ISSN 2319-5991 www.ijerst.com

Peer Reviewed, Referred & Indexed Journal

Research Paper

REAL-TIME FIRE DETECTION AND AUTOMATED SUPPRESSION IN VEHICLES USING IOT TECHNOLOGY

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Abstract: Vehicle fire accidents pose a significant threat to human life, property, and transportation safety. These incidents can occur due to fuel leakage, electrical faults, overheating, or the presence of combustible gases within the vehicle. Traditional fire safety methods rely heavily on manual detection and response, which often leads to delayed action and severe damage. To address these limitations, this paper presents an IoT-based smart fire detection and suppression system designed specifically for vehicles.

The proposed system utilizes an ESP8266 microcontroller as the central unit to monitor environmental conditions in real time. Multiple sensors, including a gas sensor, flame sensor, and DHT11 temperature and humidity sensor, are integrated to detect potential fire hazards at an early stage. When abnormal conditions such as high temperature, gas leakage, or flame detection are identified, the system immediately activates a buzzer alarm and triggers a relay mechanism to shut down the vehicle engine, thereby preventing the spread of fire.

In addition to local response mechanisms, the system incorporates GSM and GPS modules for remote alerting and location tracking. Alert messages containing real-time vehicle location are sent to the vehicle owner or emergency contacts. Furthermore, an IoT-based web interface is developed for continuous remote monitoring of sensor data. The system is powered using a solar panel and battery setup, ensuring uninterrupted and energy-efficient operation.

Experimental results demonstrate that the proposed system provides rapid detection, automated response, and reliable communication, significantly enhancing vehicle fire safety. The integration of IoT technology with multi-sensor monitoring offers an efficient, cost-effective, and scalable solution for modern intelligent transportation systems.

Keywords: Internet of Things (IoT), Fire Detection System, Vehicle Safety, ESP8266 / Node MCU, Gas Sensor, Flame Sensor, DHT11 Sensor, GSM Module.

I. INTRODUCTION

Vehicle safety has become an increasingly important concern in modern society due to the rapid growth in the number of automobiles and the complexity of onboard electronic and mechanical systems. With the advancement of automotive technology, vehicles now incorporate sophisticated electrical wiring, fuel systems, batteries, and electronic control units, all of which can potentially become sources of fire hazards. Fire accidents in vehicles can occur due to several reasons such as fuel leakage, electrical short circuits, overheating of engine components, or the presence of combustible gases. Once a fire is initiated, it can spread rapidly because vehicles contain flammable materials such as fuel, plastics, rubber components, and upholstery. These incidents can lead to severe damage to property, environmental

hazards, and, most importantly, loss of human life. Therefore, early detection and prevention of vehicle fires have become a critical area of research in automotive safety systems.

Traditional fire safety mechanisms in vehicles are generally limited and mostly rely on manual intervention. In most cases, drivers become aware of a fire only after visible smoke or flames appear, which often indicates that the fire has already reached a dangerous stage. Conventional safety measures such as fire extinguishers are reactive rather than preventive, and their effectiveness depends on the immediate availability and timely action of the user. Furthermore, many vehicles lack systems that can continuously monitor environmental conditions inside the vehicle, such as temperature, gas concentration, and flame presence. This limitation results in delayed response and increases the severity of fire-related accidents. Hence, there is a strong need for intelligent systems that can detect potential fire hazards at an early stage and initiate preventive actions automatically.

With the emergence of advanced technologies, the integration of embedded systems and communication networks has opened new possibilities for developing smart safety solutions. One of the most promising technologies in this domain is the Internet of Things (IoT), which enables devices to collect, process, and exchange data over the internet. IoT allows real-time monitoring of various parameters and provides the capability to remotely access system information from anywhere in the world. In the context of vehicle safety, IoT-based systems can continuously monitor environmental conditions and send instant alerts when abnormal situations are detected. This significantly reduces response time and enhances the effectiveness of safety mechanisms.

Recent developments in sensor technology have further improved the reliability and accuracy of fire detection systems. Multi-sensor approaches that combine gas sensors, temperature sensors, humidity sensors, and flame detectors provide better detection capabilities compared to single-sensor systems. Gas sensors can detect the presence of combustible or toxic gases, indicating possible fuel leakage or smoke. Temperature sensors help identify abnormal increases in heat that may signal overheating or fire initiation. Flame sensors can directly detect infrared radiation emitted by flames, providing immediate confirmation of fire presence. By integrating these sensors, it is possible to create a robust system capable of detecting fire hazards at different stages, from early warning signs to actual fire conditions.

In addition to detection, rapid response mechanisms are essential to minimize the impact of fire accidents. Automated systems can take immediate actions such as activating alarms, shutting down the vehicle engine, and notifying users or emergency services. For instance, disconnecting the engine supply can help prevent the spread of fire by stopping fuel flow, while audible alarms can alert nearby individuals to take necessary precautions. Moreover, communication technologies such as GSM and GPS play a crucial role in enhancing system functionality. GSM modules enable the system to send alert messages to the vehicle owner or emergency contacts, while GPS modules provide accurate location information, allowing quick identification and response to the incident.

The integration of IoT with communication technologies also enables the development of remote monitoring platforms. These platforms allow users to view real-time sensor data through web interfaces or mobile applications. Such features improve situational awareness and provide users with the ability to monitor their vehicles even when they are not physically present. Additionally, data collected from these systems can be used for analysis and future improvements in safety mechanisms. This shift toward connected and intelligent systems represents a significant advancement in vehicle safety technologies.

Another important aspect of modern safety systems is energy efficiency and reliability. Continuous monitoring requires a stable and uninterrupted power supply. The use of renewable energy sources such as solar panels, combined with rechargeable batteries, ensures that the system remains

operational even when the vehicle is not in use. Voltage regulation circuits further enhance system reliability by providing stable power to all components. This makes the system suitable for long-term deployment without frequent maintenance.

Despite the progress made in fire detection technologies, there is still a need for integrated systems specifically designed for vehicles. Many existing fire detection systems are developed for buildings, industries, or forest environments and may not be directly applicable to automotive conditions. Vehicle environments present unique challenges such as limited space, varying temperatures, vibrations, and power constraints. Therefore, designing a compact, efficient, and reliable fire detection and suppression system tailored for vehicles is essential.

The proposed system, Smart Fire Detection and Suppression in Vehicles using IoT, aims to address these challenges by combining multiple sensors, embedded processing, and communication technologies into a single integrated platform. The system continuously monitors environmental conditions, detects potential fire hazards, and automatically triggers safety mechanisms such as alarms and engine shutdown. It also provides real-time alerts and location tracking through GSM and GPS modules, along with remote monitoring via an IoT-based web interface.

In summary, the development of intelligent fire detection systems using IoT technology represents a significant step toward enhancing vehicle safety. By enabling early detection, automated response, and real-time communication, such systems can effectively reduce the risk of fire accidents and minimize damage. The proposed approach not only improves safety but also contributes to the advancement of smart transportation systems and connected vehicle technologies.

II. LITERATURE SURVEY

Fire detection systems have undergone significant advancements over the years, evolving from simple smoke and heat detectors to intelligent systems capable of real-time monitoring and automated response. Early fire detection methods primarily relied on standalone sensors such as smoke detectors and temperature sensors, which triggered alarms when certain thresholds were exceeded. However, these systems were limited in their ability to provide early warnings, often resulting in delayed detection and increased damage. Recent studies highlight that integrating multiple sensors, such as gas, temperature, and flame sensors, significantly improves detection accuracy and reduces false alarms, thereby enhancing overall system reliability.

With the emergence of the Internet of Things (IoT), fire detection systems have become more intelligent, interconnected, and efficient. IoT-based fire detection systems utilize networks of sensors, microcontrollers, and cloud platforms to continuously monitor environmental conditions and provide real-time alerts. Research indicates that IoT-enabled systems offer advantages such as faster response time, remote monitoring, scalability, and improved reliability compared to traditional systems. These systems can transmit critical data to users or emergency services instantly, enabling quick action and minimizing potential damage.

Several researchers have proposed IoT-based fire detection systems that combine multiple sensing technologies with communication modules. For instance, systems integrating gas sensors, flame sensors, and temperature sensors with microcontrollers such as NodeMCU or Arduino have demonstrated effective early detection of fire hazards. These systems typically include alert mechanisms such as buzzers and SMS notifications, ensuring that users are informed even when they are not physically present. Additionally, cloud platforms are often used to visualize real-time sensor data, enhancing situational awareness and decision-making capabilities.

In recent years, research has also focused on incorporating automated suppression mechanisms into fire detection systems. IoT-based fire detection and suppression systems use actuators such as relays, pumps, or extinguishers that are automatically activated when fire is detected. Studies show that such systems can significantly reduce response time and prevent the spread of fire by initiating immediate action without human intervention. These integrated systems are particularly useful in environments where rapid response is critical, such as industrial setups and vehicles.

Vehicle fire detection systems have gained attention as a specialized application of IoT-based safety systems. Fires in vehicles can occur due to battery overheating, fuel leakage, or electrical faults, and they spread rapidly due to the presence of flammable materials. Recent research proposes IoT-based systems specifically designed for vehicles, where sensors monitor temperature, smoke, and gas levels in real time. These systems can automatically shut down the engine, activate alarms, and send alerts to users through IoT platforms. Such approaches significantly improve vehicle safety by providing early detection and rapid response.

Communication technologies such as GSM and GPS have been widely integrated into modern fire detection systems to enhance emergency response. GSM modules enable the transmission of alert messages to users or emergency services, while GPS modules provide real-time location information. Studies show that combining these technologies with IoT-based systems reduces response time and improves the effectiveness of rescue operations. This integration is particularly beneficial in vehicle applications, where location tracking is essential for quick assistance.

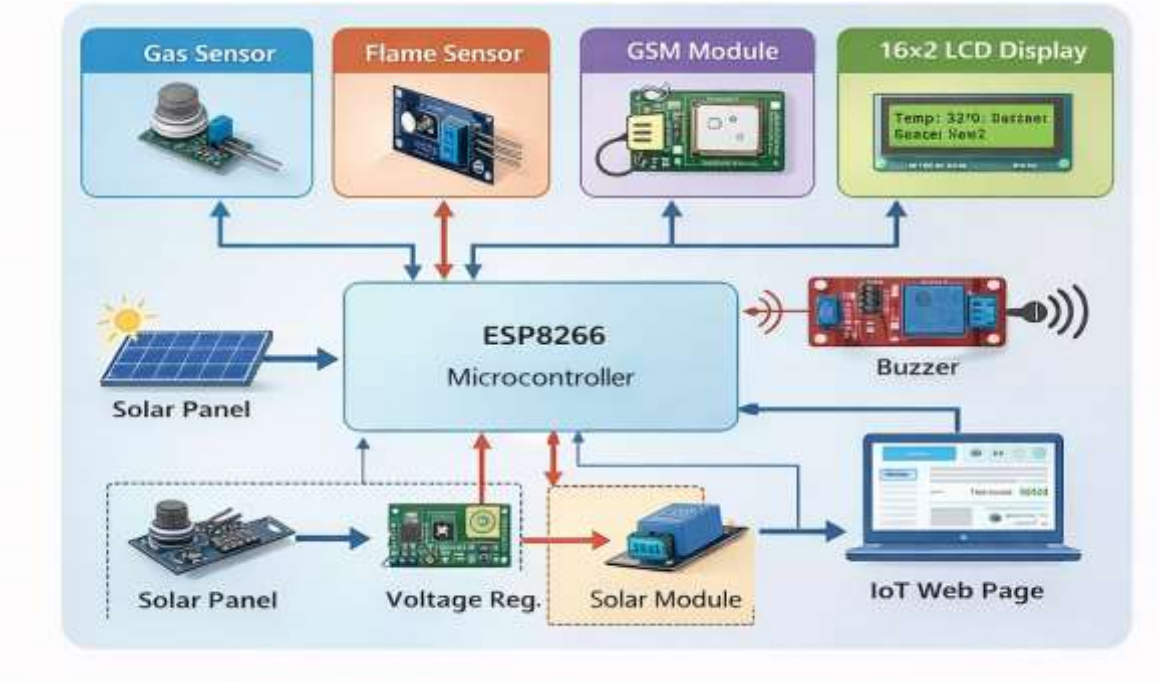
Furthermore, recent advancements in intelligent systems have introduced the use of artificial intelligence and machine learning techniques in fire detection. These approaches analyze sensor data patterns to predict fire incidents before they occur and reduce false alarms. Research using fuzzy logic and machine learning models has demonstrated improved accuracy and early detection capabilities, making fire detection systems more reliable and efficient.

Despite significant progress, several challenges remain in the development of fire detection systems. Many existing systems are designed for buildings or industrial environments and may not be suitable for vehicle applications due to space constraints, power limitations, and dynamic operating conditions. Additionally, there is a need for integrated systems that combine detection, suppression, communication, and remote monitoring in a single platform.

In summary, the literature indicates that IoT-based fire detection systems provide a promising solution for improving safety by enabling early detection, real-time monitoring, and automated response. The integration of multiple sensors, communication technologies, and intelligent algorithms enhances system performance and reliability. However, there is still a research gap in developing compact, efficient, and vehicle-specific fire detection and suppression systems. The proposed work aims to address these gaps by designing an integrated IoT-based system that ensures improved safety, faster response, and reliable operation in vehicle environments.

III. PROPOSED METHOD

The block diagram of the proposed system represents the overall architecture of the IoT-based smart fire detection and suppression system for vehicles. It illustrates how different hardware components are interconnected and how data flows through the system to detect fire hazards and initiate appropriate actions.



Proposed Block Diagram

1. Input Sensor Module

The system consists of multiple sensors that continuously monitor the internal conditions of the vehicle:

- **Gas Sensor (MQ135):** Detects the presence of combustible or toxic gases such as smoke, LPG, or fuel leakage.
- **Flame Sensor:** Identifies fire or flame using infrared radiation detection.
- **DHT11 Sensor:** Measures temperature and humidity levels to detect abnormal environmental changes.

These sensors act as the primary input units and provide real-time data to the controller.

2. Microcontroller Unit (ESP8266 / NodeMCU)

The ESP8266 microcontroller is the core component of the system.

- It receives data from all sensors
- Processes the data based on predefined threshold values
- Determines whether a fire hazard condition exists

It also enables WiFi connectivity, making the system IoT-enabled.

3. Signal Processing and Decision Making

The microcontroller continuously compares sensor readings with predefined safety limits:

- High temperature
- Presence of gas/smoke
- Detection of flame

If any of these conditions exceed safe thresholds, the system identifies it as a fire hazard.

4. Alert System (Buzzer)

- A buzzer is activated immediately when a fire condition is detected
- Produces an audible alarm to alert passengers and nearby people

This ensures instant local warning

5. Engine Control Unit (Relay Module)

- A relay module is connected to the vehicle engine
- When fire is detected, the relay:
  - Cuts off the engine supply
  - Stops fuel flow

This helps prevent fire spreading

6. Communication Module (GSM & GPS)

GSM Module:

- Sends SMS alerts to vehicle owner or emergency contacts
- Message includes fire warning details

GPS Module:

- Provides real-time location (latitude & longitude)
- Location link is included in alert message

Enables remote monitoring and quick response

7. Display Unit (LCD)

- A 16×2 LCD display is used for local monitoring
- Displays:
  - Temperature
  - Gas levels
  - Fire status

Helps users understand system status in real time

8. IoT Web Interface

- The ESP8266 hosts a webpage
- Displays live sensor data such as:
  - Temperature
  - Gas value
  - Fire detection status
  - GPS location

Enables remote monitoring from anywhere

9. Power Supply Unit

- Consists of:
  - Solar panel
  - Battery
  - Voltage regulator (LM2596)

Ensures:

- Continuous power supply
- Energy-efficient operation

Overall Working Flow

1. Sensors continuously monitor vehicle conditions
2. Data is sent to ESP8266
3. Controller analyzes data
4. If fire detected:
    - Buzzer ON
    - Engine OFF (relay)
    - SMS alert sent (GSM)
    - Location shared (GPS)
5. Data displayed on LCD & IoT webpage

The block diagram represents a complete intelligent safety system that integrates:

✔ Detection (Sensors)

✔ Processing (ESP8266)

✔ Action (Buzzer + Relay)

✔ Communication (GSM + GPS + IoT)

This ensures early detection, fast response, and improved vehicle safety

IV. CONCLUSION

This work presented an IoT-based smart fire detection and suppression system designed to enhance vehicle safety through early hazard detection and automated response. Vehicle fires, often caused by fuel leakage, electrical faults, overheating, or combustible gases, can escalate rapidly and lead to severe damage and risk to human life. Traditional safety approaches rely on manual observation and intervention, which are often delayed and ineffective in preventing the spread of fire.

The proposed system addresses these limitations by integrating multiple sensors, including gas, flame, and temperature sensors, with an ESP8266 microcontroller for continuous monitoring and intelligent decision-making. The system is capable of detecting abnormal conditions at an early stage and immediately triggering safety mechanisms such as buzzer alerts and automatic engine shutdown using a relay module. This significantly reduces the risk of fire escalation and enhances passenger safety.

Furthermore, the integration of communication technologies such as GSM and GPS enables real-time alerting and location tracking. The system sends SMS notifications to the vehicle owner or emergency contacts along with the exact location of the vehicle, ensuring quick response during emergencies. The IoT-based web interface provides remote monitoring of sensor data, allowing users to observe vehicle conditions from anywhere.

The inclusion of a solar-powered energy system improves reliability and ensures uninterrupted operation, making the system suitable for long-term deployment. Overall, the proposed solution demonstrates a cost-effective, efficient, and scalable approach to vehicle fire safety. It combines early detection, automation, and real-time communication into a single integrated platform.

In conclusion, the developed system significantly enhances vehicle safety by reducing response time, minimizing damage, and preventing fire-related accidents. Future improvements may include the integration of artificial intelligence for predictive analysis, mobile application support, and advanced suppression mechanisms such as automatic fire extinguishing systems. This work contributes to the development of smart and intelligent transportation safety systems.

REFERENCES

1. K. Balaji and M. Kumar, "IoT-Based Fire Detection and Alert System," *International Journal of Engineering Research & Technology*, 2020.
2. S. R. Prabhu et al., "Smart Fire Detection System Using IoT," *International Journal of Innovative Technology and Exploring Engineering*, 2019.
3. A. Sharma and R. Gupta, "IoT-Based Fire Monitoring and Alert System," *International Journal of Computer Applications*, 2018.
4. P. S. Kumar, "Vehicle Fire Detection and Alert System Using Embedded Systems," *International Journal of Advanced Research in Electronics and Communication Engineering*, 2017.
5. M. A. Mazidi, *The 8051 Microcontroller and Embedded Systems*, Pearson, 2015.
6. V. K. Mehta, *Principles of Electronics*, S. Chand Publications, 2014.
7. Espressif Systems, "ESP8266 Technical Reference Manual," 2020.
8. DHT11 Sensor Datasheet, Aosong Electronics, 2018.
9. MQ135 Gas Sensor Datasheet, Hanwei Electronics, 2017.
10. SIM800 GSM Module Datasheet, SIMCom Wireless Solutions, 2019.
11. GPS System Overview, U.S. Department of Defense, 2020.
12. Arduino Documentation, "ESP8266 WiFi Module Programming Guide," 2021.
13. L. Atzori, A. Iera, and G. Morabito, "The Internet of Things: A Survey," *Computer Networks*, 2010.
14. H. Karl and A. Willig, *Protocols and Architectures for Wireless Sensor Networks*, Wiley, 2005.
15. J. Gubbi et al., "Internet of Things (IoT): A Vision, Architectural Elements, and Future Directions," *Future Generation Computer Systems*, 2013.