An Efficient Novel Approach for Detection of Fuel Monitoring System through IoT Sensors for a Sustainable Environment

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ABSTRACT. To address the Fuel Theft situation currently faced by society, a project has been designed to create a Fuel Theft and Monitoring system. Fuel theft is an illegal act that involves stealing fuel from vehicles or storage facilities. With the rising fuel prices, this issue has become a growing problem. There are various methods employed by fuel thieves, including siphoning, drilling, burglary, and tampering with fuel gauges. Among these, siphoning is the most frequently used method, where thieves use a hose to extract fuel from the vehicle's tank. They may suck on the hose or use a pump to facilitate the process, which can be done quickly and easily in a matter of minutes. Burglary is a more destructive method where thieves break into a vehicle to directly access and steal fuel from the tank, potentially causing damage to the vehicle. Tampering with fuel gauges is another method used by fuel thieves, whereby they manipulate the gauges to make it appear as if the tank is empty when it is actually full. This allows them to fill up the tank without paying for the fuel. Fuel theft has significant financial implications for businesses and individuals alike. In the United States, it is estimated to cost businesses billions of dollars annually. Furthermore, fuel theft can also result in environmental pollution, as thieves may dispose of the stolen fuel on the ground or in waterways. Additionally, fuel theft during transit is a common occurrence, with reports suggesting that around 16% of diesel filled in trucks is stolen. This alone amounts to a theft of significant value each year. Addressing fuel theft requires proactive measures to protect oneself and prevent such crimes. One solution involves leveraging IoT technology, specifically using modules like GSM, GPS, and cloud computing. By implementing these technologies, we can work towards eradicating the problem of fuel theft and a sustainable environment.

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1 INTRODUCTION

Fuel theft, a pervasive criminal activity that plagues both developed and developing nations, has emerged as a significant threat to global energy security [1]. This illicit practice involves the unauthorized extraction, diversion, or illegal sale of fuel products, resulting in massive financial losses for governments, oil companies, and consumers alike. The magnitude of this issue is staggering, with estimates suggesting that fuel theft accounts for billions of dollars in annual revenue losses, undermining economic stability, environmental sustainability, and social welfare. This comprehensive introduction aims to shed light on the multifaceted nature of fuel theft, its causes (or) consequences and potential solutions. Fuel theft encompasses a wide range of illicit activities that revolve around the unlawful acquisition and misuse of fuel resources. The most common forms include pipeline tapping, fuel adulteration, smuggling, and organized crime networks engaged in the large-scale theft and resale of fuel products. These activities exploit vulnerabilities in the supply chain, resulting in substantial financial losses for governments, oil companies, and consumers. Moreover, fuel theft poses severe risks to public safety, as it often involves hazardous practices that can lead to accidents, fires, and environmental damage. Several factors contribute to the perpetuation of fuel theft, making it a complex issue to tackle. Economic factors, such as high fuel prices, income disparities, and poverty, create an incentive for individuals to engage in fuel theft as a means of economic survival. Weak governance, corruption, and inadequate law enforcement further exacerbate the problem, as they provide an enabling environment for criminal networks to operate with impunity. Moreover, the global demand for energy and the black market's profitability entices organized crime syndicates to invest in fuel theft operations, often with links to other illicit activities such as drug trafficking and money laundering [2]. The consequences of fuel theft are far-reaching and impact various aspects of society. Economically, the loss of revenue from stolen fuel undermines governments' ability to invest in public services, infrastructure, and social welfare programs. This loss of revenue also affects oil companies, leading to reduced profitability and potential job losses. Additionally, fuel theft contributes to price volatility, as the black-market availability of cheap fuel distorts the market dynamics, creating unfair competition and compromising legitimate businesses [3]. From an environmental perspective, fuel theft poses significant risks. Pipeline tapping, for example, can lead to oil spills, soil and water contamination, and damage to ecosystems. The adulteration of fuel with low-quality substances harms vehicle engines, reduces fuel efficiency, and increases harmful emissions, exacerbating air pollution and public health issues. Addressing fuel theft requires a comprehensive approach that involves cooperation between governments, law enforcement agencies, oil companies, and local communities. Strengthening legal frameworks, enhancing penalties, and improving enforcement mechanisms are crucial to deter potential fuel thieves and dismantle organized crime networks. Investing in technology, such as real-time monitoring systems, tamper-proof seals, and surveillance cameras, can enhance the security of fuel infrastructure and detect theft attempts promptly. Furthermore, public awareness campaigns can play a pivotal role in highlighting the social, economic, and environmental consequences of fuel theft. By educating consumers and fostering responsible consumption habits, societies can actively contribute to sustainable development by reducing the demand for stolen fuel and promoting ethical behaviour.

2 PREVIOUS STUDY

There are many approaches for measuring the fuel level and identifying theft. In a prototype for a fuel level monitoring system [4]. This system was used to measure the fuel level by interfacing with ultrasonic sensor. The drawback of the design was no real time location due to which we cannot track our module; the hardware requirement was more and lead to the high cost of the prototype.

In the designed a fuel level monitoring & alert system using IOT [5]. It used a float level sensor for measuring the fuel level using Raspberry PI. The drawback was the readings were not proper duel to shift in fuel surface and the angles at which it can be positioned at, and cannot be executed for lower quantities of fuel in the system thus causing errors.

In GSM based fuel theft detection system [6]. The main target was just the data transmission from module to the users using GSM technology. The drawback was not providing a measure in case of any issues using the GSM infrastructure.

In the vehicle fuel Activities Monitoring System Using IoT [7]. The drawback was the communication in rural areas was not efficient as it did not include any GSM architecture that provides a solution for areas without any stable and proper internet access.

In bus tracking System & Fuel Monitoring System. It is focused to primarily detect bus faults and detection of fire and alerting [8,9,10].

In anti-theft fuel level detector and vehicle tracking. The drawback of the system was complex in clinical settings [9,10]. The sensors data measurement did not commence until a start order is issued causing human interaction as necessary hence leaving the scope to enable a complete remote system which does not require human interaction. Only fuel is measured without any analysis and is sent via GSM architecture this is the major drawback as it does not provide an alternative [11-18].

3 PROPOSED DESIGN

The goal is to design and build a Fuel theft detection and Monitoring System that measures fuel data using an ultrasonic sensor and communicates the data to the IOTA network via a Wi-Fi module and GSM technology. The ESP8266 microcontroller-based Fuel theft detection and Monitoring System offers a practical and affordable way to keep track on fuel conditions. The ESP8266 microcontroller, a GSM transmitter, a GPS module, LCD, and a ultrasonic sensor will be used in the design and construction of the module. Data from the sensor will be gathered and processed by the ESP8266 before being sent to the IOTA network through a Wi-Fi module and GSM technology. A web-based interface will make the data available, enabling real-time monitoring and analysis.

3.1 Fuel Theft Detection and Monitoring System

The Internet of Things (IoT) is a revolutionary concept that entails connecting a wide range of devices, objects, and systems over the internet. Everything from everyday household goods and wearable devices to industrial gear and infrastructure is included. These devices in the IoT ecosystem are outfitted with sensors, actuators, and software that allow them to gather and transmit data. This information might range from basic environmental measures to detailed information about user behaviour and preferences. Various connectivity technologies, such as Wi-Fi, Bluetooth, cellular networks, and low-power wide-area networks (LPWANs), enable seamless communication and data sharing between IoT devices. These technologies offer real-time monitoring, control, and automation, which has a wide range of applications. IoT has ushered in the era of smart manufacturing, sustainable development and predictive maintenance in the industrial sector. Connected sensors and devices provide for real-time monitoring of machinery, allowing for better operations, less downtime, and lower maintenance costs. Thing Speak is a cloud based IoT analytics platform that enables users to gather, store, analyse, and visualize sensor data from connected devices. It has a simple interface and robust features for handling IoT data and developing apps. Thing Speak allows users to create channels to collect data from various sensors and devices. These channels serve as virtual containers for incoming data pieces and timestamps. The platform accepts a variety of data kinds, including numeric, textual, and geographic data. After gathering data, Thing Speak provides built-in visualization capabilities for creating custom charts, graphs, and gauges. Users can use these visualizations to acquire insights from their data, spot patterns, and track trends over time.

3.2. Gismo VII(Esp8266)

The GISMO VII is a flexible microcontroller development board known for its extensive feature set and connectivity options. It combines a dual-core processor, Wi-Fi, and Bluetooth into a tiny module and is powered by the ESP32 system-on-chip (SoC).
The board has:

- 2 Analog Grove ports
- 2 Digital Grove ports
- 2 I2C Grove ports
- 1 UART Grove port

This compact module facilitates the integration of Wi-Fi capabilities with microcontrollers, allowing the establishment of fundamental TCP/IP connections through the utilization of Hayes-style instructions.

3.3. Ultrasonic Sensor

The ultrasonic sensor is a versatile measurement tool primarily used for distance detection. It integrates advanced noise reduction and signal enhancement circuitry. Key specifications include an operational voltage range of 3.3V to 5V, a current consumption of 4mA, and a built-in LED indicator for status visualization

3.4. Buzzer Sensor

A buzzer sensor is an electromechanical device that emits audible sound signals when an electric current passes through it. It is commonly used in various applications for alerting or notifying users about specific events or conditions.

3.5. LCD

An LCD (Liquid Crystal Display) is a flat-panel screen technology that utilizes liquid crystals to produce images, text, and graphics with high clarity and color accuracy.

3.6. GSM Module

The GSM module enables wireless communication by utilizing cellular networks. It facilitates data transmission, allowing the system to send alerts and updates via text messages and calls, ensuring remote monitoring.

3.7. GPS Module

The GPS module in the system provides accurate geolocation data by communicating with satellites. It aids in tracking and monitoring the movement and location of assets in real-time.

3.8. Thing Speak Cloud

Thing Speak is a cloud - based IoT analytics platform that enables users to gather, store, analyze, and visualize sensor data from connected devices. It has a simple interface and robust features for handling IoT data and developing apps. Thing Speak allows users to create channels to collect data from various sensors and devices. These channels serve as virtual containers for incoming data pieces and timestamps. The platform accepts a variety of data kinds, including numeric, textual, and geographic data. With integration to MATLAB, Thing Speak offers advanced data analysis and predictive modeling capabilities. The platform supports various IoT communication protocols, ensuring seamless connectivity with a wide range of devices. Additionally, users can set up alerts based on specific conditions and share data channels for collaborative efforts. Thing Speak empowers IoT enthusiasts, developers, and researchers to harness the potential of their data, enabling informed decision-making and insights for various applications.

3.7. Hardware Prototype

Building an IoT circuit for a Fuel Theft Detection and Monitoring involves integrating various components to collect, process, and transmit fuel data.

1. Microcontroller: Select a microcontroller board compatible with IoT, such as Arduino, Raspberry Pi, or ESP32. This will serve as the brain of the fuel module and handle data processing and communication tasks.
2. Sensors: Choose level or distance measurement sensors suitable for your requirements, such as ultrasonic or float-level sensors. Connect these sensors to the appropriate pins of the microcontroller to collect fuel data.
3. Power Supply: Provide a stable power source to the microcontroller and sensors. This can be achieved using batteries, solar panels, or a combination of both, depending on the availability and energy requirements of your station.
4. Data Storage and Transmission: Use appropriate protocols and libraries to store the collected fuel data locally on the microcontroller or transmit it to a cloud platform for further analysis and visualization.
5. Programming and Firmware: Develop the necessary firmware or software code to handle sensor data reading, processing, and communication tasks. Utilize suitable programming languages and frameworks supported by the chosen microcontroller board.

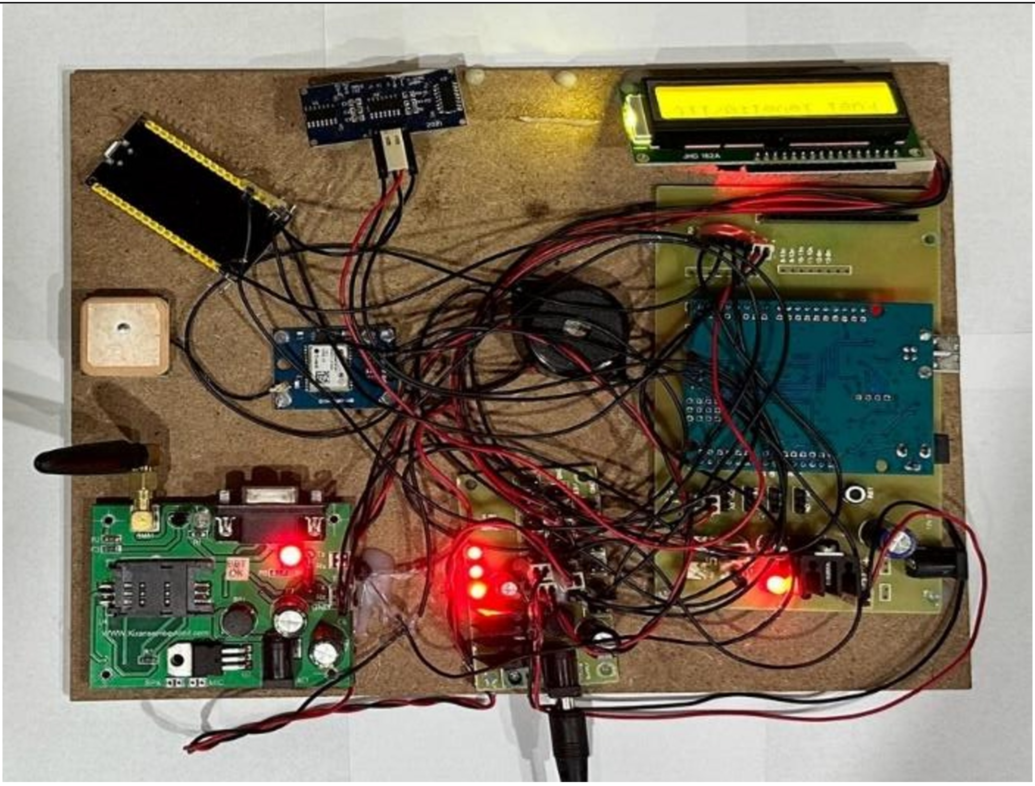

Fig.1. IoT Circuit Diagram

3.8. Stepwise Procedure

The proposed system follows the following step to complete the tasks.

Step 1: Ultrasonic Sensor collect Fuel data by measuring fuel level and transforming the data into fuel capacity, as by:

The ultrasonic sensor employs a transmitter to emit ultrasonic waves, which upon reflection, are received by the echo receiver within the sensor. Assuming the sensor is situated at a distance of 'd' above the fuel surface, the total distance covered by the ultrasonic wave's journey from the transmitter to the receiver is twice this value, equating to 2d (refer Eq. 1). If the time taken for this travel is denoted as 't' seconds, the measurement can be expressed in the International System of Units (SI). [The speed of ultrasonic wave in air is 340 m/s]

$$2 * d = t * 340 \tag{1}$$

If we consider the vertical distance between the ultrasonic sensor and the bottom surface of the fuel container as 'H', then the fuel level 'h' can be calculated as follows,

$$h = H - d \tag{2}$$

The value of ‘h’ is continuously monitored. Let at some time ‘t1’ and ‘t2’ the level heights are ‘h1’ and ‘h2’the rate of change in level can be given as,

$$r = (h1 - h2)/(t1 - t2) \quad (3)$$

When fuel theft occurs, there is a noticeable increase in the 'r' value compared to other instances. To address this, a threshold can be established. If the 'r' value surpasses this threshold, an alarm will activate, accompanied by the transmission of a message. This message will be facilitated through a micro-controller connected to a GSM modem.

Step 2: The ESP32 module processes the data and prepares it for transmission.

Step 3: The ESP32 sends the processed data to Thing speak, the cloud-based platform.

Step 4: Thing speak stores and organizes the data for easy access.

Step 5: Users visualize and analyse the data through Thing speak's user-friendly interface.

The system has some features that make the system unique.

1. Affordable Cost: The full system is cost-effective, with reasonably priced components, making it accessible to a wide range of users.

2. User-Friendly Interface: The model comes with an intuitive and user-friendly interface, ensuring that even non-technical users can quickly grasp.

3. Fast Response Time: The System exhibits a rapid response time, providing real-time fuel data and updates promptly.

4. Wide Coverage Area: Being connected to the internet and with the option of SMS networking System, the module can reach a large coverage area, allowing users to access information remotely from various locations.

3.10. Applications

The applications where this proposed system used are:

1. Transportation Industry: This system can be integrated into vehicles, trucks, and fleets to prevent fuel theft during transit. Real-time monitoring helps maintain accurate fuel records, reduce unauthorized fuel consumption, and prevent fraudulent activities.

2. Fuel Stations: Fuel theft is a common issue at fuel stations. By implementing this system, station owners can monitor fuel levels in storage tanks, detect unusual activities, and receive immediate alerts in case of theft attempts.

3. Logistics and Supply Chain: Fuel theft can disrupt supply chains. Integrating the system into transport vehicles and distribution centers helps maintain the integrity of fuel resources and enhances overall operational efficiency.

4.Remote Location Monitoring: In remote or unmanned locations, such as remote cell towers or communication stations, the system ensures that fuel is not stolen or wasted without anyone being present to monitor.

5.Rental Equipment Management: Equipment rental companies can monitor fuel usage in rented machinery, ensuring that customers only use the fuel they've paid for.

6.Public Transportation: Buses, trains, and other public transportation systems can benefit from the system to manage fuel consumption, reduce costs, and prevent theft.

4 RESULTS AND ANALYSIS

Once the system's wake-up sequence is triggered upon power connection, the subsequent initialization phase plays a pivotal role in preparing the system for operation. During this phase, the activation and powering up of all sensors and attached modules take place, encompassing components like GPS and GSM units. The significance of this phase lies in its ability to establish the foundation for accurate data collection and processing.

The LED lights, strategically integrated into the design, serve as essential indicators of the system's operational state. When illuminated, they not only offer a visual confirmation of successful initialization but also play a key role in the activation of signal collection mechanisms, particularly for the GSM module. This synchronization of visual cues with functional components enhances user confidence in the system's readiness.

However, the system's responsiveness can be vulnerable to power inconsistencies, which might arise due to external factors. Such inconsistencies can hinder the system's ability to perform optimally and promptly detect and respond to critical events. To counteract this potential issue, a reset button is conveniently located on the Power Supply Module. This button provides a straightforward means to restore the system's functionality, ensuring that it remains vigilant and effective in its monitoring and alerting capabilities, even in the face of power-related challenges..

Fig.2. LCD display output

Advantages of our System:

1. Data Visualization: The fuel data collected by the module can be visualized through graphs, charts, and dashboards, making it easy for users to interpret and understand fuel trends and patterns over time.

2. Alerts and Notifications: The various output devices are programmed to send alerts and notifications to users' devices when specific fuel conditions or thresholds are met, enabling timely response to fuel tampering events.

3. Connectivity: The IoT connectivity enables seamless data transmission to the cloud or central server, ensuring data accessibility from any internet-connected device. Reliable and stable connectivity is essential for the station's efficiency.

4. Scalability: The SMS transmission System can is scaled up to cover larger geographical areas, providing a more extensive network and range for connectivity.

5. User-Friendly Interface: It has a user-friendly interface that enhances the efficiency of the Fuel monitoring System by making it easy for users to set up, configure, and access fuel data.

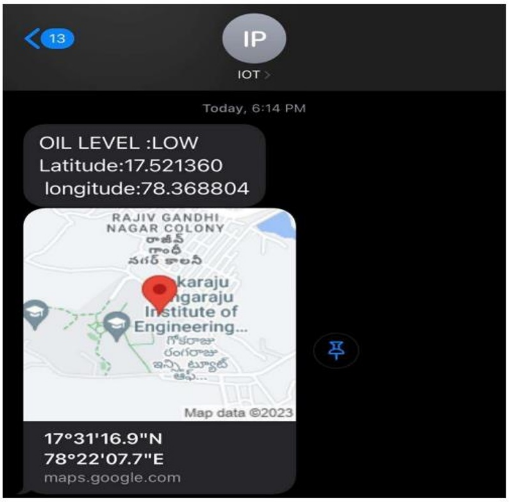

Fig.3. SMS received by user

5 CONCLUSIONS

In this study, we introduce a fuel theft detection and fuel monitoring system utilizing IoT technology to address the rising concern of fuel theft and enhance fuel management practices. Our system incorporates advanced sensors and connectivity to provide real-time monitoring, ensuring accurate fuel consumption tracking and improved security measures. By seamlessly integrating IoT devices such as smart fuel sensors and connected monitoring platforms, users can remotely monitor fuel levels, detect anomalies, and receive timely notifications for suspicious activities. With its customizable and flexible nature, our system caters to diverse needs, whether it be monitoring fuel levels in large industrial settings or tracking consumption in individual vehicles. By automating data collection and analysis, our solution streamlines fuel monitoring processes, reduces manual effort, and minimizes the risk of theft. Additionally, it contributes to environmental sustainability by identifying inefficiencies, allowing users to optimize fuel usage, minimize waste, and reduce carbon emissions. As IoT technology evolves, the potential for fuel theft detection and monitoring systems expands, revolutionizing fuel management practices and empowering users to achieve greater control, efficiency, and sustainability. This study exemplifies the transformative impact of IoT, offering a glimpse into a future where intelligent systems help protect fuel resources and propel us towards a greener and more secure world.

6 FUTURE ENHANCEMENTS

Our proposed model holds immense potential for further advancement by integrating additional measures such as sound detectors and webcams, which would enhance its capabilities in combating fuel theft. This expanded functionality would not only improve performance but also benefit a broader user base in various ways like promoting a better sustainable environment and development. Through continuous refinement and improvement of the model, we can effectively address the issue of fuel theft, ensuring the safety of vehicles and preventing any illegal activities. This ongoing development will drive the broader adoption and positive impact of Fuel Monitoring systems in the future, promoting increased security and peace of mind for users.

By incorporating supplementary features like sound detectors and webcams, our proposed model stands to reach new heights in the fight against fuel theft. These enhancements promise to bolster its effectiveness, catering to a wider range of users with diverse needs. Through a commitment to ongoing enhancements, we can seamlessly counter fuel theft, safeguard vehicles, and thwart illicit actions. This perpetual evolution will undoubtedly fuel the widespread acceptance and far-reaching benefits of Fuel Monitoring systems, ushering in heightened security and assurance for all stakeholders.

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