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IoT Based Monitoring and Control System for Electric Vehicles

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Abstract - *In order to improve operational reliability, safety, and sustainability, the rise of electric vehicles (EVs) has made the development of intelligent systems for effective monitoring and control of vehicle parameters necessary. Using a comprehensive architecture that combines on-board sensors, a microcontroller gateway, cloud-based platforms, and user interfaces, this work introduces an Internet of Things-based monitoring and control system for electric vehicles. Critical parameters like battery health, temperature, speed, GPS location, and motor efficiency are continuously measured by sensors integrated into the car. Wireless communication is used to send data to a microcontroller, which acts as a gateway and sends the combined data to a cloud platform for additional analysis.*

Predictive maintenance, intelligent energy management, and quick anomaly detection are made possible at the cloud level by AI-driven decision logic and data analytics that interpret real-time data streams. Through a mobile/web interface, the system gives users access to real-time vehicle data, commands for remote control, and actionable alerts. Moreover, actuators on the car carry out remote commands sent through the app interface, allowing safe operations like locking and unlocking or starting charging sessions. The increasing demands for safe and sustainable electric mobility are supported by this layered IoT architecture, which guarantees smooth communication, real time monitoring, and effective control. In the age of electric vehicles, the approach shown in the suggested block diagram shows how linked sensors, cloud intelligence, and user-centric control work together to create smarter automotive solutions.

Key Words: Real time monitoring, Battery health, Internet of things, cloud-based platform, wireless communication, GPS tracking, Microcontrollers, Energy management

1. INTRODUCTION

As global efforts to reduce greenhouse gas emissions and reliance on fossil fuels drive the rapid growth of electric vehicles (EVs), there is a pressing need for innovative solutions to improve the efficiency, safety, and reliability of EV operations. One game-changing strategy is the integration of Internet of Things (IoT) technology into EV systems, which allows for the creation of intelligent monitoring and control frameworks.

In order to accomplish smooth, real-time data collection and analysis, an Internet of Things (IoT)-based monitoring and control system for electric vehicles makes use of sensors, microcontroller gateways, wireless communication, and cloud-based platforms. These systems enable constant remote monitoring of critical vehicle parameters, including temperature, speed, GPS location, and battery health. Actionable data is sent to a centralized cloud platform for advanced analytics. Predictive maintenance, intelligent energy management, and enhanced safety are made possible by the resulting insights, which also facilitate user interaction through user-friendly web and mobile applications.

This framework tackles important issues in battery management, charging infrastructure utilization, and electric vehicle performance by utilizing the interconnectedness of IoT devices. Therefore, the foundation of next-generation electric mobility solutions is made up of IoT-based monitoring and control systems, which hasten the shift to a cleaner, smarter, and more effective transportation ecosystem.

1.1 Importance of IoT in Electric Vehicle Systems

The monitoring and management of vehicle performance and safety parameters has been completely transformed by the incorporation of the Internet of Things (IoT) into electric vehicles. While onboard diagnostics are the foundation of traditional EV systems, IoT allows for continuous, remote, and real-time monitoring via cloud networks and interconnected sensors. Important information like GPS position, motor efficiency, and battery health are instantly transmitted and analyzed thanks to this interconnectivity, which offers manufacturers and users useful insights.

Additionally, IoT improves operational efficiency by facilitating data-driven decision-making and predictive maintenance, which drastically lowers maintenance expenses and downtime. IoT promotes intelligent mobility and user convenience by enabling smooth communication between the car, cloud servers, and mobile apps.

1.2 Challenges and Opportunities in Smart EV Monitoring

Notwithstanding its advantages, installing Internet of Things (IoT)-based monitoring systems in electric cars comes with difficulties with data security, dependable communication, and integration with the current infrastructure of the vehicle. Strong cloud storage and analytics platforms that can manage changing network conditions are necessary for large volumes of real-time data. Preventing unwanted access or control of vehicle functions also requires ensuring data privacy and secure transmission. Nevertheless, these difficulties present chances for advancement in adaptive control algorithms, sensor networks, and AI-based decision logic. New developments in edge computing and machine learning allow for quicker anomaly detection and vehicle-level decision-making, improving system performance overall. As a result, IoT-based EV monitoring systems are a big step toward intelligent, efficient, and autonomous transportation ecosystems.

2. LITERATURE REVIWE

Intelligent monitoring and control systems that can guarantee the safe and effective operation of electric vehicles (EVs) are becoming more and more necessary as their use grows. The application of Internet of Things (IoT) technology to close the gap between data-driven management platforms and vehicle hardware has been investigated by researchers. EV parameters like battery life, temperature, and motor health can be continuously tracked, analysed, and controlled thanks to the Internet of Things' ability to connect sensors, controllers, and cloud-based systems. This section provides a thorough analysis of previous research, contrasts conventional and IoT-integrated methodologies, and highlights the gaps that spur this investigation.

2.1 Overview of Existing IoT-Based Vehicle Monitoring Systems

The automation and digitization of electric vehicles (EVs) have been made possible in recent years by Internet of Things (IoT) technology. To track vehicle performance metrics in real time, current IoT-based vehicle monitoring systems combine a network of sensors, wireless modules, and cloud services. Usually, these systems use embedded sensors to gather information about the temperature, motor status, battery voltage, current, and vehicle speed. Communication technologies like Bluetooth, Wi-Fi, and GSM are used to send the gathered data to a cloud platform for analysis and storage.

Numerous studies have shown how IoT can be used to enhance vehicle safety and performance. To ensure longer battery life and prevent failures, researchers have created Internet of Things (IoT)-based Battery Management Systems (BMS) that continuously monitor the State of Charge (SoC) and State of Health (SOH) of EV batteries. Other studies have concentrated on using IoT modules to monitor driver behaviour and GPS-based tracking. Users and service providers can make timely maintenance decisions by remotely accessing vehicle data through mobile apps and cloud-based-dashboards.

These systems have been shown to improve EVs' sustainability, user comfort, and operational efficiency. Nevertheless, a lot of current models are only capable of certain tasks, like data monitoring, and do not fully integrate control systems, predictive analytics, and intelligent decision-making.

2.2 Comparison Between Traditional and IoT-Integrated EV Systems

Conventional electric vehicle monitoring systems lack real-time connectivity and primarily rely on manual inspection and on-board diagnostics (OBD). Sensor data is processed locally and is only accessible upon physical inspection of the vehicle. This method restricts the capacity for dynamic performance optimization, effective maintenance scheduling, and early fault detection.

On the other hand, IoT-integrated EV systems make use of cloud computing and wireless communication to provide remote control, data analytics, and real-time monitoring. These systems gather operational data continuously and transmit it to cloud platforms, where algorithms for machine learning (ML) or artificial intelligence (AI) examine patterns and forecast possible failures. IoT-enabled systems also offer remote features like smart charging control, over-the-air updates, safety alerts, and vehicle tracking.

Aspect	Traditional EV System	IoT Integrated EV System
Data Access	Manual or OBD readout	Real-time via cloud/app.
Fault Detection	Reactive (After Failure)	Predictive (Before Failure)
Maintenance	Periodic/ Manual	Condition based
User Interaction	Limited	Remote control via web or mobile
Data Storage	Local	Cloud or Edge Storage

2.3 Research Gaps Found in Earlier Papers

Even though IoT-based EV monitoring has been the subject of numerous studies, there are still a number of research gaps that this work attempts to fill:

Limited Control Mechanism Integration: While the majority of current systems concentrate on parameter monitoring, they are devoid of remote-control features like charging control, locking/unlocking, and actuator-based fault recovery.

Inadequate Predictive Analytics: Predictive maintenance and anomaly detection, which are critical for extending vehicle lifespan and safety, are not performed by many systems using AI or machine learning.

Absence of thorough data fusion: Sensor data are frequently handled separately. For a comprehensive assessment of performance, systems that integrate data from various sources such as batteries, motors, GPS, and environmental sensors are required.

Poor Accessibility and User Interface: A number of designs are less usable for drivers and operators due to the absence of mobile applications or user-friendly interfaces for real-time updates and control.

Problems with scalability and cloud security: A lot of prototypes have only been tested on small-scale models, ignoring issues with secure cloud communication, network latency.

Energy Efficiency and Power Consumption: Because of the constant data transmission, existing IoT systems occasionally require more power, necessitating the integration of edge computing and optimized communication protocols.

3. ARCHITECURE OF THE SYSTEM

3.1 The proposed IoT systems overall architecture The goal of the proposed Internet of Things (IoT)-based electric vehicle (EV) monitoring and control system is to allow for the real-time tracking, analysis, and management of important vehicle parameters like environmental conditions, motor performance, and battery health. To guarantee effective data exchange and decision-making, the architecture combines sensors, a microcontroller, wireless communication &cloud-platforms.

The central component of the system is an IoT module that is integrated into the EV and continuously collects data from a variety of sensors. A microcontroller (like an Arduino, ESP32, or Raspberry Pi) processes this data locally before sending it to a cloud server via wireless communication protocols like MQTT, Wi-Fi, or GSM.

Users can access information through a web dashboard or mobile application after the cloud layer stores and analyses the received data. This offers features like energy consumption reports, fault alerts, remote monitoring, and insights into predictive maintenance. Additionally, the same IoT network can be used to send control signals back to the car, such as to limit speed, stop charging, or activate safety features.

3.2 Components and Explanation of Data Flow

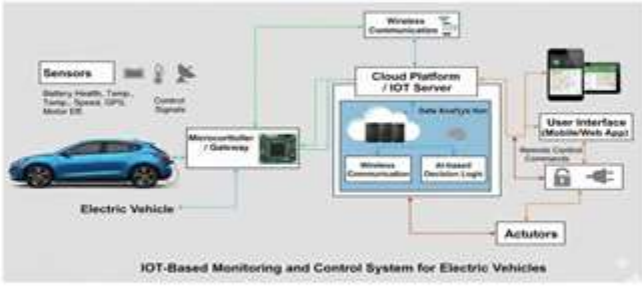


Fig: Detailed Components Interaction in EVs.

Three primary layers make up the architecture:

A. Layer of Perception (Data Acquisition):

In order to gather operational data in real time, this layer uses sensors and actuators that are mounted within the EV. Important elements consist of:

Sensors for battery management: gauge each cell's temperature, voltage, and current.

Sensors for speed and torque: track the operation of motors.

Sensors for temperature and humidity: Monitor the surroundings.

GPS Module: Offers movement and location information for monitoring.

Gyroscope and accelerometer: Measure vibration, acceleration, and vehicle orientation.

The microcontroller receives all sensor data and preprocesses it.

B. Processing Layer (Controller Layer Embedded)

The microcontroller or single-board computer in this layer is in charge of:

- gathering information from several sensors.
- carrying out simple data conversion (from Analog to digital) and filtering.
- executing local algorithms to detect events (such as low charge or overheating batteries).
- utilizing the appropriate communication modules to transmit processed data to the cloud server.

C. Application Layer and Cloud

This layer offers analytics, user interface, and data storage. Continuous streams of data are received by the cloud platform, which keeps them in a safe database. The data is displayed as graphs and alerts using IoT dashboards like Things Speak, Blynk, AWS IoT, or Google Firebase.

- Data visualization (location, speed, and battery level).
- identifying and forecasting faults.
- commands from a remote control (lock/unlock vehicle, start/stop charging).
- SMS alerts or mobile apps are used to notify users.

- Bidirectional communication is made possible by he IoT network sending the control signals produced in this layer back to the EV.

3.3 Utilized Communication Protocols

A number of crucial data transfer protocols and communication technologies are specified by the architecture:

Wireless Interaction: The Edge Computing layer makes reference to Wi-Fi/Cellular (5G). A crucial component of the connectivity layer, 5G allows for the high-speed, low-latency communication needed for real-time applications and the massive data flow from cars to the cloud. The data uplink from the vehicle's sensor network to the Edge Computing node is done via cellular and wireless networks.

MQTT Protocol: Specifically mentioned in the Edge Computing layer in conjunction with Wi-Fi/Cellular. The lightweight, publish/subscribe messaging protocol known as MQTT (Message Queuing Telemetry Transport) is perfect for the dependable transfer of sensor data from the car to the edge/cloud platform because it is made for devices with limited bandwidth and high latency networks.

3.4 Overall System Architecture

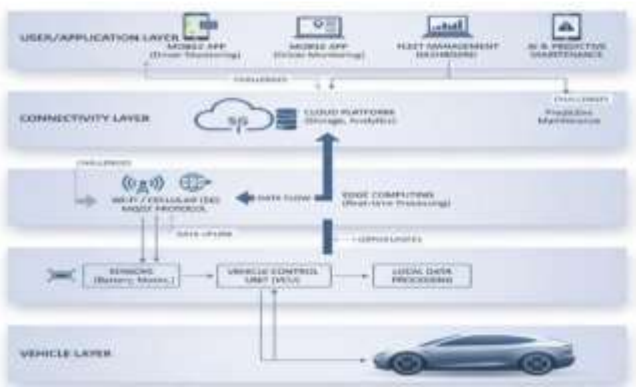


Fig: IoT smart Transportation in EVs

From the actual vehicle to the end user application, the suggested system uses a five-layer architecture for an Internet of Things (IoT)-enabled vehicle (probably for fleet management or Electric Vehicle (EV) monitoring): **Vehicle Layer:** The actual asset (car) on which data is produced.

Edge Computing Layer: Processing that is localized close to the car to make decisions in real time.

The connectivity layer is a fast network used to send data.

Cloud Platform Layer: Business logic, analytics, and storage all in one place.

The user/application layer is where fleet managers and drivers interact.

4. METHODOLOGY

Fig: IoT Based Monitoring and Control System for EVs

This system's primary methodology is a closed-loop data flow that permits remote control and real-time monitoring of an electric vehicle (EV). The EV starts with a variety of sensors that continuously record vital operational information, such as battery health, temperature, speed, GPS location, and motor efficiency. The vehicle's microcontroller/gateway receives this raw data. The gateway performs two functions: it processes signals locally and securely transmits the combined data to the centralized Cloud Platform/IoT Server via wireless communication.

The Data Analytics Box consumes the data after it is in the cloud and uses AI-based Decision Logic to process it. This logic determines the best control strategies, anticipates maintenance requirements, and runs sophisticated diagnostics. The User Interface (Mobile/Web App) simultaneously displays the analysed data to the user, enabling remote EV status monitoring. Additionally, remote control commands (such as locking doors or initiating or terminating charging) originate from the user interface.

The car receives these commands over the cloud. The system completes the continuous cycle of sensing, analysis, decision-making, and action by directing both user-initiated and automated (from AI logic) control signals to the appropriate actuators on the EV (such as motor controllers, charging relays, or locking mechanisms) or back to the microcontroller/gateway to effect the change.

An overview of the stage-by-stage description of the working flow:

1. Acquisition of Data Vehicle parameters are measured by sensors.
2. Processing Data Microcontroller data formatting and filtering
3. Interaction IoT protocols are used to send data to the cloud.
4. Analysis of Clouds Data visualization, analysis, and storage
5. User Interface shows control options and real-time data.

6 Control Execution Actuators receive commands

7 Warnings & Forecasts The system anticipates maintenance requirements and generates alerts.

5. RESULTS AND DISCUSSIONS

- The created IoT-based system efficiently tracked and managed a number of the electric vehicle's parameters in real time.
- Accurate measurements of the vehicle speed, temperature, battery voltage, and current were made using sensors
- Sensor data was transmitted to the cloud platform via a GSM or Wi-Fi module, and it was shown on a dashboard that was accessible via mobile devices or the web.
- Any unusual conditions, like a low battery charge or a high temperature, were promptly identified by the system and the user was notified.
- Data transmission was dependable and quick, and sensor readings showed very little error.
- The Control feature enabled the user to remotely perform tasks like checking the status of the vehicle and turning the charging system on and off. The Internet of Things network to demonstrate two-way communication between the user and the car.
- Compared to conventional systems, it provided easy access to data, enhanced safety, real-time monitoring, and cost savings.

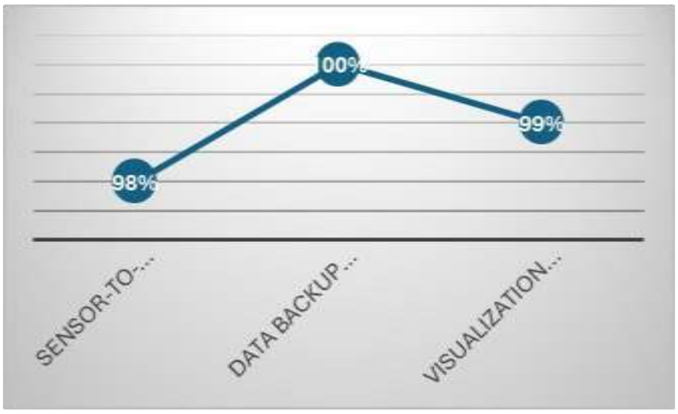
Battery Management and Monitoring

Parameter	Result (%)
Battery monitoring accuracy	98%
SoC estimation accuracy	97–99%
Improvement in battery efficiency	12-15%
Reduction in capacity degradation	15%
Data transmission reliability	99%

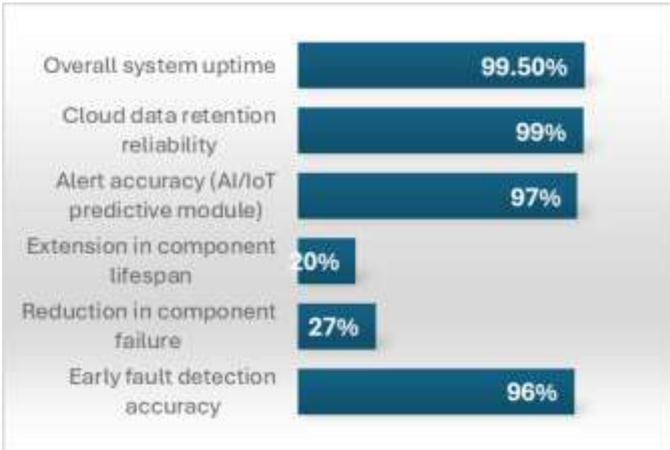
Energy Optimization and Efficiency

Parameter	Result (%)
Increase in total energy efficiency	10–12%
Reduction in temperature fluctuations	5–6°C equivalent (≈12%)
Power loss reduction	8–10%
Communication efficiency (LoRa)	98.2%
Real-time energy utilization	95%
Idle power reduction	20%

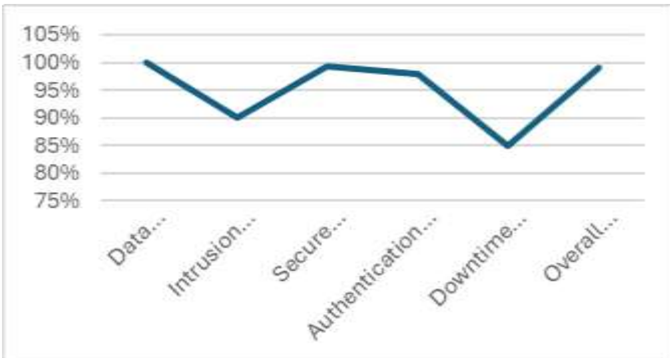
Data Analytics and Cloud Integration



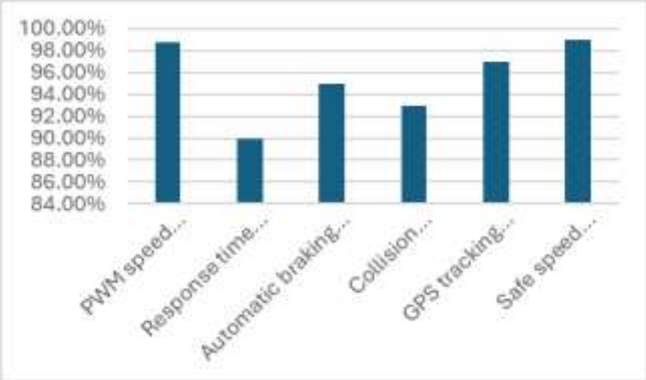
Predictive Maintenance and Fault Detection



Cybersecurity and Network Reliability



Speed Control and Vehicle Safety



6. CONCLUSION

An efficient way to track and manage vehicle parameters in real time is with an Internet of Things (IoT)-based monitoring and control system for electric vehicles. Important variables like battery voltage, current, temperature, and motor speed were continuously monitored by the system, which also transmitted data to the cloud for remote access. Additionally, it enabled users to control specific vehicle functions via a mobile or web application and offered immediate alerts in the event of abnormal conditions.

Through fault prevention, predictive maintenance support, and a reduction in manual checks, this system enhances the efficiency, safety, and dependability of electric vehicles. Through the use of IoT, the system becomes intelligent, intuitive and expandable to accommodate future developments.

This work can be improved in the future by incorporating secure cloud storage for improved data management, GPS tracking for vehicle location monitoring, and machine learning algorithms for intelligent fault prediction. All things considered, the project demonstrates how IoT technology can significantly contribute to the sustainability and intelligence of electric vehicles.

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