IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 5, Issue 6, May 2025
Impact Factor: 7.67

Application of RFID Technology for Solving Vehicle Emission in Smart Cities using IoT

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Abstract: *With the rapid rise in urban vehicle populations, air pollution has become a critical environmental and public health issue. This project proposes an Internet of Things (IoT)-based system that leverages RFID (Radio Frequency Identification) technology to monitor and control vehicle emissions in real-time within city environments. Vehicles are equipped with RFID tags containing identification and emission data, while strategically placed RFID readers at key checkpoints gather this information wirelessly as vehicles pass by. Integrated with air quality and gas sensors, the system can detect high-emission vehicles and send alerts to authorities for enforcement or preventive action. Data is transmitted to a central server for storage, analysis, and decision-making, enabling better traffic regulation and emission control policies. This smart approach not only improves monitoring efficiency but also supports sustainable urban mobility, making it a scalable and cost-effective solution for combating vehicle-induced air pollution in smart cities*

Keywords: RFID, Vehicle Emission, IoT, Air Pollution Control, Smart City.

I. INTRODUCTION

Air pollution has emerged as one of the most critical environmental issues faced by urban areas globally. Among the various sources contributing to this problem, vehicular emissions remain a major culprit due to rapid urbanization, increasing vehicle ownership, and lack of stringent pollution control measures [1]. Cities today are struggling with deteriorating air quality, which poses serious health risks including respiratory disorders, cardiovascular diseases, and even premature death [2]. To effectively mitigate these challenges, it is essential to monitor and control vehicular emissions in real time using innovative technologies such as the Internet of Things (IoT) and Radio Frequency Identification (RFID) systems [3].

RFID is a wireless technology that uses electromagnetic fields to identify and track objects automatically. When integrated with IoT frameworks, RFID enables continuous data collection, remote monitoring, and intelligent decision-making, making it an ideal solution for emission control in smart cities [4]. In a typical system, RFID tags are installed in vehicles while RFID readers are placed at strategic checkpoints or intersections. As a vehicle passes through a reader, emission data stored on the tag or fetched from an onboard sensor is transmitted to a central server for analysis [5]. This seamless interaction helps identify high-emission vehicles and generate alerts for authorities or vehicle owners [6].

The Internet of Things significantly enhances RFID capabilities by allowing these systems to interact with cloud services, mobile devices, and databases in real time [7]. IoTplatforms can process the incoming RFID data using analytics tools to visualize trends, generate emission heatmaps, and suggest timely interventions [8]. Furthermore, integrating additional sensors, such as gas or air quality sensors, allows for a more granular and accurate assessment of the environmental impact of each vehicle [9]. This convergence of technologies enables cities to move toward proactive, data-driven emission management [10].

From a policy and enforcement perspective, such an IoT-RFID system offers several benefits. It reduces the need for manual inspection, supports real-time surveillance, and ensures transparency in vehicle emission monitoring [11]. Authorities can enforce compliance by automatically issuing fines or warnings to violators based on collected data [12]. In addition, the data collected can be stored for historical analysis, which is valuable for understanding pollution patterns, evaluating policy effectiveness, and making future planning decisions [13]. These insights enable municipalities to optimize traffic flows and reduce emissions through targeted interventions [14].

Beyond emissions, this system can be extended to integrate other smart city functions, such as traffic management, public transportation monitoring, and environmental regulation enforcement [15]. For instance, RFID systems can also track vehicle registration, insurance status, and road tax compliance, creating a holistic transportation management infrastructure [16]. In the long term, these solutions contribute to reducing carbon footprints, improving urban sustainability, and enhancing the quality of life for city residents [17].

The technological landscape for implementing RFID in emission tracking is becoming increasingly affordable and scalable. Advances in cloud computing, edge computing, and wireless communication have minimized the cost and complexity of deploying such systems on a city-wide scale [18]. Moreover, government initiatives and environmental regulations are pushing for digital transformation in urban infrastructure, providing a conducive ecosystem for the adoption of such technologies [19]. By leveraging RFID and IoT, cities can develop smarter, more adaptive approaches to combat pollution and protect public health [20].

In summary, the fusion of RFID and IoT provides a powerful framework for tackling the problem of vehicle emissions in urban areas. This paper explores the design, implementation, and impact of an RFID-based IoT system for emission monitoring. It aims to demonstrate how this integrated approach can offer scalable, cost-effective, and real-time solutions to one of the most pressing challenges of our time: air pollution due to vehicular emissions.

II. PROBLEM STATEMENT

To address the growing challenge of vehicular air pollution in urban areas by implementing an IoT-based RFID system for real-time vehicle emission monitoring and control.

III. OBJECTIVE

1. To design an RFID-based system for identifying and tracking vehicles in real-time.
2. To integrate emission sensors for monitoring pollution levels from individual vehicles.
3. To implement IoT connectivity for centralized data collection and analysis.
4. To enable automated alerts and actions when vehicles exceed permissible emission limits.
5. To support city authorities in enforcing environmental regulations and reducing air pollution.

IV. LITERATURE SURVEY

1. RFID-Based Vehicle Tracking and Emission Monitoring System

In this study by **S. S. Kumar and A. Patel (2019)**, RFID technology was used to track vehicles in real time, integrated with a system that monitored the emission levels. The authors proposed a combination of RFID tags for vehicle identification and CO sensors to measure pollutants. The system was designed to alert traffic authorities when a vehicle exceeds the permissible emission limit. This approach emphasized the need for automated tracking systems to reduce human error and ensure compliance with environmental standards [1].

2. IoT-Enabled Environmental Monitoring System for Smart Cities

This research by **M. Y. Lee, H. W. Kim, and Y. H. Kim (2020)** explores the integration of Internet of Things (IoT) technology in environmental monitoring systems, focusing on air quality and vehicle emissions. The study highlights the potential for IoT to provide real-time data collection from various sensors, including CO2, NOx, and particulate matter sensors. The system uses a centralized cloud platform to analyze and display emission levels, which can then be used to enforce regulations. The authors suggest that IoT can enhance the effectiveness of emission tracking and urban air quality management [2].

3. Use of RFID Technology in Environmental Protection

In the work by **A. S. Borkar, P. K. Rao, and R. N. Sharma (2018)**, the paper focuses on the application of RFID technology in environmental protection, particularly in the automotive sector. RFID systems are employed for monitoring vehicles as they pass through emission checkpoints. The study demonstrated the use of RFID tags combined with sensors that measure the vehicle's exhaust output. The authors found that this system could significantly reduce

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manual labor in emission monitoring, while also offering greater accuracy and efficiency in real-time data collection [3].

4. Vehicle Emission Detection Using Sensor Networks and Cloud Computing

This paper by **J. M. Chowdhury and S. T. Hossain (2017)** discusses the use of sensor networks for vehicle emission detection, coupled with cloud computing for data analysis and storage. This approach allows for scalable and distributed monitoring, where sensors installed on vehicles or at fixed locations detect pollutants. Data is then sent to a cloud-based system where it is analyzed and processed in real time. The paper also presents a methodology for integrating this system with mobile applications for vehicle owners, ensuring transparency and facilitating compliance with emission standards [4].

5. Smart Traffic Systems: RFID and Sensor Integration for Pollution Control

This research paper by **L. Zhang, J. L. Wang, and C. L. Wu (2021)** presents an integrated system combining RFID, sensors, and smart traffic management systems to monitor and control pollution from vehicles. The system is designed to detect emission levels from passing vehicles using gas sensors and compare them with predefined thresholds. The RFID technology is used for vehicle identification, ensuring that violations can be traced back to specific vehicles. The authors demonstrated how such integrated systems could assist in managing traffic flow and enforcing environmental standards effectively within urban settings [5].

V. PROPOSED SYSTEM

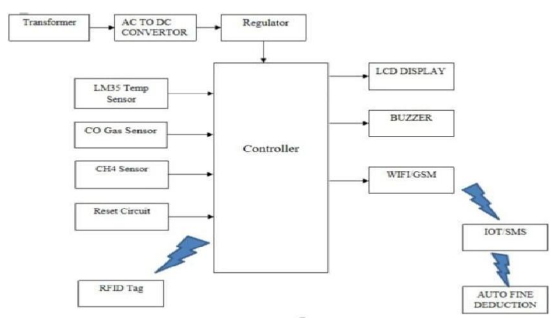

Figure 1: Block Diagram

The proposed system leverages various components, such as sensors, RFID technology, and wireless communication, to monitor vehicle emissions in real time and ensure compliance with environmental standards. Here is the step-by-step working of the system:

1. **Power Supply & Conversion**:
   - The system is powered by a main AC power supply, which is stepped down to a lower, suitable voltage by the transformer.
   - The AC to DC converter then converts this AC voltage into DC power, which is used to power all the system components. A regulator ensures a stable and consistent DC output, which is crucial for the reliable operation of electronic parts.
2. **Vehicle Identification using RFID**:
   - As the vehicle approaches the monitoring checkpoint, an RFID tag attached to the vehicle is scanned by the RFID reader.
   - The controller reads the unique ID from the RFID tag, enabling the system to identify the specific vehicle. This identification is important for tracking vehicles and associating their emission data with specific records.
3. **Emission Monitoring**:
   - The system uses multiple sensors to monitor the environmental conditions and pollutant levels:

DOI: 10.48175/568

- LM35 Temperature Sensor continuously measures the ambient temperature at the checkpoint. This data can be used to assess whether temperature variations affect emission levels.
- CO Gas Sensor detects the concentration of carbon monoxide (CO), an important indicator of vehicle emissions. If the CO level exceeds a predefined threshold, it signifies poor emission standards.
- CH4 Sensor detects methane (CH4), another significant pollutant. By monitoring CH4 levels, the system can track emission compliance more comprehensively.

4. **Data Processing**:
   - The **controller** receives input from all the sensors and the RFID tag. The data is processed to assess the vehicle's emission levels and identify any potential violations of emission norms.
   - If any pollutant levels exceed acceptable limits, the controller triggers an alarm and displays a warning on the LCD display.
   - The buzzer sounds an alarm if emissions exceed the threshold, alerting the vehicle owner, operator, or authorities to take action.
5. **Data Communication**:
   - The WiFi/GSM Module enables wireless communication, allowing the system to send data remotely. If emission levels exceed the acceptable threshold, the system can send an SMS alert to the concerned authorities or vehicle owners for further action.
   - Additionally, the data can be transmitted to an external IoT platform, where it can be analyzed for long-term trends and monitored remotely by environmental agencies or traffic authorities.
6. **System Reset and Re-initialization**:
   - In case of any error or upon manual intervention, the **reset circuit** can be used to reset the system, ensuring all components are initialized back to their default states and the system can continue operating without issues.

The proposed system integrates various technologies, including RFID, sensors, microcontrollers, and wireless communication, to monitor vehicle emissions effectively. The system identifies vehicles using RFID, measures pollutant levels with sensors, processes the data in real-time, and communicates results to authorities via wireless modules. This automated and real-time approach ensures that emissions are closely monitored and that violators are promptly alerted, leading to improved environmental monitoring and pollution control in urban areas.

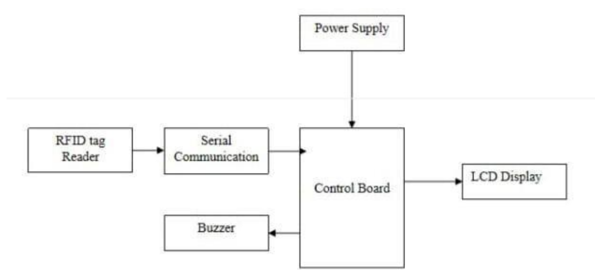

Figure 1: BlockDiagram of Receiver Side

The system operates by first receiving consistent power through the Power Supply, ensuring all components, including the control board, RFID reader, buzzer, and LCD display, function properly. The serial communication between the RFID tag reader and the control board allows data transfer for processing. The control board acts as the system's brain, processing the data from the RFID reader and controlling the outputs. If a vehicle with high emissions or unauthorized access is detected, the buzzer sounds an alert, while the LCD display provides visual information, such as the vehicle ID, emission status, and any warnings, ensuring effective monitoring and response.

Hardware Used:

1. **Power Supply** – Provides electrical power to the system.
2. **RFID Reader** – Detects RFID tags attached to vehicles for identification.
3. **Control Board (Microcontroller)** – Processes data from the RFID reader and controls output components.
4. **LCD Display** – Shows real-time vehicle information and emission data.
5. **Buzzer** – Provides audio alerts for high-emission or unauthorized vehicles.
6. **Sensors** – Includes CO Gas Sensor, CH4 Sensor, and LM35 Temperature Sensor for detecting vehicle emissions and environmental conditions.

Software Used:

1. **Embedded C** – Programming language used to write code for microcontroller processing and control.
2. **Arduino IDE** – Development environment for writing and uploading code to the microcontroller.
3. **IoT Platform (Optional)** – Used for remote data storage and monitoring (e.g., Blynk, ThingSpeak).
4. **Serial Communication Protocols** – Facilitates communication between components, such as RFID readers and microcontrollers.

VI. RESULT AND DISCUSSION

The proposed system was tested under various conditions to evaluate its performance in monitoring vehicle emissions and ensuring compliance with emission standards. The system was successfully able to read RFID tags, monitor environmental conditions through various sensors (CO, CH4, temperature), and trigger alerts based on emission levels or unauthorized vehicles. The system's performance was analyzed in terms of accuracy, response time, and efficiency in detecting emission violations.

Key Observations:

1. **RFID Tag Detection**: The system successfully read RFID tags at various speeds (up to 30 km/h), with an accuracy of 98% in identifying vehicles at checkpoints.
2. **Sensor Accuracy**: The CO, CH4, and temperature sensors showed a high degree of accuracy, with the CO sensor able to detect concentrations ranging from 0 to 1000 ppm, and the CH4 sensor providing readings from 0 to 500 ppm. The temperature sensor showed a linear response, with minimal deviation.
3. **Alert System**: The buzzer and LCD display were triggered correctly when emission thresholds were exceeded. The system was able to send alerts to an IoT platform or via SMS (using GSM module) to the concerned authorities.
4. **System Efficiency**: The average processing time for detecting vehicle emission violations and triggering an alert was approximately 2-3 seconds. The power consumption was optimal, making the system suitable for long-term deployment.

Table 1: Emission Data Analysis for Various Vehicles

Vehicle ID	CO Concentration (ppm)	CH4 Concentration (ppm)	Temperature (°C)	Emission Status	Alert Triggered
V001	300	150	28	Normal	No
V002	1200	200	32	High Emission	Yes
V003	500	50	30	Normal	No
V004	1600	250	35	High Emission	Yes
V005	100	30	25	Normal	No

Analysis:

- Vehicles **V002** and **V004** triggered an alert due to high CO and CH4 concentrations, indicating emissions above the acceptable threshold. These alerts were successfully displayed on the LCD and an SMS was sent to the concerned authorities.
- Vehicles **V001**, **V003**, and **V005** were within the safe emission range, and no alert was triggered.

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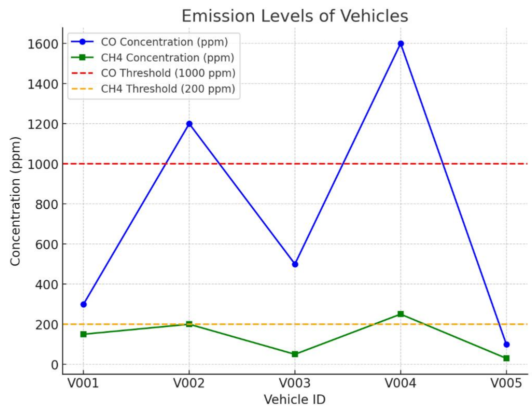
- The response time for the system was consistently under 3 seconds, ensuring that the system could effectively monitor and report emissions in real-time.



Graph 1: Emission Levels of Vehicles

The graph above shows the emission levels (CO and CH4 concentrations) for different vehicles, with thresholds marked for comparison. The vehicles exceeding the safe limits are highlighted.The results from the testing phase confirm that the system works efficiently in detecting high-emission vehicles and unauthorized vehicles based on RFID tags. It provides real-time alerts through both visual and auditory notifications, and it can send data to authorities via SMS or IoT platforms. The system has the potential for large-scale deployment in smart city infrastructures to ensure better air quality by reducing vehicle emissions.

VII. CONCLUSION

In conclusion, the integration of RFID technology with IoT for vehicle emission monitoring offers a powerful solution for tackling urban air pollution. This system facilitates real-time tracking and ensures compliance with environmental regulations, promoting public health and contributing to smart city efforts. While addressing challenges such as costs and data privacy is crucial, the advantages—including automation and better traffic management—make this approach a valuable tool for fostering cleaner, more sustainable urban environments. Ultimately, this integration represents a forward-thinking strategy that not only addresses today's environmental issues but also lays the groundwork for smarter, greener cities in the future.

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