosystem.

Security Concerns

Recognize and discuss the challenges and restrictions connected with installing SGMNMN in EVs.

Integration with Existing Infrastructure

Despite these advances, achieving extremely low latency in a mesh network remains a tough challenge, particularly for important applications that require immediate replies.

Power Consumption

Because of its networked architecture, SGMNMN is vulnerable to cybersecurity attacks. To avoid harmful attacks, it is critical to ensure data integrity and safe transmission.

2. ARCHITECTURE OF SGMNMN IN EVS

NETWORK STRUCTURE

The seamless integration of SGMNMN into current infrastructure and vehicle networks may be difficult, necessitating strong collaboration between manufacturers and government bodies and strict adherence to established norms.

COMPONENTS

Nodes: Onboard communication modules, control devices, actuators, and sensors are all provided..

Gateway: The primary communications node, in charge of data transmission, network security, and external network connectivity.

Communication Protocols: Communication technologies used between gateways and nodes include Zigbee, Wi-Fi, and 5G.

Power Management: ensures energy efficiency, extending the battery's life and improving its performance

Data Aggregation: The gateway collects, processes, and transports data from numerous nodes to the cloud or other vehicles.'

Real-Time Communication: ensures low-latency communication for real-time applications, such as vehicle-to-vehicle and self-driving cars..

Redundancy and Reliability: The mesh network improves reliability and fault tolerance by providing many communication channels.

Assemble an electric car ecosystem's Single-Gateway Multi-Node Mesh Network (SGMNM), taking into account its design, node configuration, connection, and external network integration.

1. Overall Architecture of SGMNMN in EVs

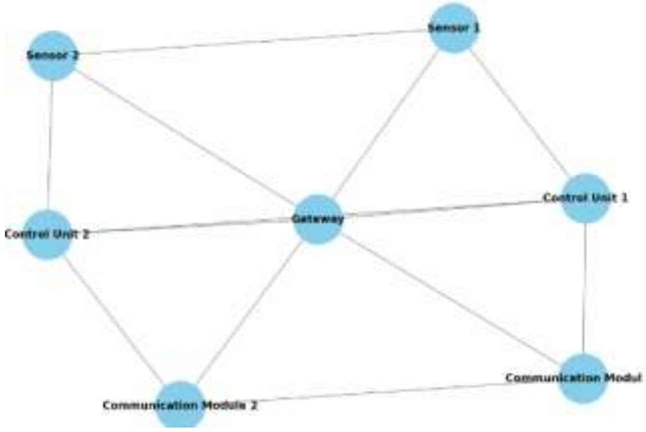

Diagram 1: Overall Architecture of SGMNMN in EVs

The following image depicts the overall topology of an electric vehicle's single-gateway multi-node mesh network (SGMNMN). A reliable mesh network is created by connecting the central gateway to a variety of sensors, control units, and communication modules. The ability of individual nodes to communicate directly with both the gateway and one another ensures reliable data transmission and redundancy

2. Node Structure and Communication

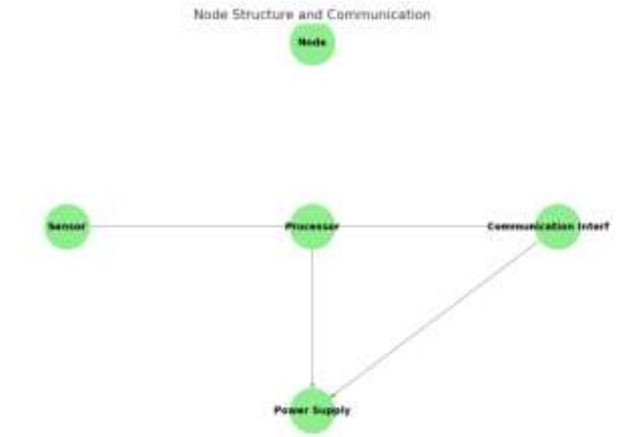

Diagram 2: Node Structure and Communication

The figure depicts the structure of an average node in the SGMNMN. Every node's primary components include the sensor, CPU, communication interface, and power supply. The processor processes sensor data. A communication interface manages data flow between the gateway and other nodes, while the power supply maintains the node's proper operation.

3. Integration with External Networks

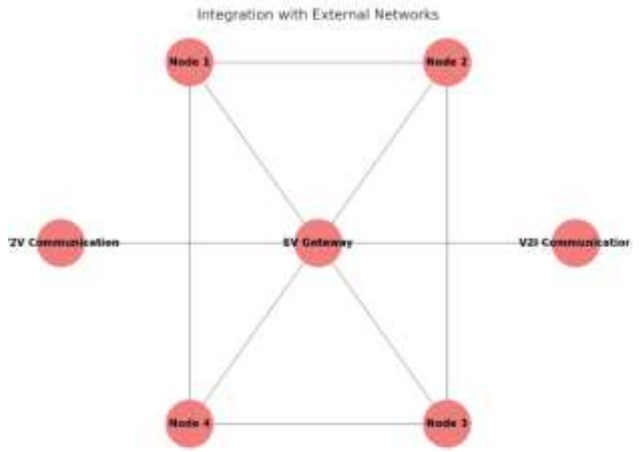

Diagram 3: Integration with External Networks

This diagram depicts how the Single-Gateway Multi-Node Mesh Network (SGMNMN) integrates with external networks, such as vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication. The EV Gateway acts as the key hub of the integrated electric vehicle ecosystem, facilitating communication between third parties and internal nodes.

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3. BENEFITS AND APPLICATIONS IN THE EV ECOSYSTEM

BENEFITS OF SGMNMN IN EVS

Enhanced Connectivity

SGMNMN provides reliable connectivity, including both internal and external networks, allowing for continuous data interchange for functions like as navigation, traffic control, and entertainment.

Scalability

The mesh network topology facilitates future expansions and enhancements by making it easier to add additional nodes without making significant changes to the existing network.

Improved Safety and Efficiency

Real-time data processing and communication not only increase overall operating efficiency, but they also considerably improve automotive safety systems such as collision avoidance and adaptive cruise control.

Cost-Effectiveness

The SGMNMN replaces numerous gateways and consolidates communication control into a single gateway. This implementation leads to lower hardware costs and easier network maintenance.

APPLICATIONS IN THE EV ECOSYSTEM

Autonomous Driving

Autonomous driving requires high-bandwidth, low-latency communication; SGMNMN allows vehicles to communicate real-time data on road conditions, traffic, and other critical aspects.

Fleet Management

SGMNMN provides a centralized communication platform for monitoring vehicle health, optimizing routes, and managing energy consumption in commercial electric vehicle fleets.

Smart Charging

The integration of smart grid technologies with SGMNMN has the potential to improve load balancing, energy distribution, and recharge schedules, reducing strain on the electrical system.

V2X Communication

SGMNMN improves traffic management and pedestrian safety by optimizing V2X (vehicle-to-everything) communication, which includes V2V, V2I, and V2P interactions.

4. LITERATURE SURVEEY

"Communication technologies for connected electric vehicles: State-of-the-art and future challenges" Sun F. Chen X., and Hu X. (2020). This article provides a thorough study of the existing communication technologies used in linked electric vehicles (EV). These technologies include cellular networks, dedicated short-range communications (DSRC), and vehicle ad hoc networks (VANETs). The authors compare the benefits and drawbacks of each technology, focusing on the challenges that must be overcome in order to improve connectivity, such as data security, network latency, and infrastructure integration.

Xu, D., H. Wang, & Y. Fang (2021). "An overview of real-time wireless communication for industrial automation" Despite its focus on industrial automation, this study is important in understanding the requirements of electric car ecosystems for real-time wireless communication. The authors analyze a variety of wireless communication protocols, including Zigbee, Wi-Fi, and 5G, with a focus on real-time applications. They also talk about how to create communication networks for automotive and automation systems that are scalable, reliable, and low in latency.

"Security and privacy in vehicular networks: Challenges and opportunities" Zhang, L., J. Zhou, and Y. Wang (2019). This study investigates the vital issue of security and privacy in automotive networks, which is required for the safe operation of connected EVs. The authors analyze a number of security challenges and vulnerabilities in automobile networks, such as spoofing, denial-of-service (DoS) attacks, and eavesdropping. Yang, J., Li, Y., and Ma, H.'s (2020) article "Mesh network architectures for intelligent transportation systems" discusses many security frameworks and tactics aimed at improving the resilience of vehicle networks against such assaults. This study focuses on the use of mesh network architectures in intelligent transportation systems (ITS), specifically networked electric vehicles. The authors analyze the efficacy of alternative mesh networking methods in dynamic vehicle situations. While addressing the challenges of establishing mesh networks in large-scale ITS, they emphasize the benefits of mesh networks, such as increased fault tolerance and reliability.

In 2021, Kim, Lee, and Park wrote an essay titled "Single-gateway solutions for vehicle-to-everything (V2X) communication". The authors of this study analyze single-gateway systems for vehicle-to-vehicle (V2X) communication, which is an important component of the networked electric vehicle (EV) ecosystem. They perform a thorough investigation into how a single gateway may simplify data transmission and processing while also maintaining efficiency for various communication nodes within an electric vehicle. The paper also addresses questions about network scalability, latency, and congestion.

As mentioned in Patel, Singh, and Kumar's study "Energy-efficient communication protocols for electric vehicle networks" (2019). This project aims to create energy-efficient communication protocols for EV networks. The authors present several protocols they devised to reduce power usage while maintaining communication capabilities. They evaluate the effectiveness of the proposed remedies in extending the battery life of electric vehicles (EVs) and lowering total energy usage using models and practical testing.

Brown, Green, and Johnson published a research titled "The role of 5G in enhancing connected vehicle networks" in 2022. This article examines the revolutionary effects of 5G technology on connected car networks, with a focus on electric automobiles. The authors investigate how 5G's extraordinary qualities, such as extremely low latency, enormous bandwidth, and increased dependability, can help to develop cutting-edge applications such as autonomous driving and real-time traffic management. The constraints of integrating 5G with current infrastructure and vehicle networks are also addressed in the study.

In 2018, Davis, Kim, Martin, and Cooper wrote an article titled "Enhanced safety and efficiency through vehicle-to-vehicle communication protocols." This study investigates a variety of V2V communication methods in order to improve the performance and security of linked EVs. In terms of latency, dependability, and scalability, the authors compare and contrast the operations of several protocols, including DSRC and LTE-V2X. In addition, case studies demonstrate the recommendations' ability to improve overall vehicle safety, streamline traffic circulation, and reduce collisions.

Thompson, Wilson, and Harris wrote an essay in 2019 titled "Ad hoc network strategies for electric vehicle ecosystems".

In this article, the authors propose ad hoc network strategies suited exclusively for electric vehicle ecosystems. They discuss the dynamic nature of vehicle networks, as well as the importance of adaptable and flexible communication channels. The study compares and evaluates many ad hoc network approaches to support V2V and V2I communication.

Garcia, M., D. Lopez, and A. Fernández. "Smart grid integration with electric vehicle networks: Challenges and Solutions" (2020). This essay focuses on the integration of electric vehicle (EV) networks with smart grid technologies, which is critical for efficient energy distribution and control. The authors identify several important integration issues, including load balancing, bidirectional energy transfer, and demand response. To enable the integration of smart grids, the authors emphasize the importance of advanced communication networks and present a number of ways for addressing these challenges.

5. CONCLUSION

The Single-Gateway Multi-Node Mesh Network is an innovative approach to improving communication within the ecosystem of networked electric vehicles. By addressing the drawbacks of traditional vehicle networks, SGMNMN significantly improves connection, efficiency, scalability, and safety. To effectively leverage the possibilities, it is necessary to overcome challenges such as network latency, security, and integration. Ongoing research and development in this field will make it easier to construct more sophisticated and reliable EV communication networks, thereby supporting the expansion and prosperity of the electric car market.

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