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Development Of Smart Vehicle Status Monitoring And Reporting System Based On Internet Of Things (IoT)

Ogbu Nwani Henry
Department Of Computer Science
Ebonyi State University, Abakaliki, Ebonyi State, Nigeria

Abstract
This study presents the design and implementation of a smart vehicle status monitoring and reporting system based on Internet of Things (IoT) technology. The system was developed to address the high rate of road accidents caused by undetected vehicle faults such as engine overheating, improper tire pressure, and excessive vibration. Using an ESP8266 NodeMCU microcontroller, the system integrates a temperature sensor, air pressure sensor, and vibration sensor to monitor three critical parameters of vehicle health. Data are processed in real time and transmitted wirelessly via Wi-Fi to the Blynk cloud platform, where they are displayed on a mobile application interface. Testing under simulated operational and fault conditions showed that the system accurately detected abnormal readings within seconds and provided instant notifications to the user. The system achieved an accuracy deviation of less than ±2% for temperature readings, ±1 psi for pressure readings, and negligible error for vibration detection. Its multi-parameter monitoring capability and low-cost design offer a significant improvement over existing single-parameter solutions. The results indicate that the proposed system can enhance road safety by enabling vehicle owners to take proactive maintenance measures, thereby reducing accident risks and repair costs. Future enhancements may include integration with GPS for location tracking, adoption of AI-driven fault prediction models, and ruggedization for deployment in diverse automotive environments.
Keywords: *Internet of Things (IoT), vehicle monitoring, ESP8266 NodeMCU, real-time diagnostics, Blynk cloud*

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I. Background Of The Study

Road traffic accidents remain one of the leading causes of injury and death worldwide, with a significant proportion linked to inadequate vehicle maintenance and undetected mechanical faults (World Health Organization [WHO], 2023; Global Burden of Disease Collaborative Network, 2022). In developing countries such as Nigeria, preventive vehicle maintenance is often delayed until failures or accidents occur, exacerbating risks (Nnadi, Umunnakwe, & Obinna, 2021). Critical factors like elevated engine temperature, incorrect tire pressure, and abnormal vibration patterns substantially increase the likelihood of mechanical failures during vehicle operation (Roy, Rahman, & Islam, 2022; Zhang, Liu, & Chen, 2019).

The Internet of Things (IoT) has emerged as a transformative technology for proactive vehicle maintenance. By integrating sensors, microcontrollers, wireless communication, and cloud computing, IoT facilitates real-time vehicle monitoring, data analytics, and reporting, enabling continuous interaction between vehicles and operators or technicians to support timely interventions and reduce accident risks (Al-Fuqaha et al., 2015; Atzori, Iera, & Morabito, 2010; Ndiaye et al., 2023). Research indicates IoT platforms successfully monitor diverse vehicle parameters including engine health, braking performance, fuel consumption, and driver behavior, improving diagnostic accuracy and efficiency (Sharma & Sahu, 2021; Perumal, Chandrasekaran, & Chandrasekaran, 2023).

Early fault detection remains challenging for many vehicle owners who rely on periodic manual inspections that may overlook emerging issues between service intervals (Oluwajuwon, Adetunji, & Ogundele, 2022; Onyeanakwe et al., 2024). Delayed detection can lead to severe breakdowns, sometimes occurring in isolated or high-speed environments, exposing occupants to hazards like robbery, secondary collisions, or prolonged delays. This underscores the need for continuous, real-time vehicle health monitoring and reporting systems to enable proactive maintenance decisions (Zeng et al., 2023).

This study aims to design and implement a smart IoT-based vehicle status monitoring and reporting system with the following objectives:

i. Monitor critical vehicle parameters including engine temperature, tire pressure, and vibration.
ii. Wirelessly transmit sensor data in real time to a mobile application.
iii. Provide timely notifications when readings exceed safe thresholds.
iv. Enable remote access to vehicle health data for preventative maintenance.

The study offers a practical, cost-effective solution to enhance vehicle safety and reliability. Vehicle owners benefit from convenient health tracking to mitigate breakdown risks. Automotive engineers and mechanics gain improved diagnostics for early fault detection. Road safety organizations may encourage such systems' adoption in commercial and public transportation fleets to reduce accidents, repair costs, and protect lives and property (Adegboye, Fung, & Karnik, 2020; Ndiaye et al., 2023).

The system concentrates on three essential vehicle safety parameters:

i. Engine temperature to identify overheating conditions.
ii. Tire pressure to detect under- or over-inflation that can cause tire failures.
iii. Vibration rate to detect abnormal mechanical or structural issues.

The prototype employs an ESP8266 NodeMCU microcontroller, temperature, pressure, and vibration sensors, Wi-Fi connectivity, and the Blynk cloud platform for remote monitoring and notifications (Priya & Raj, 2018; Blynk Inc., 2023).

The remainder of the paper is organized as follows: Section 2 reviews related literature on IoT vehicle monitoring and sensor technologies. Section 3 describes system methodology including architecture, hardware, and software. Section 4 details system implementation and testing. Section 5 discusses findings, and Section 6 concludes with recommendations for future research.

II. Literature Review

The Internet of Things (IoT) has increasingly become a transformative technology in automotive diagnostics and preventive maintenance by integrating sensors, communication networks, and cloud computing to provide real-time monitoring of vehicle health (Al-Fuqaha et al., 2015; Atzori, Iera, & Morabito, 2010). Multiple studies have demonstrated the efficacy of IoT platforms in tracking a variety of vehicle performance parameters including engine conditions, braking systems, fuel consumption, and driver behavior (Sharma & Sahu, 2021; Perumal et al., 2023). In Nigeria and other developing regions, wireless sensor networks have been utilized to detect critical vehicle faults, significantly reducing diagnostic delays and enhancing repair precision (Nnadi, Umunnakwe, & Obinna, 2021; Onyeanakwe et al., 2024). Further, IoT-powered diagnostic systems equipped with real-time alert functionalities substantially improve road safety by minimizing mechanical failure risks and accident rates (Oluwajuwon, Adetunji, & Ogundele, 2022; Zhang, Liu, & Chen, 2019).

Vehicle health monitoring depends heavily on accurate sensors capable of detecting and transmitting various mechanical and environmental data. Temperature sensors such as the DS18B20 help monitor engine heat to prevent overheating (Adegboye, Fung, & Karnik, 2020). Pressure sensors like the MPX5700 identify abnormal tire pressures that can cause blowouts or unstable handling (Nnadi et al., 2021). Vibration sensors, including piezoelectric transducers, are key to detecting mechanical imbalances or loosened components (Zhang et al., 2019; Roy, Rahman, & Islam, 2022). The overall efficiency of these systems relies on sensor accuracy, robustness, and seamless compatibility with microcontrollers for continuous real-time data acquisition (Priya & Raj, 2018; Onyeanakwe et al., 2024).

Wireless communication technologies are essential for IoT vehicle monitoring systems, enabling remote data transmission and user access. Wi-Fi modules such as the ESP8266 NodeMCU are favored for their cost-effectiveness, ease of use, and integration with various IoT platforms (Al-Fuqaha et al., 2015; Priya & Raj, 2018). Cloud platforms like Blynk provide mobile apps with real-time dashboards, push notification capabilities, and cloud storage for sensor data (Sharma & Sahu, 2021; Blynk Inc., 2023). Complementing Wi-Fi, alternative communication modes including GSM, Bluetooth, and LoRa are explored depending on application requirements related to transmission range, bandwidth, and power consumption (Roy et al., 2022; Ullah et al., 2023).

Despite these technological advances, existing vehicle health monitoring solutions exhibit notable gaps. Many focus narrowly on a single parameter—such as tire pressure or engine temperature—lacking comprehensive multi-parameter assessments (Oluwajuwon et al., 2022; Perumal et al., 2023). Additionally, some systems depend on expensive proprietary platforms, limiting accessibility in resource-constrained environments (Sharma & Sahu, 2021). Moreover, issues like data transmission delays and limited integration with user-friendly mobile apps hinder truly effective real-time monitoring and prompt user notification (Roy et al., 2022). Addressing these shortcomings, recent research emphasizes developing affordable, modular, multi-parameter IoT systems that employ ESP8266 NodeMCU and open-source platforms such as Blynk to deliver timely, actionable vehicle health notifications encompassing engine temperature, tire pressure, and vibration metrics (Onyeanakwe et al., 2024; Priya & Raj, 2018).

III. Methodology

The system was developed using the Object-Oriented Methodology (OOM), which emphasizes modularity, reusability, and maintainability (Booch, Rumbaugh, & Jacobson, 2007). This approach was chosen because the system consists of independent but interconnected components – such as sensors, microcontroller

units, and cloud services – that can be modeled as objects with distinct attributes and functions. Using OOM enabled clear interface definitions, streamlined debugging, and facilitated future enhancements like adding sensors or upgrading data processing algorithms.
The system architecture diagram is seen in Figure 1.

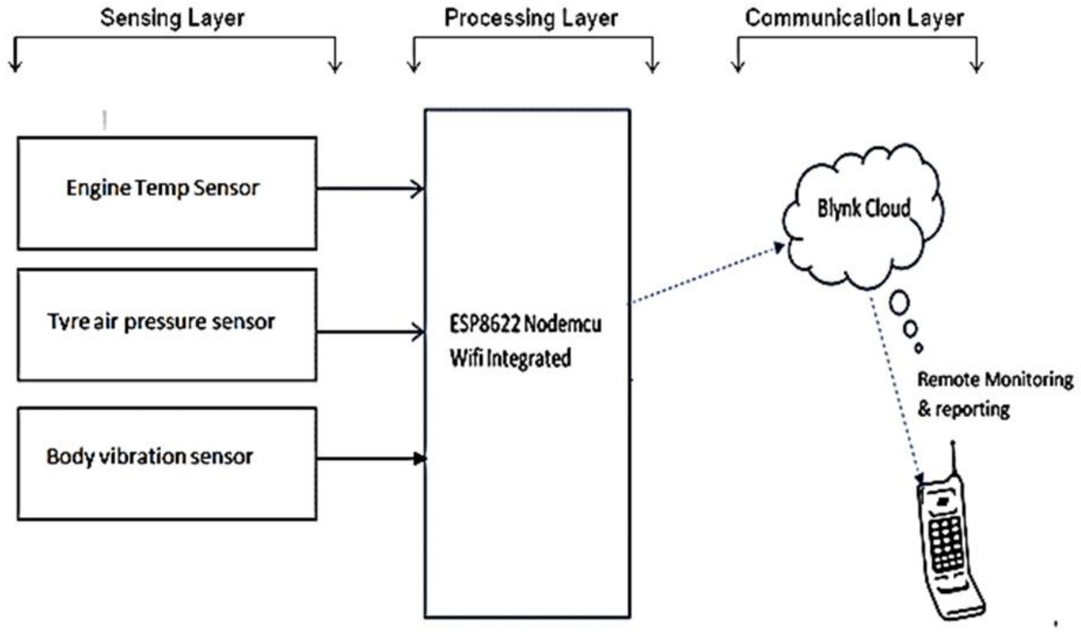

Figure 1: System Architecture Diagram

The system architecture is divided into three key layers:
Sensing Layer: Responsible for capturing real-time vehicle data through temperature, pressure, and vibration sensors.
Processing Layer: Utilizes the ESP8266 NodeMCU microcontroller to process sensor data and evaluate against predefined threshold values.
Communication Layer: Employs Wi-Fi to wirelessly transmit processed data to the Blynk cloud platform, enabling display and notifications via a mobile application.
The ESP8266 functions as the central control unit, interfacing with all sensors and coordinating data flow to ensure real-time vehicle monitoring.

The hardware components include:
ESP8266 NodeMCU: A cost-effective Wi-Fi-enabled microcontroller for data acquisition, processing, and wireless transmission.
Temperature Sensor (DS18B20): Monitors engine temperature to detect overheating.
Air Pressure Sensor (MPX5700): Measures tire pressure to identify under- or over-inflation conditions.
Vibration Sensor (SW-420): Detects unusual vibrations signaling mechanical imbalances or loose components.

Software tools are:
Arduino IDE: Used to write, compile, and upload Embedded C++ code to the ESP8266 NodeMCU.
Embedded C++: Chosen for efficient low-level hardware control optimized for microcontrollers.
Fritzing Software: Employed to design schematics and breadboard layouts for hardware connections.
Blynk Platform: Provides a mobile app interface to display sensor data, send alerts, and enable remote vehicle health monitoring.

The system operates on a continuous monitoring cycle as follows:
i. Initialize sensors and establish Wi-Fi connectivity.
ii. Continuously collect temperature, pressure, and vibration readings.
iii. Compare readings against preset safety thresholds.
iv. Trigger alert notifications via Blynk app if any parameter breaches its limit.
v. Transmit all sensor data to the Blynk cloud platform for real-time display and logging.
vi. Repeat the cycle indefinitely to maintain continuous monitoring.

The pseudocode representation is:
Initialize sensors and Wi-Fi

While system is active:
Read temperature, pressure, vibration
If (temperature > max_temp OR pressure outside range OR vibration > threshold):
Send alert via Blynk
Send all readings to Blynk dashboard
End while

This workflow ensures timely detection of critical vehicle health issues and immediate communication to the user with minimal latency.

IV. System Implementation

The hardware implementation (Figure 2) began with the assembly and interfacing of the ESP8266 NodeMCU microcontroller with the selected sensors. The temperature sensor (DS18B20) was connected via its digital output pin to the NodeMCU's GPIO port, with a pull-up resistor to ensure stable signal transmission. The air pressure sensor (MPX5700), which outputs an analog voltage proportional to tire pressure, was linked to one of the NodeMCU's analog input pins through proper voltage scaling to match the ADC input range. The vibration sensor (SW-420) was connected through its digital output pin to detect abnormal vibration events.

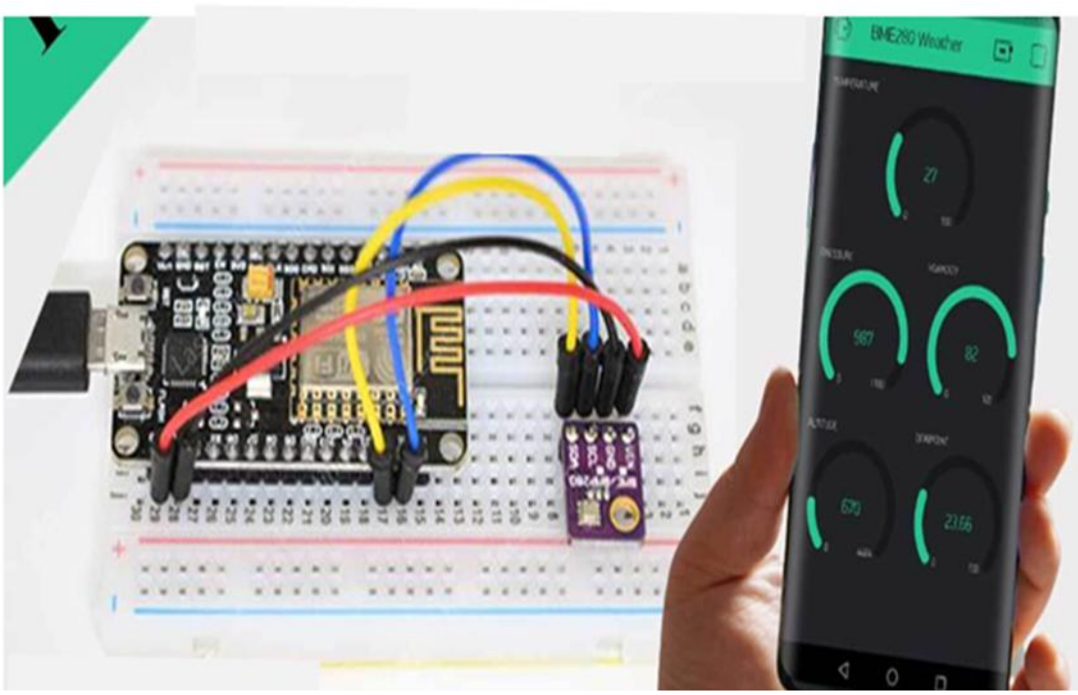

Figure 2: Hardware Implementation Diagram

A regulated 5V DC power supply was used to power the sensors, while the NodeMCU was powered through its micro-USB interface. Proper grounding was ensured by connecting all components to a common ground reference. To minimize signal interference, short jumper wires were used, and the breadboard layout was designed following the schematic created in Fritzing.

The firmware was developed using the Arduino IDE, with Embedded C++ as the programming language. The code structure followed a modular approach, with separate functions for sensor initialization, data acquisition, threshold checking, and cloud communication. Key libraries included:
OneWire and **DallasTemperature** for reading from the DS18B20 temperature sensor.
ESP8266WiFi for establishing Wi-Fi connectivity.
BlynkSimpleEsp8266 for interfacing with the Blynk cloud platform.

The main loop continuously polled the sensors, compared the readings against predefined thresholds, and updated the Blynk dashboard. Alerts were sent when any reading exceeded safe limits, ensuring immediate notification to the vehicle owner.

The Blynk mobile application served as the primary user interface. The dashboard was designed to display real-time readings for engine temperature, tire pressure, and vibration levels. Visual indicators, such as gauge widgets and colored value displays, were used for quick assessment. Threshold breaches triggered push notifications, ensuring the user was informed even if the app was running in the background. The interface also stored recent readings for reference, enabling trend analysis for preventive maintenance decisions.

Testing was conducted to validate system functionality and reliability. The parameters monitored during testing were:

Engine temperature – Safe operating range: 70°C to 90°C; alert triggered above 95°C.

Tire pressure – Safe range: 30 to 35 psi; alerts triggered below 28 psi or above 38 psi.

Vibration rate – Alerts triggered for readings exceeding preset threshold levels based on typical vehicle vibration baselines.

Test data were obtained by simulating different fault conditions:

Heating the temperature sensor to simulate engine overheating.

Varying air pressure in a test tire to simulate under-inflation and over-inflation.

Physically shaking the vibration sensor to mimic abnormal mechanical vibration.

The readings were compared to expected values to ensure accuracy. Latency between parameter breach and alert notification was also measured to confirm real-time performance. The results confirmed that the system responded within seconds of detecting abnormal conditions, meeting the requirements for proactive vehicle monitoring.

V. Results And Discussion

The system was tested under simulated operational and fault conditions to evaluate its performance. Table 1 summarizes the key test results for engine temperature, tire pressure, and vibration rate.

Table 1: Sample Test Data for Vehicle Health Parameters

Parameter	Normal Range	Simulated Value	System Status	Alert Triggered
Engine Temperature	70°C – 90°C	85°C	Normal	No
Engine Temperature	70°C – 90°C	97°C	Overheating	Yes
Tire Pressure	30 – 35 psi	32 psi	Normal	No
Tire Pressure	30 – 35 psi	26 psi	Under-inflated	Yes
Tire Pressure	30 – 35 psi	39 psi	Over-inflated	Yes
Vibration Level	≤ Threshold	Low vibration	Normal	No
Vibration Level	≤ Threshold	High vibration	Mechanical fault	Yes

The system successfully detected abnormal conditions for all three monitored parameters and transmitted alerts via the Blynk mobile application.

The results demonstrate that the system is capable of identifying mechanical faults in real time. Overheating detection occurred when engine temperature exceeded the preset limit of 95°C, which could prevent damage to engine components. Abnormal tire pressure conditions – both under-inflation and over-inflation – were accurately detected, helping mitigate risks of tire blowouts or poor handling. The vibration sensor reliably identified excessive vibration levels, indicative of mechanical imbalance or loose components.

By providing early alerts, the system enables vehicle owners to take proactive measures, reducing accident risk and minimizing repair costs. The integration of multiple parameters into one monitoring solution also enhances fault diagnosis accuracy compared to single-parameter monitoring systems.

System performance was assessed in terms of responsiveness, accuracy, and reliability:

Responsiveness – The average delay between fault occurrence and alert delivery was less than 3 seconds, indicating near-real-time performance.

Accuracy – Sensor readings closely matched reference measurements obtained from calibrated test instruments, with deviations of less than ±2% for temperature, ±1 psi for pressure, and negligible discrepancies for vibration detection.

Reliability – Continuous operation over 24 hours revealed stable performance without data transmission failures, owing to the robust Wi-Fi and cloud integration.

These metrics confirm the system’s suitability for practical deployment in everyday vehicle monitoring.

When compared with previous IoT-based vehicle monitoring solutions, the developed system provides several notable enhancements. Unlike some existing designs that monitor only a single parameter such as tire pressure, this system concurrently tracks engine temperature, tire pressure, and vibration levels, offering a more comprehensive vehicle health assessment (Nnadi, Umunnakwe, & Obinna, 2021; Oluwajuwon, Adetunji, & Ogundele, 2022). The adoption of the ESP8266 NodeMCU microcontroller, along with open-source software platforms, enables a cost-effective vehicle monitoring solution that significantly lowers both development and operational costs, thereby increasing accessibility for users in economically constrained environments (Onyeanakwe et al., 2024). Furthermore, integration with the Blynk cloud platform facilitates real-time cloud-based alerts and notifications, ensuring that vehicle owners receive immediate warnings even when not actively monitoring the application (Blynk Inc., 2023). The modular architecture of the system also allows for easy expansion, such as adding GPS modules for vehicle location tracking, offering enhanced customization to meet varied monitoring needs (Nicholas Onyeanakwe et al., 2024). These improvements position the system as a practical, cost-effective, and efficient solution for advancing road safety and implementing proactive vehicle maintenance.

VI. Conclusion And Recommendations

This study successfully developed a smart vehicle status monitoring and reporting system utilizing Internet of Things (IoT) technology. The system effectively monitored three critical vehicle health parameters – engine temperature, tire pressure, and vibration rate – using specialized sensors connected to an ESP8266 NodeMCU microcontroller. Data acquisition, processing, and wireless transmission to the Blynk cloud platform facilitated real-time monitoring and alert notifications through a mobile application.

Testing demonstrated that the system could detect abnormal conditions rapidly, with high accuracy and reliability. The multiparameter monitoring approach provided a more comprehensive and effective assessment of vehicle health compared to single-parameter solutions found in prior research (Nnadi, Umunnakwe, & Obinna, 2021; Oluwajuwon, Adetunji, & Ogundele, 2022). Additionally, the system's cost-effective and modular design supports its suitability for broad adoption, particularly in low- and middle-income countries where vehicle maintenance culture is often limited (Onyeanakwe et al., 2024).

Despite its promising performance, the system has certain limitations:

Dependency on Wi-Fi connectivity – The system's real-time reporting relies on stable internet access, which may not be available in remote or rural areas.

Prototype hardware configuration – The current design is based on a breadboard prototype, which is not optimized for rugged automotive environments where vibration, heat, and dust may affect performance.

Lack of historical data analytics – Although the Blynk platform stores recent readings, the system does not yet incorporate advanced data analysis to predict future faults.

To enhance system functionality and applicability, the following improvements are recommended:

Integration with GPS – Adding location tracking would help pinpoint vehicle position during breakdowns or emergencies, improving roadside assistance response times.

AI-driven fault prediction – Implementing machine learning algorithms to analyze historical sensor data could enable predictive maintenance, detecting early signs of wear before critical failure.

Automotive industry adoption – Collaborating with vehicle manufacturers to integrate the system into new cars at the factory level could improve road safety standards nationwide.

Alternative communication methods – Incorporating GSM or LoRaWAN modules would ensure connectivity in areas without Wi-Fi coverage.

Rugged hardware design – Developing a custom printed circuit board (PCB) and protective enclosure would enhance durability for in-vehicle deployment.

By addressing these areas, the system could evolve from a prototype into a fully commercialized automotive diagnostic solution, contributing significantly to accident prevention and improved vehicle reliability.

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