

IOT-Based Vehicle Fuel Theft Detection and Alert System Using ESP32 and Blynk Application

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Abstract

Fuel is an essential resource used in vehicles, industries, generators, and agricultural machinery. The increasing cost of fuel has led to a rise in fuel theft incidents, causing significant financial losses to vehicle owners and transport organizations. Traditional fuel monitoring methods rely on manual inspection and cannot provide immediate detection of unauthorized fuel removal. To overcome these limitations, this paper proposes an IoT-Based Vehicle Fuel Theft Detection and Alert System using an ESP32 microcontroller, fuel flow sensor, LCD display, buzzer, and Blynk mobile application. The system continuously monitors fuel movement and compares it with the engine status to identify abnormal fuel flow. When suspicious fuel activity is detected, the system generates instant alerts through a mobile application and activates an audible alarm. The proposed solution offers real-time monitoring, improved fuel security, reduced fuel losses, and remote accessibility. Experimental results demonstrate the effectiveness of the system in detecting fuel theft and providing timely notifications to users.

Keywords: *Internet of Things (IoT); Fuel Theft Detection; ESP32; Flow Sensor; Blynk Application; Vehicle Security; Real-Time Monitoring.*

1. INTRODUCTION

Fuel remains one of the most critical and costly resources consumed globally across transportation, agriculture, power generation, and industrial sectors. With escalating fuel prices and growing demand, incidents of fuel theft have become increasingly prevalent. Fleet operators, logistics companies, and individual vehicle owners face enormous financial burdens due to unauthorized fuel removal, which often goes undetected until significant quantities have been stolen.

Conventional fuel monitoring approaches—such as manual dipstick readings and periodic visual inspections—are inadequate in the context of modern operational requirements. These methods are not only time-consuming but also fail to provide real-time detection of theft events. The absence of immediate alert mechanisms means that theft incidents are often discovered too late, rendering preventive action impossible.

The advent of the Internet of Things (IoT) has opened new avenues for intelligent and automated monitoring systems. IoT-enabled devices can continuously collect, process, and communicate sensor data over wireless networks, enabling remote supervision and timely response. The ESP32 microcontroller, in particular, has emerged as a powerful, cost-effective platform for developing embedded IoT applications owing to its integrated Wi-Fi and Bluetooth capabilities, dual-core processor, and extensive peripheral support.

This paper proposes an IoT-Based Vehicle Fuel Theft Detection and Alert System that leverages the ESP32 microcontroller, a fuel flow sensor, an LCD display, and a buzzer, integrated with the Blynk mobile platform. The system monitors fuel flow in real time, correlates it with engine operational status, and triggers audible and mobile notifications upon detection of anomalous fuel movement. The proposed system aims to provide an affordable, reliable, and scalable solution to the growing problem of fuel theft.

The remainder of this paper is organized as follows: Section 2 reviews related literature; Section 3 describes the system architecture and methodology; Section 4 details the hardware and software components; Section 5 presents experimental results; Section 6 discusses the findings; and Section 7 concludes the paper.

2. LITERATURE REVIEW

Numerous studies have been conducted on fuel monitoring and theft prevention using embedded systems and IoT technologies. Early approaches relied primarily on mechanical flow meters and manual record-keeping, which proved ineffective against determined adversaries.

Researchers have explored GSM-based fuel monitoring systems that send SMS alerts to vehicle owners upon detection of abnormal fuel levels [1]. While functional, such systems suffer from latency issues and lack real-time dashboard capabilities. GPS-integrated systems have also been proposed to track vehicle location alongside fuel consumption, enabling fleet managers to detect anomalies during transit [2].

More recent work has introduced microcontroller-based systems using Arduino and Raspberry Pi platforms coupled with ultrasonic and capacitive fuel-level sensors [3]. These systems improved detection accuracy but were often constrained by limited wireless connectivity and the absence of dedicated mobile applications for remote monitoring.

The introduction of cloud-connected IoT platforms such as Blynk, ThingSpeak, and Firebase has significantly enhanced the capabilities of remote monitoring systems. Kale et al. [4] demonstrated a Blynk-integrated fuel management system that provided real-time data visualization but did not incorporate theft detection logic based on engine state correlation. Patil and Deshmukh [5] proposed a flow sensor-based system with GSM alerts, but lacked cloud connectivity and mobile app support.

The present work addresses the gaps identified in prior research by combining engine-state-aware theft detection logic with real-time IoT cloud connectivity, an audible alarm, and a Blynk-based mobile dashboard, providing a more comprehensive and responsive solution.

3. SYSTEM ARCHITECTURE AND METHODOLOGY

3.1 Overall Architecture

The proposed system consists of three major layers: (i) the sensing layer, comprising the fuel flow sensor and engine status input; (ii) the processing layer, centered on the ESP32 microcontroller; and (iii) the communication and alert layer, involving the Blynk mobile application, buzzer, and LCD display.

The ESP32 continuously reads pulse signals from the YF-S201 flow sensor to compute instantaneous fuel flow rate. Simultaneously, it monitors the engine status (ON/OFF) via a digital input signal. The system applies a rule-based detection algorithm: if fuel flow is detected while the engine is OFF, or if the flow rate deviates abnormally from the expected consumption profile during engine operation, a theft event is flagged.

3.2 Detection Algorithm

The theft detection logic operates as follows:

1. Read fuel flow rate $F(t)$ from the flow sensor at time t .
2. Read engine status $E(t)$: 1 = ON, 0 = OFF.
3. If $E(t) = 0$ and $F(t) > \text{threshold_idle}$, raise THEFT_ALERT.
1. If $E(t) = 1$ and $F(t) > \text{threshold_engine_on} \times \text{safety_factor}$, raise THEFT_ALERT.
2. On THEFT_ALERT: activate buzzer, update LCD message, push notification via Blynk.

Threshold values are configurable and can be calibrated for specific vehicle types and fuel systems.

3.3 Communication Flow

The ESP32 connects to a Wi-Fi access point and communicates with the Blynk cloud server via the Blynk IoT protocol. Virtual pins are mapped to sensor data streams and alert flags. The Blynk mobile application subscribes to these virtual pins, rendering live data and push notifications on the user's smartphone in near real time (latency < 1 second under normal network conditions).

4. SYSTEM COMPONENTS

4.1 Hardware Components

Table 1 lists the hardware components employed in the proposed system.

Table 1. Hardware Components

Component	Model / Specification	Quantity	Function
Microcontroller	ESP32 (Dual-core, 240 MHz)	1	Central processing & Wi-Fi
Flow Sensor	YF-S201 (1–30 L/min)	1	Measure fuel flow rate
LCD Display	16×2 I2C LCD	1	Local status display
Buzzer	Active Buzzer 5V	1	Audible theft alarm
Power Supply	12V / 5V DC Adapter	1	System power
Relay Module	5V Single-channel Relay	1	Engine status input interface

4.2 Software and Platform

The firmware was developed using the Arduino IDE (v2.x) with the ESP32 board support package. The Blynk IoT library (v1.x) was used for cloud connectivity. The YF-S201 sensor interface was implemented using hardware interrupt routines to accurately count flow pulses and calculate the volumetric flow rate using the sensor's calibration factor ($F = 7.5 \times Q$ pulses/sec, where Q is flow in L/min).

The Blynk mobile application was configured with a dashboard containing: (i) a real-time gauge for fuel flow rate, (ii) an LED indicator for engine status, (iii) an event log for theft alerts, and (iv) push notification settings.

5. EXPERIMENTAL RESULTS

The system was evaluated under three operational scenarios to verify detection accuracy and response time: (i) normal engine-on fueling, (ii) unauthorized fuel removal with engine off, and (iii) abnormal flow during engine operation simulating siphoning.

Table 2 summarizes the experimental test cases and outcomes.

Table 2. Experimental Test Results

No.	Test Scenario	Engine Status	Flow Rate (L/min)	Alert Triggered	Response Time (s)
1	Normal operation	ON	2.1	No	—
2	Theft (engine OFF)	OFF	1.8	Yes	< 2
3	Theft (engine ON, excess flow)	ON	9.5	Yes	< 2
4	System idle, no flow	OFF	0.0	No	—
5	Authorized refueling	OFF*	3.2	No**	—

* Engine OFF with authorized override input active. ** Override suppresses alert during authorized refueling.

The system achieved a 100% detection rate across all theft simulation trials, with an average alert response time of under 2 seconds from the moment of anomalous flow detection to receipt of the Blynk push notification on the test smartphone. No false positives were recorded when the authorized override was activated during legitimate refueling.

The buzzer alarm activated within 500 ms of threshold crossing, providing an immediate on-site deterrent, while the LCD display updated instantaneously to show the THEFT DETECTED message. The Blynk dashboard reflected live sensor readings at approximately 1-second intervals.

6. DISCUSSION

The experimental results confirm that the proposed system reliably identifies unauthorized fuel removal under both engine-off and engine-on conditions. The use of engine status as a contextual signal alongside flow rate data significantly reduces false alarm rates compared to flow-sensor-only approaches reported in prior work.

The Blynk platform proved effective for real-time remote monitoring, offering low-latency push notifications and an intuitive mobile dashboard without requiring custom server infrastructure. This makes the system highly accessible for deployment by individual vehicle owners and small fleet operators alike.

The main limitation of the current implementation is its dependence on Wi-Fi connectivity. In areas with poor network coverage, alert delivery may be delayed. Future iterations of the system will incorporate GSM/4G fallback communication to ensure uninterrupted alert capability. Additionally, integration of machine learning-based anomaly detection could further enhance the system's ability to differentiate between normal consumption variations and theft events.

The overall cost of the hardware prototype is estimated at under USD 20, making it a cost-effective alternative to commercial fleet telematics solutions, which typically cost several hundred dollars per vehicle.

7. CONCLUSION

This paper presented an IoT-Based Vehicle Fuel Theft Detection and Alert System using an ESP32 microcontroller, YF-S201 fuel flow sensor, LCD display, buzzer, and Blynk mobile platform. The system continuously monitors fuel flow in correlation with engine status and triggers real-time alerts upon detection of suspicious activity.

Experimental evaluation demonstrated 100% detection accuracy across simulated theft scenarios with an average alert response time of under 2 seconds. The system's low hardware cost, ease of deployment, and remote accessibility make it a practical solution for addressing fuel theft in vehicles, generators, and industrial equipment.

Future work will focus on incorporating GSM/4G backup communication, GPS-based location tracking, machine learning-based anomaly detection, and cloud-based analytics for long-term fuel consumption profiling.

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