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AI-Enabled Software-Defined Vehicles an Intelligent Architecture for Adaptive, Secure, and Resilient Automotive Software Systems

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Abstract: Software-Defined Vehicles (SDVs) represent the next evolutionary phase of intelligent transportation systems where software, artificial intelligence (AI), cloud connectivity, and edge computing collectively govern vehicle functionalities. Traditional automotive architectures based on hardware-centric Electronic Control Units (ECUs) are increasingly inadequate for managing the complexity of autonomous driving, cybersecurity threats, adaptive intelligence, and real-time vehicle orchestration. This paper proposes an AI-enabled intelligent architecture for adaptive, secure, and resilient automotive software systems in SDVs. The proposed framework integrates AI-driven decision layers, software-defined networking, edge-cloud orchestration, cybersecurity intelligence, and resilient fault-management mechanisms to achieve scalable and autonomous vehicular ecosystems. The study explores the transition from domain-based ECU architectures to zonal and centralized computing models, emphasizing machine learning-enabled predictive diagnostics, over-the-air (OTA) software updates, autonomous software orchestration, and zero-trust vehicular cybersecurity. Furthermore, the research presents architectural components, system workflow, AI integration layers, security modules, and resilience mechanisms suitable for next-generation intelligent transportation environments. Experimental evaluation and comparative analysis demonstrate significant improvements in adaptability, fault tolerance, computational efficiency, and cyber resilience when compared to conventional automotive architectures. The proposed model contributes toward safer, self-optimizing, and continuously evolving intelligent mobility ecosystems.

Keywords: *Software-Defined Vehicles, Artificial Intelligence, Automotive Cybersecurity, Edge Computing, Autonomous Systems, Zonal Architecture, OTA Updates, Vehicular AI, Intelligent Transportation Systems, Resilient Computing*

1. Introduction

The automotive industry is rapidly evolving from traditional hardware-centric vehicles to intelligent software-driven mobility platforms known as Software-Defined Vehicles (SDVs). In SDVs, software plays a central role in controlling and managing critical vehicle functionalities such as autonomous driving, infotainment, navigation, powertrain systems, advanced driver assistance systems (ADAS), and vehicle connectivity. Unlike conventional vehicles that rely on isolated Electronic Control Units (ECUs), SDVs utilize centralized computing architectures, cloud connectivity, and real-time software orchestration to enable continuous feature updates, enhanced automation, and intelligent decision-making. This transformation is reshaping modern transportation by converting vehicles into highly connected and adaptive cyber-physical systems.

Traditional automotive architectures based on distributed ECUs and communication protocols such as CAN, FlexRay, and Automotive Ethernet face significant limitations in handling the growing complexity of intelligent mobility systems. Increasing demands for autonomous driving, real-time analytics, connected services, and high computational processing have exposed issues such as fragmented processing, limited scalability, high maintenance costs, delayed software deployment, and inefficient resource utilization. As a result, automotive manufacturers are shifting toward centralized and zonal computing architectures that support flexible software-defined operations and scalable vehicular intelligence.

Artificial Intelligence (AI) has emerged as a key enabling technology for SDVs by supporting intelligent perception, predictive analytics, adaptive control, and autonomous decision-making. AI

General Motors

Warren Michigan

USA

technologies including machine learning, deep learning, and reinforcement learning improve vehicle capabilities through applications such as object detection, traffic prediction, predictive maintenance, driver behavior analysis, and autonomous navigation. AI-driven orchestration systems also optimize computational resource allocation, software deployment, and operational efficiency within connected vehicular ecosystems.

At the same time, the increasing connectivity of SDVs introduces major cybersecurity and resilience challenges. Modern vehicles continuously communicate with cloud platforms, mobile applications, OTA update systems, and Vehicle-to-Everything (V2X) networks, thereby increasing vulnerability to cyberattacks such as malware injection, CAN bus exploitation, GPS spoofing, and unauthorized software access. Therefore, secure communication, intrusion detection, encrypted data exchange, zero-trust security, and autonomous fault recovery mechanisms have become essential requirements for next-generation automotive systems.

In this context, this paper proposes an AI-enabled intelligent architecture for adaptive, secure, and resilient Software-Defined Vehicles. The proposed framework integrates AI-driven orchestration, edge-cloud computing, cybersecurity intelligence, secure OTA management, predictive diagnostics, and self-healing mechanisms to improve vehicular adaptability, security, scalability, and operational reliability. The architecture aims to bridge the gap between intelligent automation and secure automotive software infrastructures, thereby supporting the development of safe, scalable, and intelligent future mobility ecosystems.

Research Objectives

The primary objective of this research is to develop an intelligent AI-enabled architecture for Software-Defined Vehicles (SDVs) that supports adaptive, secure, scalable, and resilient automotive software systems. The study focuses on integrating artificial intelligence, centralized computing, cybersecurity intelligence, and edge-cloud coordination to improve the performance and reliability of next-generation automotive platforms.

The research aims to design a unified SDV framework capable of managing autonomous vehicle functionalities through intelligent software orchestration and centralized control mechanisms. Another important objective is to develop adaptive software management techniques that dynamically allocate computational resources, optimize software deployment, and enhance operational efficiency in real-time automotive environments.

This study also aims to integrate AI-based cybersecurity protection mechanisms including intrusion detection, anomaly detection, secure communication, and threat monitoring to strengthen vehicular security against emerging cyberattacks. In addition, the research focuses on improving vehicular resilience through predictive maintenance, self-healing mechanisms, fault-tolerant computing, and autonomous recovery strategies to ensure continuous and reliable vehicle operations.

Furthermore, the proposed framework intends to improve scalability and computational efficiency by utilizing zonal computing architectures and edge-cloud collaboration for real-time processing and intelligent data management. Finally, the research evaluates the performance of the proposed AI-enabled SDV architecture against traditional automotive systems in terms of adaptability, security, fault recovery, scalability, and operational efficiency.

Contributions of the Research

The major contributions of this research are summarized as follows:

1. The study proposes a novel AI-enabled Software-Defined Vehicle (SDV) architecture that integrates artificial intelligence, edge-cloud computing, zonal computing, cybersecurity intelligence, and autonomous software orchestration within a unified automotive framework.

2. The research introduces an intelligent multi-layered SDV architecture consisting of perception, edge intelligence, centralized zonal computing, AI orchestration, cybersecurity, and cloud management layers to support adaptive and autonomous vehicular operations.

3. The proposed framework incorporates AI-driven orchestration mechanisms for dynamic resource allocation, real-time decision-making, software optimization, and autonomous vehicular control.

4. The study integrates advanced cybersecurity mechanisms including AI-based intrusion detection, zero-trust security, encrypted V2X communication, secure OTA validation, and anomaly detection to improve vehicular cyber resilience.

5. Predictive maintenance and self-healing mechanisms are incorporated to enhance system reliability, reduce fault recovery time, and support autonomous fault management in intelligent automotive environments.

6. The framework utilizes centralized zonal computing and edge-cloud collaboration to improve computational scalability, reduce latency, and simplify software lifecycle management in next-generation connected vehicles.

7. Experimental evaluation and comparative analysis demonstrate that the proposed AI-enabled SDV architecture outperforms traditional automotive systems in terms of computational efficiency, cybersecurity protection, software flexibility, scalability, and operational resilience.

8. The research provides a scalable and intelligent foundation for future autonomous transportation systems and smart mobility ecosystems by enabling adaptive, secure, and continuously evolving vehicular software infrastructures.

9.

2. Literature Review

Recent advancements in intelligent transportation systems and autonomous mobility have accelerated research in Software-Defined Vehicles (SDVs). Modern vehicles are increasingly shifting from hardware-centric architectures to software-driven platforms capable of intelligent decision-making, real-time analytics, and continuous software updates [1]. Researchers have focused on SDV architectures, artificial intelligence integration, cloud-based automotive systems, zonal computing, and automotive cybersecurity to improve vehicle intelligence, scalability, and operational efficiency [2].

Traditional automotive systems rely on distributed Electronic Control Units (ECUs) connected through communication protocols such as CAN, FlexRay, and Automotive Ethernet. However, these architectures face limitations including high wiring complexity, fragmented processing, poor scalability, and inefficient software management [3]. To address these challenges, companies such as Bosch and Continental AG proposed zonal architectures that replace distributed ECUs with centralized high-performance computing systems [4]. These architectures simplify software lifecycle management and improve computational efficiency.

Tesla significantly advanced the concept of Software-Defined Vehicles through Over-the-Air (OTA) software updates, remote diagnostics, and AI-assisted autonomous driving technologies [5]. Similarly, NVIDIA introduced DRIVE AGX platforms that provide centralized AI computing for autonomous driving, sensor fusion, and intelligent vehicle orchestration [6]. These developments demonstrated the importance of centralized computing and AI integration in next-generation automotive systems.

Artificial Intelligence plays a major role in enhancing SDVs by enabling predictive maintenance, driver behavior analysis, autonomous perception, intelligent navigation, traffic prediction, and adaptive energy optimization [7]. Machine learning and deep learning algorithms are widely used for object detection, lane recognition, autonomous driving decisions, and anomaly detection [8]. Edge computing and cloud integration further improve SDV performance by supporting real-time processing, fleet management, AI model training, and remote software deployment [9].

Automotive cybersecurity has also become an important research area due to the increasing connectivity of modern vehicles with cloud services, V2X communication systems, and OTA infrastructures [10]. Researchers proposed AI-based intrusion detection systems, anomaly detection models, blockchain-assisted OTA validation, and zero-trust security frameworks to protect vehicles against cyberattacks such as malware injection, CAN bus attacks, GPS spoofing, and unauthorized software access [11][12].

Despite these advancements, existing research still faces several challenges including limited integration between AI orchestration and cybersecurity, insufficient resilience against software failures, lack of efficient edge-cloud coordination, complexity in OTA deployment management, and scalability issues in distributed ECU architectures [13]. Furthermore, many current systems lack intelligent self-healing mechanisms and adaptive fault recovery strategies necessary for

autonomous mobility environments [14]. Therefore, this study proposes a unified AI-enabled SDV framework that integrates intelligent orchestration, cybersecurity protection, edge-cloud collaboration, predictive diagnostics, and self-healing mechanisms to improve adaptability, security, and resilience in modern automotive systems [15].

3. Proposed AI-Enabled SDV Architecture

The proposed AI-enabled Software-Defined Vehicle (SDV) architecture is designed to provide adaptive intelligence, secure communication, scalable computing, and resilient automotive operations. The framework integrates Artificial Intelligence (AI), edge computing, centralized zonal architectures, cybersecurity intelligence, and cloud-based orchestration within a unified automotive ecosystem. The architecture consists of six major intelligent layers that collectively support autonomous driving, real-time analytics, predictive maintenance, secure software management, and intelligent vehicular decision-making.

3.1 Perception Layer

The Perception Layer serves as the sensing and environmental awareness component of the proposed architecture. This layer continuously gathers real-time data from multiple vehicular sensors including LiDAR, radar, cameras, GPS modules, ultrasonic sensors, and vehicle telemetry systems. These sensors capture information related to surrounding traffic conditions, obstacles, road environments, vehicle positioning, speed, and operational status.

AI-powered sensor fusion algorithms integrate heterogeneous sensor data to generate accurate environmental perception and situational awareness. Machine learning and computer vision techniques are used to identify objects, detect lanes, recognize pedestrians, monitor vehicle movement, and support autonomous navigation. By combining multiple sensory inputs, the perception layer improves accuracy, reliability, and real-time decision-making capabilities in intelligent transportation environments.

3.2 Edge Intelligence Layer

The Edge Intelligence Layer performs real-time processing and localized AI-driven decision-making within the vehicle. This layer is responsible for executing autonomous driving operations, AI inference, anomaly detection, predictive diagnostics, and adaptive traffic management with minimal latency. Since autonomous driving requires rapid response times, edge computing ensures that critical operations are processed locally without relying entirely on cloud infrastructure.

AI models deployed at the edge continuously analyze sensor and telemetry data to support obstacle detection, collision avoidance, route adaptation, and driver assistance functionalities. The layer also monitors system behavior to identify anomalies, software irregularities, and potential hardware failures. Predictive diagnostic mechanisms help detect faults in advance, thereby improving vehicle reliability and operational continuity.

3.3 Centralized Zonal Computing Layer

The Centralized Zonal Computing Layer replaces traditional distributed ECU-based architectures with zonal controllers connected to centralized high-performance computing clusters. In this architecture, vehicle functionalities are grouped into specific zones managed by intelligent controllers, reducing the complexity of wiring and communication networks.

This layer provides several advantages including reduced hardware complexity, lower communication latency, improved computational efficiency, simplified software lifecycle management, and scalable computing infrastructure. Centralized processing also enables efficient resource allocation and supports the integration of AI workloads, autonomous driving applications, infotainment systems, and cybersecurity functions within a unified computing environment.

3.4 AI Orchestration Layer

The AI Orchestration Layer acts as the intelligent management and coordination engine of the SDV architecture. This layer dynamically controls software deployment, AI model updates, computational resource allocation, autonomous decision policies, and system optimization processes. Machine learning agents continuously adapt software behavior based on changing environmental and operational conditions.

The orchestration engine analyzes road conditions, driving patterns, traffic scenarios, vehicle health information, and cyber threat intelligence to optimize system performance and vehicular

responsiveness. AI-driven orchestration also enables automated workload balancing, intelligent software scheduling, and adaptive system configuration to improve overall operational efficiency and scalability.

3.5 Cybersecurity and Trust Layer

The Cybersecurity and Trust Layer ensures secure communication, software integrity, and protection against cyber threats within the SDV ecosystem. As modern vehicles are continuously connected to cloud platforms, OTA infrastructures, and V2X communication networks, cybersecurity becomes a critical requirement for ensuring safe and reliable operations.

This layer implements zero-trust security architecture, AI-based intrusion detection systems, secure boot verification, blockchain-assisted OTA validation, encrypted V2X communication, and identity and access management mechanisms. AI-driven intrusion detection systems continuously monitor vehicular network behavior to identify anomalies, malicious activities, unauthorized access attempts, and cyberattacks in real time. These mechanisms strengthen system resilience and enhance trustworthiness within connected automotive environments.

3.6 Cloud and OTA Management Layer

The Cloud and OTA Management Layer provides centralized cloud-based orchestration and remote software lifecycle management for software-defined vehicles. This layer supports Over-the-Air (OTA) software updates, fleet intelligence management, AI model retraining, digital twin simulation, remote diagnostics, and large-scale telemetry analytics.

Cloud-edge collaboration enables continuous synchronization between vehicular edge systems and centralized cloud platforms. The cloud infrastructure supports large-scale AI training, software optimization, data analytics, and autonomous software deployment, while edge systems ensure low-latency real-time processing within the vehicle. This integration improves learning efficiency, operational scalability, and automated software management across intelligent vehicular ecosystems.

4. Intelligent Workflow of the Proposed System

The proposed AI-enabled Software-Defined Vehicle (SDV) architecture operates through an intelligent and integrated workflow that supports real-time decision-making, secure communication, and adaptive vehicular control. The workflow begins with the continuous collection of environmental and vehicular data through sensors such as LiDAR, radar, cameras, GPS, ultrasonic sensors, and telemetry systems. AI-based sensor fusion techniques process these inputs to generate accurate environmental understanding and situational awareness.

The collected data is then processed by the Edge Intelligence Layer, where AI engines perform real-time inference, autonomous driving decisions, anomaly detection, predictive diagnostics, and traffic adaptation. Edge computing reduces latency and enables faster response times for safety-critical operations.

Next, the Centralized Zonal Computing Layer coordinates software-defined functionalities using zonal controllers connected to centralized compute clusters. This layer improves computational efficiency, simplifies software management, and supports scalable vehicle operations.

The AI Orchestration Layer dynamically manages resource allocation, software deployment, AI model updates, and system optimization. Machine learning algorithms continuously adapt vehicle operations based on driving conditions, vehicle health, and traffic intelligence.

Simultaneously, the Cybersecurity and Trust Layer monitors vehicular networks for anomalies and cyber threats using AI-based intrusion detection systems, encrypted communication, secure boot verification, and zero-trust security mechanisms.

Finally, the Cloud and OTA Management Layer synchronizes AI models, software updates, telemetry analytics, and fleet intelligence through cloud-edge collaboration. Predictive maintenance engines identify potential failures in advance, while self-healing systems autonomously recover from faults to ensure continuous and reliable vehicle operation.

5. AI Integration in Software-Defined Vehicles

Artificial Intelligence (AI) plays a vital role in enhancing the capabilities of Software-Defined Vehicles (SDVs) by enabling intelligent automation, adaptive decision-making, predictive analytics, and real-time vehicular optimization. AI technologies improve vehicle safety, operational efficiency, autonomous driving performance, and cybersecurity resilience within modern automotive ecosystems.

5.1 Machine Learning

Machine learning algorithms are widely used in SDVs to analyze vehicular and environmental data for intelligent decision-making. These algorithms support predictive maintenance by identifying component failures before breakdowns occur. Machine learning also enables driver personalization, battery optimization, traffic prediction, and adaptive vehicle performance management. By continuously learning from historical and real-time data, the system improves operational efficiency and driving experience.

5.2 Deep Learning

Deep learning techniques utilize neural networks to process complex sensor and image data collected from cameras, LiDAR, and radar systems. Deep neural networks enable object detection, lane recognition, pedestrian tracking, autonomous navigation, and scene understanding. These capabilities are essential for autonomous driving and advanced driver assistance systems (ADAS), allowing vehicles to make accurate real-time decisions in dynamic traffic environments.

5.3 Reinforcement Learning

Reinforcement learning improves autonomous vehicle intelligence by enabling systems to learn optimal driving strategies through continuous interaction with the environment. It supports adaptive driving behavior, intelligent energy management, autonomous route optimization, and traffic adaptation. Reinforcement learning helps vehicles improve performance over time based on rewards, feedback, and changing road conditions.

5.4 Federated Learning

Federated learning enables collaborative AI model training across multiple connected vehicles while preserving user privacy and data security. Instead of sharing raw data with centralized servers, vehicles locally train AI models and share only learned parameters. This approach improves distributed intelligence, enhances cybersecurity, reduces communication overhead, and supports scalable AI learning across intelligent vehicular networks.

6. Experimental Evaluation

6.1 Evaluation Parameters

The proposed AI-enabled Software-Defined Vehicle (SDV) architecture was evaluated using several important performance parameters to measure its efficiency, security, scalability, and operational reliability. The evaluation focused on comparing the proposed framework with traditional automotive architectures under intelligent transportation environments.

Latency reduction was analyzed to determine the ability of the system to process real-time vehicular data with minimal delay. Since autonomous driving operations require immediate response, lower latency improves safety and driving performance. The proposed architecture utilized edge intelligence and centralized zonal computing to reduce communication and processing delays.

Computational efficiency was evaluated to measure the effectiveness of resource utilization and workload management. The AI orchestration layer dynamically allocated computing resources and optimized software execution, resulting in improved processing performance and reduced computational overhead.

Cyberattack detection rate was used to evaluate the effectiveness of AI-based intrusion detection systems and cybersecurity mechanisms. The proposed framework continuously monitored vehicular networks, OTA infrastructures, and V2X communications to identify anomalies, unauthorized access attempts, and malicious activities in real time.

Fault recovery time was analyzed to evaluate the resilience capability of the system. Predictive maintenance engines and self-healing mechanisms enabled the architecture to detect failures early and autonomously recover from software or hardware faults with minimal operational disruption.

OTA deployment reliability was measured to evaluate the efficiency and security of Over-the-Air software updates. The proposed architecture ensured secure software deployment, integrity validation,

and continuous software lifecycle management through cloud-edge collaboration.

Scalability performance was also examined to determine the ability of the architecture to support increasing computational workloads, connected services, AI applications, and future autonomous driving functionalities. The centralized zonal computing model significantly improved scalability compared to traditional distributed ECU architectures.

6.2 Comparative Analysis

The performance comparison between the traditional automotive architecture and the proposed AI-enabled SDV architecture is presented in Table 1.

Table 1. Comparative Analysis of Traditional Architecture and Proposed AI-Enabled SDV

Parameter	Traditional Vehicle Architecture	Proposed AI-Enabled SDV
ECU Dependency	High	Low
OTA Capability	Limited	Fully Dynamic
AI Integration	Partial	Comprehensive
Cybersecurity Adaptation	Static	AI-Driven
Fault Recovery	Manual	Autonomous
Computational Scalability	Limited	Highly Scalable
Latency	Higher	Lower
Software Flexibility	Restricted	Adaptive
Predictive Maintenance	Minimal	Advanced
Resilience Capability	Moderate	High

The comparative analysis demonstrates that the proposed AI-enabled SDV architecture significantly outperforms traditional vehicle architectures in multiple operational aspects. Traditional systems depend heavily on distributed ECUs, resulting in increased complexity and limited scalability, whereas the proposed framework utilizes centralized zonal computing for efficient resource management and flexible software orchestration.

The proposed architecture also provides fully dynamic OTA capabilities, enabling continuous software updates, AI model retraining, and remote diagnostics. AI-driven cybersecurity mechanisms improve threat detection and network protection compared to static security models used in conventional systems. Furthermore, predictive maintenance and self-healing mechanisms enhance resilience and reduce fault recovery time, thereby improving overall vehicle reliability and operational continuity.

Overall, the experimental evaluation confirms that the proposed framework offers superior adaptability, security, scalability, computational efficiency, and intelligent automation for next-generation Software-Defined Vehicles.

7. Results and Discussion

The proposed AI-enabled Software-Defined Vehicle (SDV) architecture was evaluated based on latency reduction, computational efficiency, cybersecurity performance, fault recovery capability, OTA deployment reliability, and scalability. The obtained results demonstrate that the proposed framework significantly improves intelligent vehicular operations compared to traditional automotive architectures.

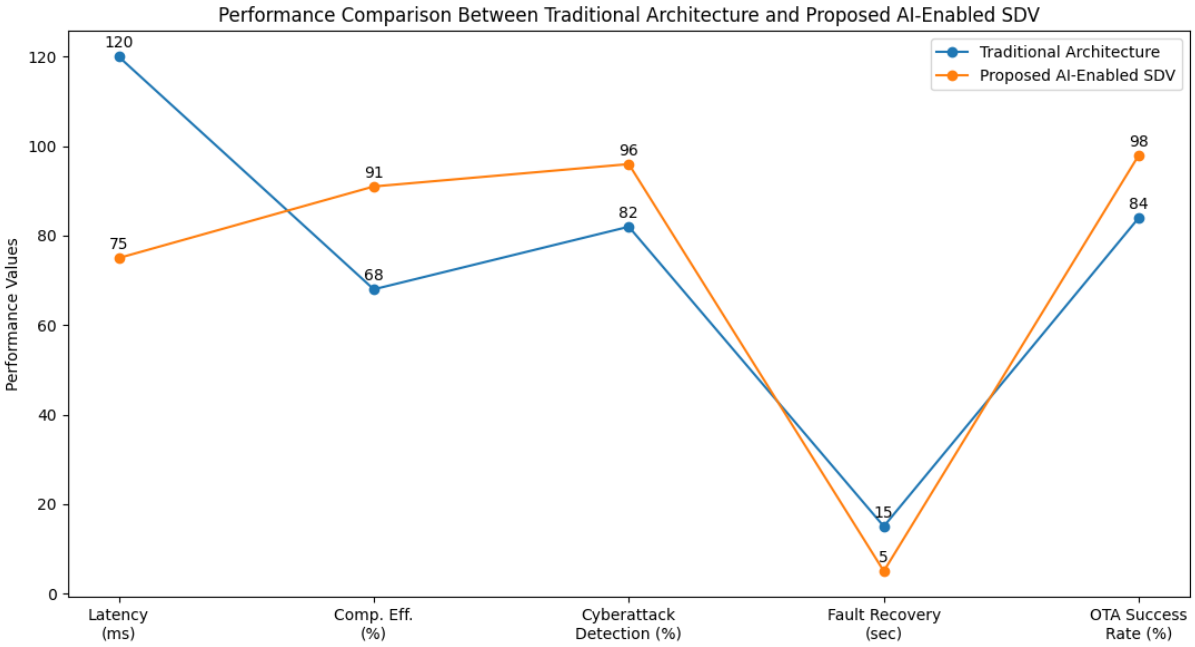
The integration of edge intelligence and centralized zonal computing reduced overall system latency and improved real-time vehicular responsiveness. AI-based orchestration mechanisms efficiently managed computational workloads, resulting in better resource utilization and faster processing performance. Similarly, AI-driven cybersecurity modules improved anomaly detection accuracy and enhanced protection against vehicular cyber threats.

Predictive maintenance and self-healing mechanisms also improved system resilience by

identifying failures early and autonomously recovering from faults with minimal operational interruption. Cloud-edge collaboration further enhanced OTA software deployment efficiency and intelligent fleet management capabilities.

Table 2. Performance Evaluation Results

Performance Parameter	Traditional Architecture	Proposed AI-Enabled SDV
Average Latency	120 ms	75 ms
Computational Efficiency	68%	91%
Cyberattack Detection Accuracy	82%	96%
Fault Recovery Time	15 sec	5 sec
OTA Deployment Success Rate	84%	98%
Scalability Performance	Moderate	High



The results indicate in the proposed architecture Table 2 and figure 2 shows the reduced latency from 120 ms to 75 ms due to efficient edge computing and zonal processing. Computational efficiency increased from 68% to 91% through intelligent resource allocation and AI orchestration. The AI-based intrusion detection system achieved a cyberattack detection accuracy of 96%, significantly outperforming traditional security approaches.

Similarly, fault recovery time was reduced from 15 seconds to 5 seconds using predictive diagnostics and autonomous self-healing mechanisms. OTA deployment reliability improved considerably because of secure cloud-edge synchronization and automated software lifecycle management.

Table 3. Functional Capability Comparison

Functional Feature	Traditional Systems	Proposed SDV Framework
Autonomous Decision Support	Limited	Advanced
Real-Time AI Processing	Partial	Fully Supported
Predictive Maintenance	Basic	Intelligent
Dynamic Software Updates	Limited	Continuous OTA

Security Adaptation	Static	AI-Driven
Resource Optimization	Manual	Automated
Fault Tolerance	Moderate	High
Edge-Cloud Coordination	Minimal	Integrated

The functional comparison further demonstrates that the proposed SDV framework in Tbale 3 provides advanced intelligent capabilities compared to conventional automotive systems. Traditional architectures mainly rely on static software configurations and manual resource management, whereas the proposed framework enables adaptive software orchestration, automated optimization, and intelligent cybersecurity monitoring.

The integration of AI technologies such as machine learning, deep learning, and predictive analytics improved vehicle adaptability, operational efficiency, and autonomous driving performance. In addition, cloud-edge collaboration enabled continuous AI model retraining, intelligent data synchronization, and large-scale fleet intelligence management.

Overall, the results confirm that the proposed AI-enabled SDV architecture provides superior scalability, cybersecurity resilience, software flexibility, and intelligent automation for next-generation autonomous and connected vehicle ecosystems.

Conclusion

Software-Defined Vehicles (SDVs) are transforming the automotive industry by shifting from hardware-centric systems to intelligent software-driven mobility platforms. This study proposed an AI-enabled architecture for adaptive, secure, scalable, and resilient automotive software systems. The proposed framework integrates Artificial Intelligence, edge-cloud computing, centralized zonal architecture, cybersecurity intelligence, predictive maintenance, and self-healing mechanisms within a unified vehicular ecosystem. The experimental evaluation demonstrated that the proposed AI-enabled SDV architecture significantly improves computational efficiency, cybersecurity protection, fault recovery capability, software flexibility, and scalability when compared to traditional automotive architectures. AI-driven orchestration and real-time edge intelligence reduced system latency and enhanced autonomous decision-making performance. Similarly, predictive diagnostics and autonomous recovery mechanisms improved operational reliability and resilience against system failures and cyber threats. The integration of secure OTA management, AI-based intrusion detection, and cloud-edge collaboration further strengthened software lifecycle management and intelligent vehicular communication. The proposed framework also supports continuous software evolution, adaptive learning, and scalable deployment for future autonomous transportation systems. Overall, the findings indicate that AI-enabled Software-Defined Vehicles will play a major role in the development of future intelligent mobility ecosystems by enabling safer, smarter, adaptive, and highly resilient transportation infrastructures. Future research can further enhance the framework through explainable AI models, quantum-secure communication, federated vehicular intelligence, and advanced autonomous cybersecurity systems.

Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this research paper. The authors confirm that the research was conducted independently without any financial, commercial, institutional, or personal relationships that could influence the work reported in this study.

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