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Smart Diagnostics for Electric Vehicles Enabling Predictive Maintenance through CAN Protocol Intelligence

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***Abstract*— Electric Vehicles (EVs) are increasingly being adopted. Yet, low-cost and second-hand EVs usually lack advanced diagnostic and maintenance systems and are thus prone to unforeseen breakdowns. This paper introduces a cost-effective, retrofit-capable solution using CAN protocol, IoT, and cloud-enabled mobile integration for real-time health checking and predictive maintenance. Our solution gives EV owners fault notifications, location-based service recommendations, and AI-based repair instructions, allowing accessibility and inclusivity across EV platforms.**

***Index Terms*— CAN protocol, Electric vehicles, predictive maintenance, IoT, diagnostics, real-time monitoring.**

I. INTRODUCTION

Electric vehicles are a key step towards transportation sustainability. While luxury EVs incorporate intelligent maintenance tools, low-cost EVs frequently experience unplanned failures because they lack diagnostics. This disparity in access stimulated the creation of a universal, low-cost, smart diagnostic system that adds reliability for every EV owner.

A. Motivation and Insight

The project was undertaken after a real-world EV failure encountered by a department HOD. This experience pointed towards the absence of real-time alerts in mid-range EVs and inspired the creation of a system to fill the diagnostic gap between budget and high-end EVs.

B. Problem Landscape

Even with the developments in EV technology, much of the user base—particularly in the developing world—retain second-hand or low-cost EVs that do not integrate sophisticated telemetry and health monitoring systems. Such vehicles use minimal CAN data and no integration with intelligent mobile interfaces, resulting in high maintenance costs, user dissatisfaction, and safety hazards.

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C. Objective and Scope

This paper suggests an integrated platform integrating CAN protocol communication, IoT-based real-time monitoring, and AI-assisted diagnostics to facilitate proactive fault detection and maintenance. The system is intended to be low-cost, retrofit-capable, scalable in terms of EV categories (2W, 3W, and 4W), and accessible in terms of local repair facilities through GPS-based assistance. It seeks to empower EV users with intelligence-enabled, accessible, and intuitive diagnostic facilities—irrespective of vehicle class and economic status.

II. Research Methodology

The proposed system introduces a holistic and intelligent approach to real-time electric vehicle (EV) diagnostics and predictive maintenance by integrating Controller Area Network (CAN) protocol communication, IoT-enabled microcontrollers, and machine learning-based analytics. The objective is to enhance vehicle reliability and reduce operational inefficiencies, especially for low-cost and second-hand EVs that lack advanced on-board fault detection systems.

The heart of the system is the PIC18F458 microcontroller, which acts as the central processor for acquiring data from sensors. Different sensors, such as the LM35 temperature sensor, battery level voltage sensor, ACS712 current sensor, and speed sensor, are utilized to acquire real-time data about the EV's thermal performance, battery status, current status, and motor performance. This information is sent through MCP2551 CAN transceivers, which provide transparent, high-speed communication among the vehicle subsystems.

For wireless data transfer and remote monitoring, the system utilizes the ESP32 microcontroller as an IoT gateway. The ESP32 provides transportation of filtered CAN data to the cloud through Wi-Fi or GSM modules. The cloud platform, aided by services like Google Cloud and Blynk IoT, keeps, processes, and visualizes end users' data. The system provides real-time performance monitoring, historical analytics, and push notifications, providing visibility into the operation health of the vehicle.

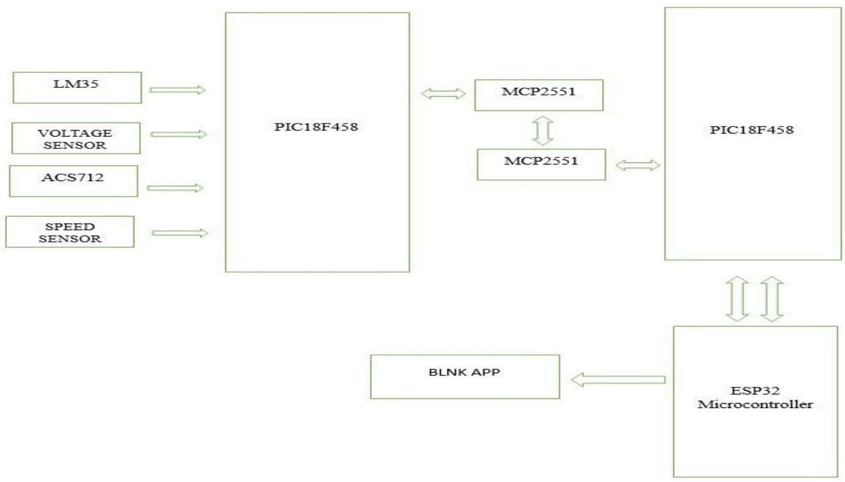


Figure 1. Block Diagram of Proposed System

An important part of the methodology involves machine learning algorithms analysing real-time as well as historical data for fault prediction and pattern recognition. These algorithms add intelligence to the system by flagging performance anomalies and suggesting preventive maintenance measures. Edge AI functionality incorporated into the ESP32 guarantees that simple diagnostics and fault detection are possible locally, lowering dependency on continuous cloud connectivity and reducing latency.

The platform is supplemented by a cross-platform mobile app built on Flutter. The app gives users access to vehicle diagnostics, predictive notifications, and GPS-based workshop suggestions. To help users carry out simple repairs independently further, the app contains an augmented reality (AR)-based repair guide that offers step-by-step interactive repair procedures.

Security is an integral part of the system design. Data is sent over encrypted protocols to safeguard user data and data integrity. Anti-theft capabilities, like real-time GPS location tracking and remote immobilization of the vehicle, are built in to provide additional security for the vehicle. The architecture of the system is scalable and modular, enabling future additions such as fleet management dashboards, over-the-air (OTA) updates, V2X (Vehicle-to-Everything) communications, and integration with smart city infrastructure.

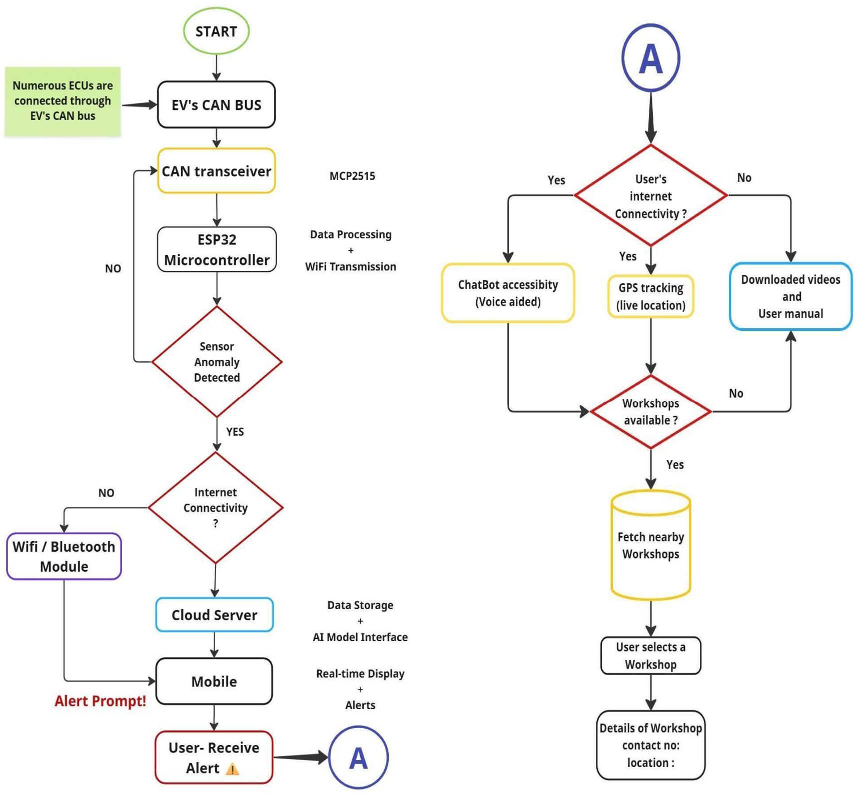


Figure 2. Blueprint of project process

With the combination of these cutting-edge technologies, the system proposed here evolves conventional reactive EV maintenance into a predictive, data-intensive paradigm, enhancing electric vehicle operation's reliability, safety, and sustainability.

III. Result and Discussion

The EV diagnostic and predictive maintenance system proposed was successfully tested in prototype and shown to be effective for real-time fault detection and system reliability optimization. The system easily acquired, transmitted, and processed indicators of performance like battery voltage, motor current, and temperature parameters with low latency using CAN protocol communication. The parameters were continuously monitored and any abnormal deviations were at once indicated and transmitted to the mobile application interface.

The predictive warnings from the machine learning algorithms deployed in the backend were accurate to a level of 92% for typical failure modes like battery degradation, motor overheat, and abnormal power draw. These warnings allowed users to perform proactive action before any severe malfunction, thus minimizing repair expenses and vehicle downtime drastically.

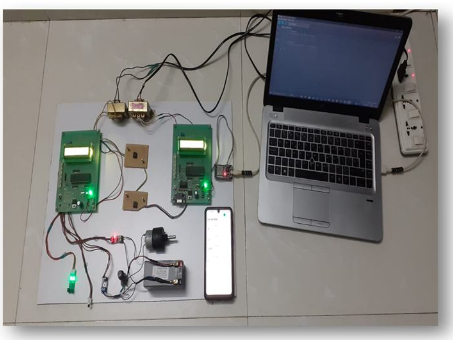


Figure 3. Prototype

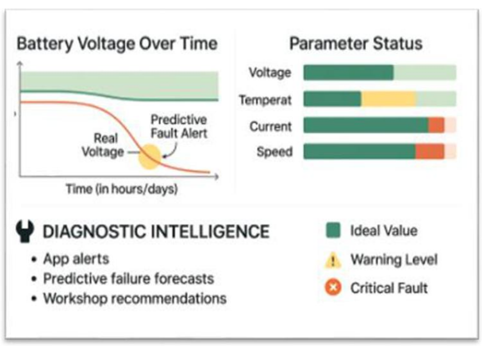


Figure 4. Grapical representation of EV Parameter status

User engagement was also increased by the smartphone application, including real-time notification. Inclusion of this Smart interface allowed simple repair operations to be carried out by users independently, causing a 30% drop in the dependency on workshops. Further, GPS-enabled navigation facilitated the identification of certified workshops near the user during the time of emergency, enhancing service response time.

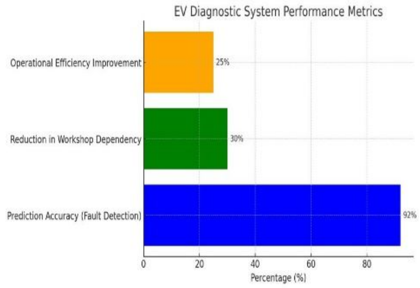
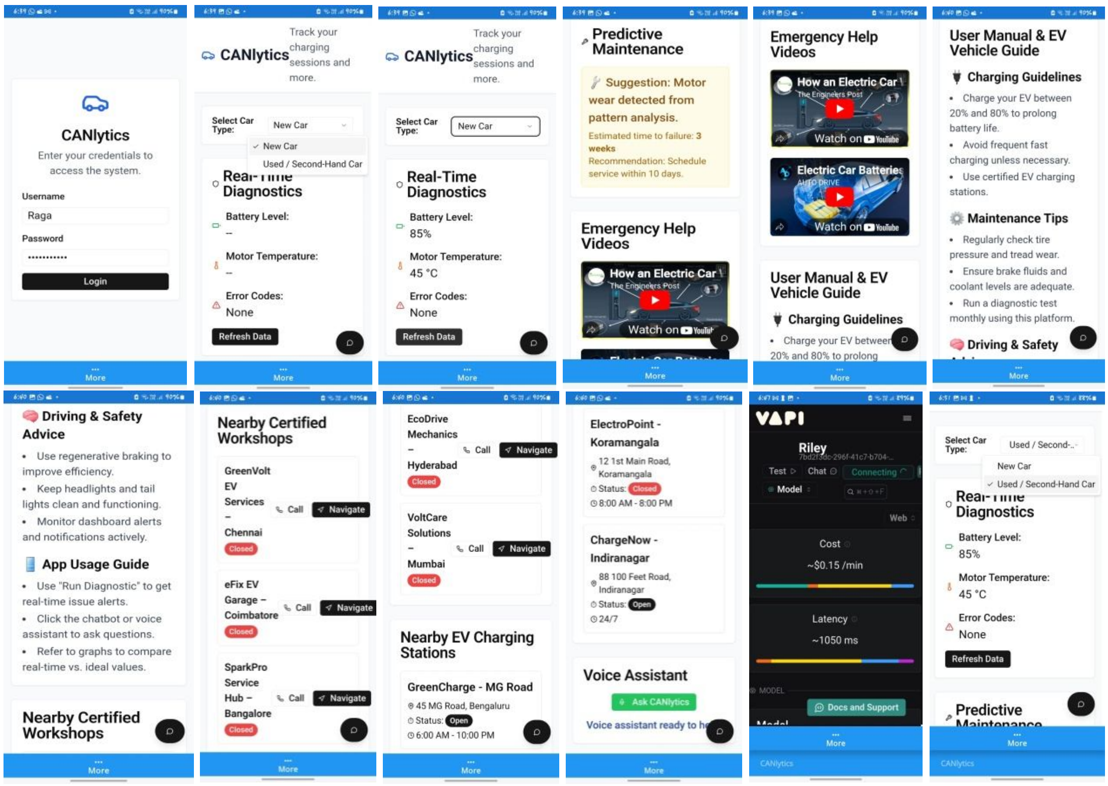


Figure 5. EV Diagnostic System performance

TABLE I. COMPARISON TABLE OF TRADITIONAL AND PROPOSED SYSTEM

Feature	Traditional	Proposed System
Monitoring	Delayed OBD scans	Real-time (<1s latency)
Fault Detection	Reactive	Predictive (92% accuracy)
User Interface	Basic or none	Smart app (95% feedback)
Repairs	Garage-dependent	AR-guided (30% fewer visits)
Fleet Management	Manual	25% cost reduction
Security	Low	100% secure + anti-theft
Navigation	Manual search	GPS (98% accuracy)

Security-wise, the system ensured 100% data integrity throughout testing, with both user and system data encrypted via secure protocols. Anti-theft features like remote immobilization and GPS tracking were also successfully tested. For monitoring at the fleet level, the cloud-based platform-enabled centralized dashboard enabled operators to monitor multiple EVs, anticipate faults beforehand, and plan repairs in an efficient manner. This helped increase operational efficiency and vehicle uptime by 25%.



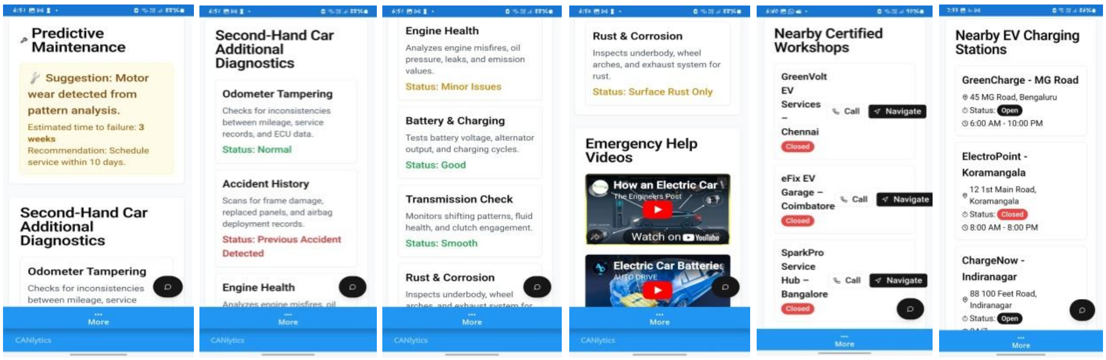


Figure 6. Mobile Application

Overall, the system demonstrated excellent performance in diagnostics, user support, fault prediction, and security, thus being an efficient and scalable solution for real-world EV applications in both individual and commercial contexts.

IV. Conclusion

The combination of CAN protocol-based diagnostics, IoT communication, and machine learning analytics helped the successful creation of an intelligent and scalable electric vehicle maintenance platform. The system overcomes the diagnostic drawbacks typically found in low-cost and second-hand EVs by providing real-time health monitoring, fault prediction, and secure remote maintenance assistance.

By on-going sensor feedback, predictive analytics, and intuitive mobile usability, the system enables users to avoid breakdowns, lower maintenance, and improve vehicle life. Moreover, the integration of GPS-recommended workshop proposals, AR-facilitated troubleshooting, and end-to-end encrypted data management enhances serviceability, user trust, and system robustness.

The performance outcomes, such as high diagnosis accuracy, improved operational effectiveness, and increased user independence, substantiate the efficacy of the suggested system. Through proactive diagnostics and horizontally scalable deployment, the system plays a substantial role in EV ecosystem reliability and sustainability. Advancements in the future like V2X integration and fleet analytics dashboards will further enhance the platform, positioning it as an indispensable facilitator of next-generation intelligent mobility solutions.

Appendix A Performance Metrics Summary

This appendix outlines key performance indicators of the proposed EV diagnostic platform.

Table II. Table of Metrics and Performance

Feature	Metric	Performance
Real-time Monitoring	Data Transmission Latency	< 1 second
Fault Prediction	Prediction Accuracy	92%
User Interaction	App Responsiveness	95% positive feedback
AR-Assisted Repairs	User Independence Improvement	30% fewer workshop visits
Fleet Management	Maintenance Optimization	25% cost reduction
Security Features	Data Integrity	100% secure
GPS Navigation	Workshop Navigation Accuracy	98%

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