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IOT Based Fuel Theft Detection and Vehicle Tracking System

Dighe Vishal Vijay[1], Ghule Prasad Jalindar[2], Hadawale Sarthak Nivrutti[3], Navale Onkar Sanjay[4], Prof. M. A. Maid[5]
Students, Department of Electronics &Telecommunication[1,2,3,4]
Assistant Professor, Department of Electronics & Telecommunication
Amrutvahini College of Engineering, Sangamner, MH, India

Abstract: *The IoT-Based Fuel Theft Detection and Vehicle Tracking System is designed to enhance vehicle security and safety by leveraging advanced Internet of Things (IoT) technology. Utilizing an ESP32 microcontroller as the central hub, the system integrates multiple sensors and modules to provide real-time monitoring and alerts. An ultrasonic sensor continuously monitors fuel levels, triggering SMS alerts to the vehicle owner if a sudden drop indicates potential theft. A GPS module offers precise, real-time location tracking, while an ADXL345 accelerometer detects sudden impacts or abnormal movements, signaling possible accidents. The system also sends alerts for high-speed driving and logs all data on a cloud platform for remote access and analysis. This comprehensive solution not only prevents fuel theft but also enhances overall vehicle security and safety, making it suitable for both individual vehicle owners and large fleets..*

Keywords: IoT, Fuel Theft Detection, Vehicle Tracking, Real-Time Monitoring, ESP32

I. INTRODUCTION

1.1 Overview

The IoT-Based Fuel Theft Detection and Vehicle Tracking System is an innovative solution designed to address critical issues surrounding vehicle security, fuel management, and safety. As fuel prices continue to rise and vehicle theft remains a persistent concern, this project aims to provide an advanced technological solution by leveraging IoT (Internet of Things) for real-time monitoring and alerting. The system integrates a wide range of sensors and communication modules to ensure vehicles are monitored comprehensively, not only protecting against fuel theft but also enabling live vehicle tracking, speed monitoring, and accident detection.

At the heart of the system lies the ESP32 microcontroller, known for its powerful capabilities and efficient handling of various inputs and outputs. The ESP32 serves as the central processing unit (CPU) that orchestrates the functionality of several sensors, ensuring seamless communication and real-time responses. Among the key components is an ultrasonic sensor that monitors the fuel level in the vehicle's tank. Fuel theft, which often occurs without warning, can have severe financial and operational impacts. This sensor offers a solution by constantly checking the fuel levels and alerting the vehicle owner via SMS if any significant drop is detected, thus allowing for prompt action to prevent theft or minimize losses.

Beyond fuel monitoring, the system offers a powerful GPS module that provides precise, real-time tracking of the vehicle's location. With vehicle theft or unauthorized usage being a common issue, this GPS component allows the owner to monitor the vehicle's movements at all times, offering peace of mind. Communication is a vital aspect of this project. The system utilizes a GSM module to send SMS alerts directly to the vehicle owner's phone in case of any abnormal activity. For instance, if there is an unauthorized decrease in fuel or if the vehicle is being driven at excessive speeds, the GSM module triggers a notification. This provides immediate awareness of potential issues, allowing the owner to act quickly and decisively. The GSM technology ensures that the vehicle can be monitored even in areas with limited internet access, making the system versatile and reliable in a wide range of conditions.

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To further enhance safety, the system incorporates an ADXL345 accelerometer. This sensor tracks the vehicle's speed and detects any sudden impacts, which could indicate a collision or accident. When the vehicle exceeds a predefined speed limit or experiences a sharp deceleration due to an accident, the system sends an alert to the owner. This functionality not only provides real-time speed monitoring but also enables rapid response in case of emergencies, potentially saving lives and reducing damage.

The integration of the cloud platform is another key element of the project. The system continuously updates fuel levels, vehicle location, speed, and any accident-related data to the cloud, ensuring that the information is securely stored and can be accessed remotely. This data can be analyzed over time, allowing vehicle owners to track trends in fuel consumption, driving patterns, and overall vehicle usage. The cloud-based system ensures that even if the vehicle is stolen or damaged, critical data is still preserved, providing invaluable insights for recovery efforts or insurance claims.

One of the standout features of the system is its user-friendly interface, which allows vehicle owners to easily interact with the system and access live data. Through the interface, users can set speed limits, define fuel thresholds, and customize alert preferences based on their specific needs. The system's versatility makes it suitable for both individual vehicle owners and businesses with large vehicle fleets. Fleet managers can monitor multiple vehicles simultaneously, ensuring that any abnormal activity is promptly detected and addressed.

The design of the IoT-Based Fuel Theft Detection and Vehicle Tracking System focuses not only on security but also on ensuring maximum efficiency and ease of use. The ESP32 microcontroller is optimized for low-power consumption, ensuring that the system can run continuously without draining the vehicle's battery. This makes the system ideal for long-term use, particularly in commercial vehicles or fleets where consistent monitoring is required. Additionally, the use of widely available components like the GSM module and GPS ensures that the system is easy to maintain and upgrade, allowing for scalability as the needs of the user grow.

1.2 Motivation

The development of the IoT-Based Fuel Theft Detection and Vehicle Tracking System is driven by the pressing need to address the significant challenges of fuel theft, vehicle security, and driver safety in modern transportation. Fuel theft is a pervasive issue, particularly in industries such as logistics and transportation, where fuel costs represent a major operational expense. Traditional methods of fuel monitoring, which often rely on manual checks, are inefficient and prone to errors, making them inadequate for detecting theft in real-time. Similarly, vehicle theft remains a significant concern for both individual vehicle owners and businesses, with stolen vehicles often being difficult to recover and leading to substantial financial losses. Additionally, road accidents pose a critical threat to driver safety and can result in severe consequences if not detected and responded to promptly. The motivation behind this project is to leverage advanced IoT technology to create a comprehensive, real-time monitoring system that not only detects fuel theft and unauthorized vehicle movements but also enhances overall vehicle safety by providing immediate alerts and continuous tracking capabilities. This system aims to provide a cost-effective, efficient, and reliable solution that can be easily integrated into existing vehicle fleets, offering enhanced security and peace of mind to vehicle owners and fleet managers alike.

1.3 Problem Definition and Objectives Problem Definition

Fuel theft and vehicle security are significant challenges in the transportation industry, causing financial losses and operational disruptions. Traditional fuel monitoring methods are inefficient and prone to errors, while vehicle theft and unauthorized usage remain common issues. Additionally, timely detection and response to accidents are critical for ensuring driver safety and minimizing damage. To address these challenges, an advanced IoT-based system is needed to provide real-time monitoring, detection, and alerting capabilities for fuel theft, vehicle tracking, and accident detection.

Objectives

- To study the real-time detection of fuel theft using ultrasonic sensors.

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- To study continuous vehicle location tracking with GPS technology.
- To study the monitoring of vehicle speed and detection of accidents with an accelerometer.
- To study the transmission of immediate alerts via GSM for theft, speeding, or accidents.
- To study the storage and remote access of vehicle data on a cloud platform.

1.4 Project Scope and Limitations

The scope of the IoT-Based Fuel Theft Detection and Vehicle Tracking System encompasses the development and implementation of a comprehensive solution for enhancing vehicle security and safety. This includes the integration of ultrasonic sensors for real-time fuel level monitoring, GPS modules for precise location tracking, ADXL345 accelerometers for detecting sudden impacts or abnormal movements, and GSM modules for sending immediate SMS alerts. The system is designed to be compatible with various vehicle types and operational environments, ensuring broad applicability. Additionally, the project involves the development of a user-friendly interface for remote monitoring and data access through a cloud platform. The primary focus is on providing a reliable, efficient, and cost-effective solution to address fuel theft, vehicle security, and accident detection, making it suitable for both individual vehicle owners and large fleets.

Limitations

- The system's performance may be affected by poor GPS signal reception in urban canyons or remote areas.
- The accuracy of fuel level monitoring may vary depending on the vehicle's fuel tank shape and installation position.
- The system relies on GSM network coverage for sending SMS alerts, which may be limited in certain regions.
- Continuous monitoring may lead to higher power consumption, requiring reliable power sources or frequent battery replacements.
- The initial setup and installation may require technical expertise, potentially limiting adoption by non-technical users.

II. LITERATURE REVIEW

1. Smart IoT-Based System for Monitoring and Detecting Fuel Theft and Fuel Indication for Refilling Process (2023)
This study presents an IoT-based system that employs sensors to detect fuel theft and monitor fuel levels. The system provides real-time notifications via GPS and ensures fuel refilling alerts. While the approach enhances security and monitoring, its accuracy is dependent on the precision of the sensors and GPS, which may lead to errors in fuel level detection.
2. IoT-Based Fuel Level Monitoring and Fuel Theft Detection System (2020)
This research introduces an IoT-based system using the ESP8266 NodeMCU microcontroller, fuel level sensors, and a web-based dashboard for real-time monitoring. The system effectively detects theft and alerts users, but it may not be suitable for all types of fuel tanks, limiting its application across different vehicle or storage systems.
3. IoT-Based Fuel Theft Monitoring System (2018)
This paper proposes a fuel theft monitoring system that utilizes sensor-based technology to detect unauthorized fuel extraction and provide real-time alerts. It integrates a communication system for remote monitoring. However, a major drawback is that the system needs to be compatible with various fuel tank models and sensor technologies, which can be challenging.
4. Automatic Fuel Tank Monitoring and Leakage Detection (2022)
This study focuses on fuel tank monitoring using a microcontroller, ultrasonic sensors for level measurement, and gas sensors for leakage detection. The system enhances safety by preventing fuel leakage hazards. However, frequent sensor calibration is necessary to maintain accuracy, which increases maintenance efforts.

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5. GSM-Based Fuel Theft Detection (2023)
This paper presents a GSM-based system that employs infrared sensors for fuel monitoring and SMS alerts for theft detection. The GSM network ensures that alerts are sent immediately. However, the system's performance is reliant on GSM network availability, making it ineffective in areas with poor connectivity.

IV. REQUIREMENT AND ANALYSIS

Hardware Requirements

The IoT-Based Fuel Theft Detection and Vehicle Tracking System requires a variety of hardware components to function effectively. These components are essential for monitoring, processing, and communicating data related to fuel levels, vehicle location, and vehicle movement.

ESP32 Microcontroller:

Acts as the central processing unit, coordinating the operations of all connected sensors and modules.
Provides connectivity options such as Wi-Fi and Bluetooth for data transmission.

Ultrasonic Sensor (HC-SR04):

Measures the fuel level in the vehicle's tank by emitting ultrasonic waves and calculating the time it takes for the echo to return.
Triggers alerts if a significant drop in fuel level is detected, indicating possible theft.

ADXL345 Accelerometer:

Detects sudden movements or impacts, which could indicate a collision or accident.
Sends data to the ESP32 for processing and potential alert triggering.

GPS Module (NEO-6M):

Provides real-time location tracking of the vehicle.
Ensures continuous monitoring of the vehicle's movements for security and tracking purposes.

GSM Module (SIM800L):

Enables the transmission of SMS alerts to the vehicle owner under various conditions, such as fuel theft or accidents.
Ensures communication even in areas with limited internet access.

LCD Display (16x2):

Used for displaying real-time information to the user, including fuel levels, vehicle location, and alerts.
Enhances user interaction with the system.

Buzzer:

Provides audible alerts for various events, such as fuel theft or when speed thresholds are exceeded.
Enhances the system's ability to notify the user of emergencies.

Power Supply:

A reliable power source is required to ensure continuous operation of the system.
The system should be designed to minimize power consumption to extend battery life.

Software Requirements

The system also relies on specific software tools and platforms to process data, manage user interfaces, and enable communication.

Arduino IDE:

Used for programming the ESP32 and Arduino Uno microcontrollers.
Provides a user-friendly environment for writing and uploading code.

MicroPython:

An implementation of Python 3 that allows for scripting and rapid prototyping on the ESP32.
Useful for developing complex algorithms and data processing tasks.

Communication Protocols:

GSM Protocol: For sending SMS alerts via the GSM module.
HTTP/HTTPS: For secure data transmission between the system and the cloud platform.

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Analysis

The combination of these hardware and software components ensures that the IoT-Based Fuel Theft Detection and Vehicle Tracking System is capable of real-time monitoring, processing, and alerting. The system is designed to be highly responsive, providing immediate notifications for any issues or potential threats. The use of a cloud platform for data storage and retrieval enhances the security and accessibility of the data, while the user-friendly interfaces allow for easy interaction and customization of the system's parameters. The system's design focuses on security, efficiency, and ease of use, making it suitable for a wide range of applications from individual vehicle owners to large-scale fleet management operations.

IV. SYSTEM DESIGN

4.1 System Architecture

The below figure specified the system architecture of our project.

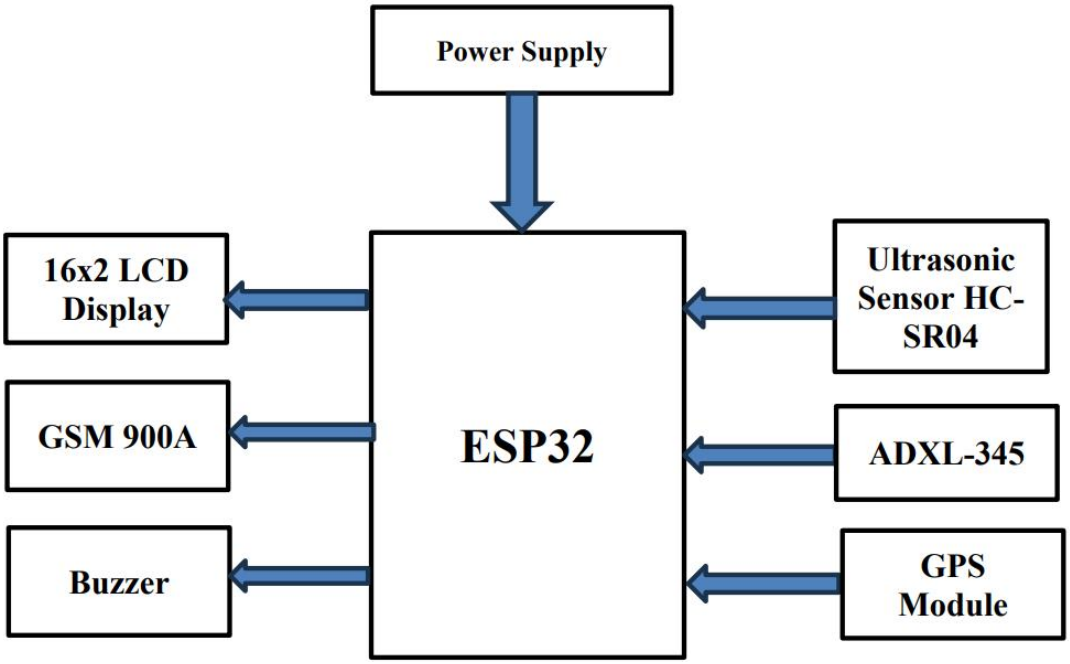

Figure 4.1: System Architecture Diagram

4.2 Working of the Proposed System

1. System Initialization and Power Management

Upon powering the system, the ESP32 microcontroller initiates a start-up sequence, which includes self-checks and initialization of all connected components. The power supply ensures that each module receives the required voltage, and the voltage regulator (LM7805) stabilizes the input to protect the sensitive electronics. The system is designed to operate within a range of power sources, including vehicle batteries and alternative power solutions, to ensure uninterrupted operation.

2. Fuel Level Monitoring

The ultrasonic sensor (HC-SR04) is continuously active, sending ultrasonic waves to measure the distance to the fuel surface within the tank. This data is relayed to the ESP32, which calculates the fuel level based on the time delay of the returning echo. If the fuel level drops below a predefined threshold or decreases rapidly, the system interprets this as a potential theft and triggers an alert.

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3. Vehicle Location Tracking

The GPS module (NEO-6M) continuously tracks the vehicle's geographical location by receiving signals from satellites. The real-time location data is processed by the ESP32 and can be accessed remotely through a cloud platform. This feature is crucial for vehicle owners and fleet managers to monitor the vehicle's movements and ensure it is not moved without authorization.

4. Accident and Movement Detection

The ADXL345 accelerometer is responsible for detecting any sudden movements or impacts that may indicate an accident or unauthorized usage. It sends data to the ESP32, which analyzes the acceleration forces to determine if an incident has occurred. If an accident is detected, the system sends an immediate alert via GSM to the vehicle owner or fleet manager.

5. Communication and Alerts

The GSM module (SIM800L) is integral for communication. It sends SMS alerts to predefined phone numbers in the event of fuel theft, speeding, or accidents. The system is programmed to construct messages that include essential information, such as the vehicle's location and the nature of the alert, ensuring that the recipient can respond appropriately.

6. User Interface and Data Display

The 16x2 LCD display provides a user interface for the system, showing real-time data such as fuel level, vehicle location, and system status. It also displays alerts and warnings, allowing the driver or user to be informed of any issues immediately. The buzzer provides an additional layer of alert notification through audible signals.

7. Data Logging and Remote Access

All critical data, including fuel levels, vehicle location, and speed, is logged and stored on a cloud platform. This data can be accessed remotely, allowing vehicle owners and fleet managers to review historical information, track trends, and make informed decisions regarding vehicle usage and maintenance. The cloud-based approach also ensures data redundancy and accessibility, even in the event of theft or damage to the vehicle.

In summary, the proposed IoT-Based Fuel Theft Detection and Vehicle Tracking System operates as a cohesive unit, with each component playing a vital role in ensuring vehicle security and safety. The system's ability to monitor, process, and communicate data in real-time provides a proactive approach to dealing with fuel theft, vehicle tracking, and accident detection, making it a valuable asset for individual vehicle owners and fleet operators alike.

Circuit Diagram of Proposed System

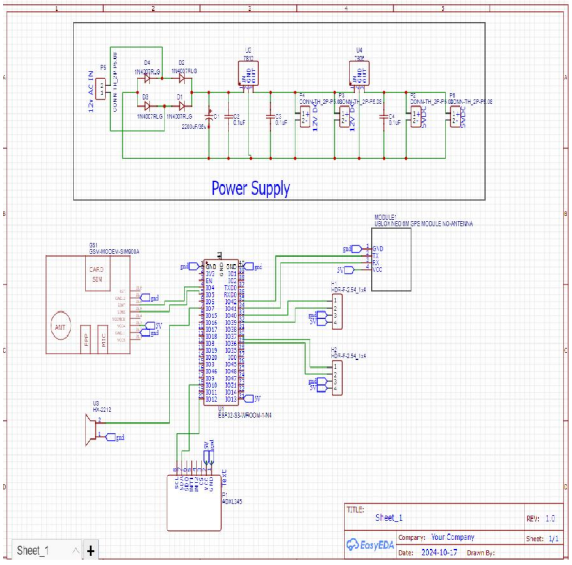

Figure 4.2: Circuit Diagram

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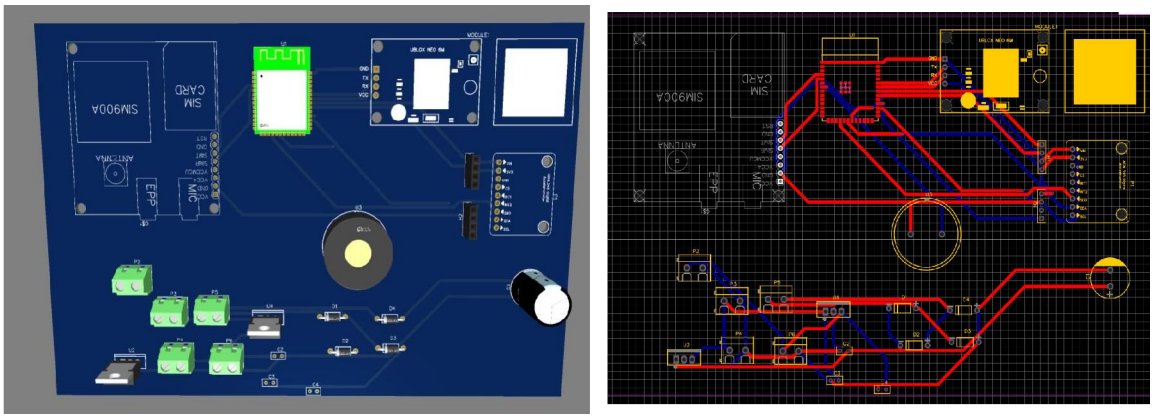

Figure 4.3: PCB Layout and Design

Algorithm
Start
Begin the system.
Initialize System
Power on the ESP32 microcontroller. Initialize GPS module.
Initialize ultrasonic sensor. Initialize ADXL345 accelerometer.
Check GPS Status
If GPS is functioning correctly, proceed to the next step. If GPS fails, retry initialization.
Continue Monitoring
Continuously perform the following checks:
Read fuel level from the ultrasonic sensor.
Read acceleration data from the ADXL345 accelerometer.
Check Fuel Level
If the fuel level drops rapidly (e.g., below a predefined threshold)Else,continue monitoring.
Check for Accident
If the ADXL345 detects sudden movements or an accident, Else, return to monitoring.
Send Live Location
Retrieve the current GPS location.
Prepare the message containing the live location.
Send Alert via GSM
Send an alert message via GSM to the designated phone number.
Update Location
Update the current GPS location in the database.
Return to Monitoring
Return to continue monitoring fuel level and acceleration.
End
The system continues to operate until powered off or reset

V. CONCLUSION

Conclusion

In conclusion, the IoT-Based Fuel Theft Detection and Vehicle Tracking System presents a robust solution to the pressing issues of fuel theft, unauthorized vehicle use, and road safety. By leveraging the capabilities of the ESP32 microcontroller, alongside an array of sensors and modules, the system offers real-time monitoring and immediate

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alerts, thereby enhancing vehicle security and providing actionable insights for vehicle owners and fleet managers. The integration with cloud platforms ensures data accessibility and storage, while the user-friendly interfaces facilitate easy system interaction. This comprehensive system not only deters theft and promotes vehicle safety but also optimizes operational efficiency, marking a significant advancement in IoT applications for vehicle management.

Future Work

In future work, the IoT-Based Fuel Theft Detection and Vehicle Tracking System can be further enhanced by incorporating advanced data analytics and machine learning algorithms for predictive maintenance and to improve theft detection accuracy. Additionally, the system could be adapted to integrate with smart city infrastructure for more extensive monitoring capabilities and could explore the use of solar-powered systems for sustainable energy solutions. Expanding the system's compatibility with various vehicle types and enhancing its user interface for better accessibility are also potential avenues for development.

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