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IOT technology-based vehicle pollution monitoring and control

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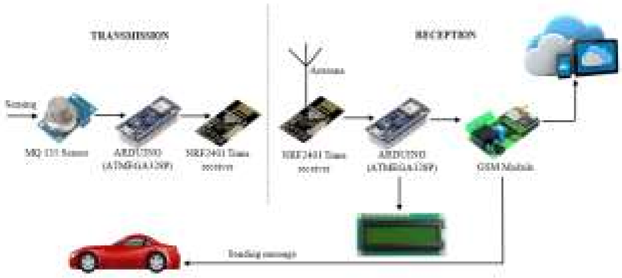
Graphical abstract



Abstract

Every year, the number of people who die because of pollution rises. Air pollution is generated by a variety of factors, which is pollution caused by automobiles. Technological improvements make great efforts to detect accidents and monitor pollution. In this paper, a novel Internet of Things-based Vehicle Gas Emission Monitoring System (IoT-VGEMS) to monitor and control the reduction of gas emissions. The overall work is categorized into two sections: One is Transmission Part, and the other is receiving part. The Transmitting Part consists of Arduino UNO, MQ-135 Sensor, and nRF24L01 transmitter. The Receiving Part consists of Arduino UNO, LCD Display, GSM, and nRF24L01 receiver. Initially, creating code to sense the data from the MQ-135 sensor to the Arduino UNO and store the data in Arduino 1 is fetched to transfer with the help of the nRF24L01 module. Using an Arduino UNO to interface with a GSM module. GSM module that would deliver the warning and intimation messages to the vehicle owner and display them on LCD. Finally, GSM can able to send a message to the respective user if the pollution level exceeds the threshold. Hence the message from our device will give information about the emission and the user could rectify it.

Keywords: Arduino UNO, MQ-135 sensor, nRF24L01, GSM, transmission, receiving, data

1. Introduction

In recent years, pollution has had a direct influence on human health. To rising levels of noise and air pollution, people are more susceptible to different health issues (Muthukumar S. *et al.*, 2018). Growing industrialization and urbanization are the main contributors to noise and air pollution. The primary factors that harm both human health and the environment (Janeera D.A. *et al.*, 2021). Monitoring and limiting such emissions are crucial.

Monitoring contamination using traditional methods was time-consuming and ineffective (Bhuvaneswari T. *et al.*, 2020). With the development of technology, quick and effective pollution monitoring has been developed in the Internet of Things (IoT) (Nižetić S. *et al.*, 2020; Abid M.A. *et al.*, 2022). With the aid of many sensors, it allows data exchange between the internet, electrical and electronic appliances, and people. IoT is successful because it is affordable, effective, and feasible (Sasikumar A. *et al.*, 2023). Pollutants from cars, vehicles, and buses are causing an increase in environmental issues, which is why asthma attacks and respiratory illnesses are on the rise. The only traffic is responsible for 50% of the carbon monoxide in the air (Rakhonde M.A. *et al.*, 2018).

According to data statistics, India is at the top of the list of nations with pollution-related transience in 2016, with 2.51 million people dying ahead of time due to illnesses connected to air, water, and other kinds of pollution (Ravindra K. *et al.*, 2022; Li X. *et al.*, 2022). The Lancet investigation found that air pollution, followed by water pollution (1.76 million) and industrial pollution (0.83 million), were the main causes of 6.49 million catastrophes in 2016. Examples of air pollutants include volatile organic compounds (VOCs), oxides of carbon, nitrogen, and sulphur, as well as other contaminants (Zhang Y. *et al.*, 2020; Teixeira P. *et al.*, 2020). Statistics also suggest that automotive emissions account for around 30% of total air pollution as shown in Figure 1.

Delhi, India's capital, is widely regarded as one of the world's most polluted cities (Krishan M. *et al.*, 2019). Air pollution disrupts the maintenance of normal air quality and causes various problems for animals, plants, and humans. When external substances such as CO and CO2 enter the air, it leads to air pollution. Poor air quality can cause eye, nose, and throat irritation, shortness of breath, and other respiratory, heart, and cardiovascular diseases (Billings M.E. *et al.*, 2020; Kendzerska T. *et al.*, 2022). To overcome the problem a novel IoT VGEMS model has been proposed to reduce BC emissions and mitigate climate change by proposing an IoT model that estimates his current CO2 levels and performs historical analysis of the measurements. This will help drive investment in more healthy towns and purifier kinds of energy.

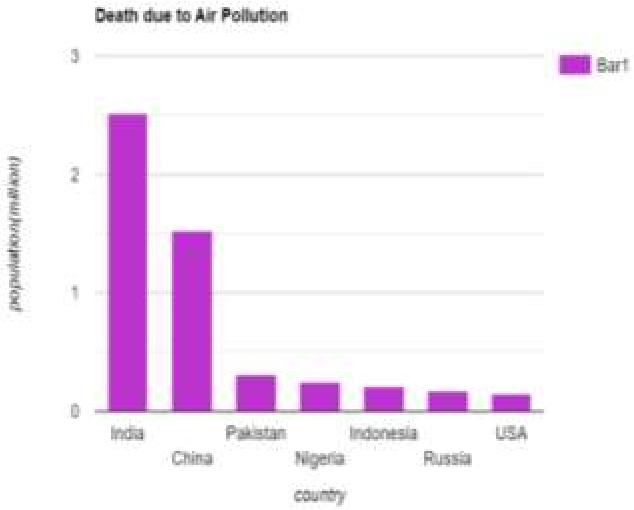


Figure 1. Lancet Statistics

The main contributions are:

- A novel Internet of Things-based Vehicle Gas Emission Monitoring System (IoT-VGEMS) has been proposed to monitor and control the reduction of gas emissions through the web server in the vehicle based on IoT.
- Initially, creating code to sense the data from the MQ-135 sensor to the Arduino UNO and store the data in Arduino 1 is fetched to transfer with the help of the nRF24L01 module.
- Using an Arduino UNO to interface with a GSM module. Creating code for a GSM module that would deliver the warning and intimation messages to the vehicle owner and display them on LCD.
- GSM can able to send a message to the respective user if the pollution level exceeds the threshold. Instead of using the Wi-Fi and GSM module, the data is uploaded to the cloud.
- Finally, the data will be sensed by the sensor and stored in the last and current variables. If the current value exceeds the last stored value will be updated.

In this research paper, Section 2 describes the literature review in detail. The proposed IoT-VGEMS model is discussed in Section 3. Section 4 covers the result and discussion, while Section 5 provides a conclusion.

2. Literature survey

Most pollution monitoring methods used today monitor and take into account a variety of environmental factors. This section is an overview of a few recent advanced methods used to, monitor and control the reduction of gas emissions in the vehicle.

In 2020, Hu, Z. and Tang, H., suggested an IoT-based intelligent transportation system. It features a distance-based adaptive cruise control system. The simulation's results show that the intelligent transportation system is capable of understanding the condition of the road and effectively realizing information flow between the vehicle and the command centre. It can increase the speed at which cars travel while lowering the amount of air pollution brought on by petrol emissions.

In 2022, Rauniyar, A., *et al.*, design an IoT-based car emissions monitoring system for smart cities. Real-time monitoring of vehicle noise and pollution sensor data is done by infrastructure managers and analysts. The data was analysed using artificial intelligence (AI) algorithms, which classified the sources into high, medium, and normal emitters. the development of a complete software solution that might work with existing intelligent transport systems in smart cities.

In 2020, Kaivonen, S. and Ngai, E.C.H., *et al.*, suggested using wireless sensors on public vehicles for real-time air pollution monitoring. The measurements from the sensors on public transportation cars supplement those from the stationary sensors and Uppsala's sole ground-level monitoring station. As a result of the experiments, the system's data and communication quality have been assessed.

In 2020, Zhang, D. and Woo, S.S., suggested designing the air quality pattern in the area using both moving and fixed IoT sensors mounted in the vehicles patrolling the area. The entire spectrum of air quality is examined in surrounding areas. The ability of the proposed technique to accurately measure and predict air quality using various ML algorithms and real-time data demonstrates its effectiveness. The results show that air quality forecasting and monitoring in a smart city is efficient and promising.

In 2020, Jo, J., *et al.*, suggested an IoT-based Smart-Air method to efficiently monitor air quality and send data to the web server in real-time via LTE. An LTE modem, sensors for tracking pollutants, and a microprocessor make up the device. You can monitor the air quality via the web server at any time and from anywhere. The web server can keep all the data in the cloud to give users access to resources for additional analysis of indoor air quality.

In 2020, Shetty, C., *et al.*, suggested an IoT technique for observing vehicle emission rates. The real-time data is used to create a predictive algorithm that forecasts the levels of carbon monoxide. To monitor the levels of pollutants, sensors are built into the vehicles. At the same time that the emission level is being monitored, the fuel delivery to the engine is being shut off using a solenoid valve.

In 2020, Kalia, P. and Ansari, M.A., suggested an IoT-based platform is used for real-time monitoring system of all the data to check air quality. On your smartphone or computer, Thing Speak offers a digital dashboard that shows current air quality readings for your surroundings. The collected data can be analyzed by comparing it to the standardized parameters of PM2.5 (0–30 µg/m3), PM10 (0–50 µg/m3), and AQI (0–50 PPM).

In 2021, Gautam, A., *et al.*, suggested a sensor-based embedded system that uses IoT to manage and screen air pollution generated from anywhere in the globe. A Raspberry Pi-based embedded system prototype that employs sensors and actuators is based on the IoT. A website is also made to virtually check the level of gases anywhere. The outcomes show that the entire system has been effectively tested and put into use.

In 2022, Kumar, A., *et al.*, suggested an IoT-based system for monitoring vehicle pollution. The Arduino Uno's sensors keep track of the number of pollutants coming from car exhaust. And the prototype uses a raspberry pi for monitoring and control. Here the vehicle user will be warned by the buzzer and if it is ignored, a challan is filed to the user and it is sent to the mail id.

In 2022, Asha, P., *et al.*, suggested the ETAPM-AIT model, eight pollutants—NH3, CO, NO2, CH4, CO2, PM2.5, temperature, and humidity are sensed using an IoT-based sensor array. The sensor array calculates the pollutant amount and sends it, via gateways, to the cloud server for analysis. In 5, 15, 30, and 60 minutes. The simulation analysis is complete, and the findings are examined using the AI technique.

Existing monitoring techniques require laboratory analysis and have poor accuracy and sensitivity. Consequently, better vehicle monitoring methods are required. To overcome the above drawbacks, a novel IoT-VGEMS has been proposed in this paper.

3. System model

In this section, a novel IoT-VGEMS to monitor and control the reduction of gas emissions in the vehicle based on IoT. The proposed work was completed in the following manner: Basic understanding of all system components (Arduino UNO, MQ-135 CO and SO2 gas sensor, GSM module, nRF24L01). MQ-135 sensor to Arduino UNO interface. Calculate the pollutant threshold values in vehicle emissions. Creating code to sense the data from the MQ-135 sensor to the Arduino UNO. The Stored data in Arduino 1 is fetched to transfer with the help of the nRF24L01 module. Whenever the crossover near tollgates or poles is carried out, the data from Arduino1's flash memory will be transferred from Arduino 1's nRF24L01 to Arduino 2. Using an Arduino UNO to interface with a GSM module. Creating code for a GSM module that would deliver warning and intimation messages to users. For authorities, the cloud (using IOT technology) is used to deliver fines. The numerous building blocks and components used in this project's creation each have specific functions that are carefully examined. The different blocks include an nRF2401, a GSM module, an MQ-135 gas sensor, and an Arduino UNO. This part provides an explanation of each block's operation, function within the project, and technical requirements. The overall operation is depicted in Figure 2.

1. **MQ135 sensor**: The MQ135 monitor is capable of detecting various gases, including CO, SO2, smoke, NH3, NOx, alcohol, and benzene. It outputs data in the form of voltage levels.
2. **Arduino UNO:** The microcontroller board for the Arduino Uno is constructed using the ATmega328P. It has a USB connection, a power jack, an ICSP header, a 16 MHz quartz crystal, six analogue input pins, fourteen digital input and output pins, and a reset switch.
3. **WIFI module:** The ESP8266 is a low-cost Wi-Fi chip with a complete TCP/IP stack and MCU (microcontroller unit) capability. Our device can connect to Wi-Fi or the internet thanks to its 3.3-volt operation.
4. **LCD:** This is a basic (16x2) 16-character, the 2-line display has a green background and black lettering. It's employed to display the air and humidity in PPM.
5. **GSM module:** Communication between a computer and a GSM device is established using a GSM module. The architecture used for mobile transmission is called the Global System for Mobile Communication (GSM).

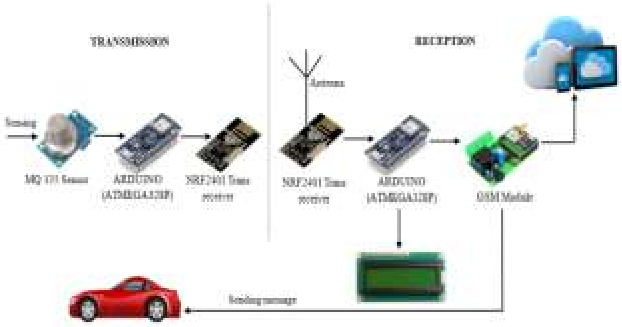


Figure 2. The overall process of the proposed IoT-VGEMS method

To maintain the air quality, CO and SO2 gas sensors are used to constantly check the pollution. Figure 3 displays the block diagram of the suggested air pollution monitoring system. RFID reader, wireless gas sensors, and a microcontroller are incorporated at the monitoring site. The air pollution generated by the vehicle is measured by the microcontroller. The car owner receives a warning notification if the pollutant levels exceed the threshold levels. The LCD shows the same information. The server of the approved agencies and the vehicle owner is also sent information regarding the levels of CO and SO2, vehicle number, RFID, and time and date of the vehicle. For later use, this material is kept in the server database.

The Overall Working is categorized into two sections: One is Transmission Part, and the other is receiving part. The Transmitting Part consists of Arduino UNO, MQ-135 Sensor, and nRF24L01 transmitter. The Receiving Part consists of Arduino UNO, LCD Display, GSM, and nRF24L01 receiver. The Outline of the system can be explained in detail using the flow chart depicted in Figure 3.

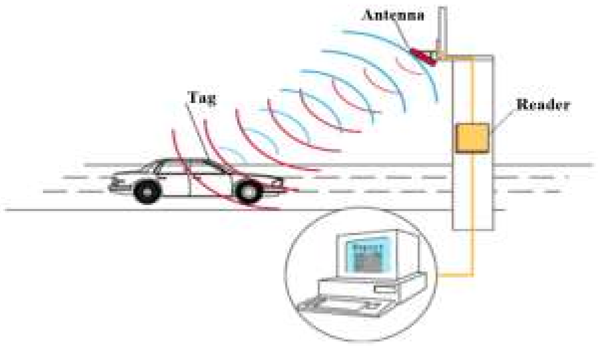


Figure 3. Air Pollution Monitoring System

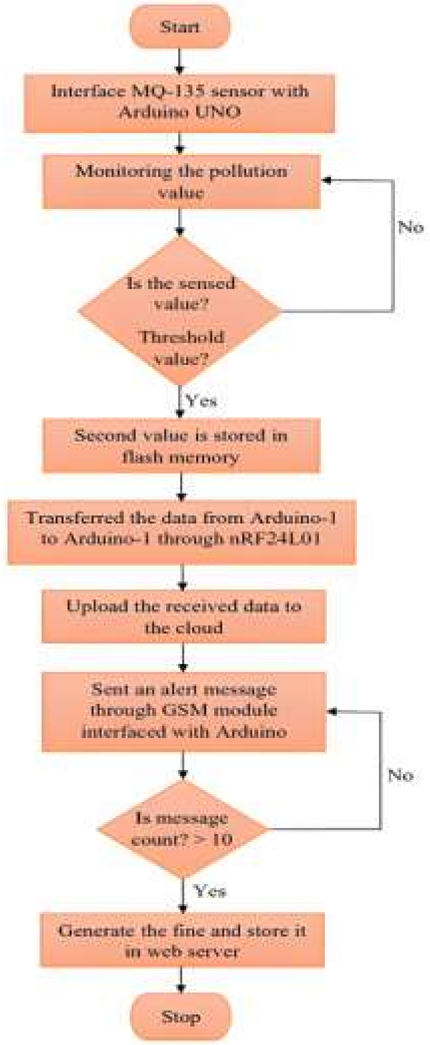


Figure 4. Diagram of Suggested System

3.1. Working of suggested system

This system can be installed in any automobile that contributes to air pollution in the environment. Our model installation is as follows: The MQ-135 sensor is connected to the Arduino. The Arduino is then interfaced with nRF24L01 which acts as a transmitter. A Code should be uploaded to the Arduino to create a communication of nRF24L01.The Header files for the sensor, memory, and nRF module are set up and the pins are initialized. The Transmission memory address is fixed, to create a handshake with the receiver. The nRF24L01 pins are initialized and the Arduino is set to test whether the RF module is initialized or not. The Variable for sensing is initialized to zero. The Values will be sensed by the sensor and stored in the last and current variables. If the current value exceeds the last stored value will be updated. This process runs continuously and the nRF transmitter module will look for the receiving module as shown in Figure 4.

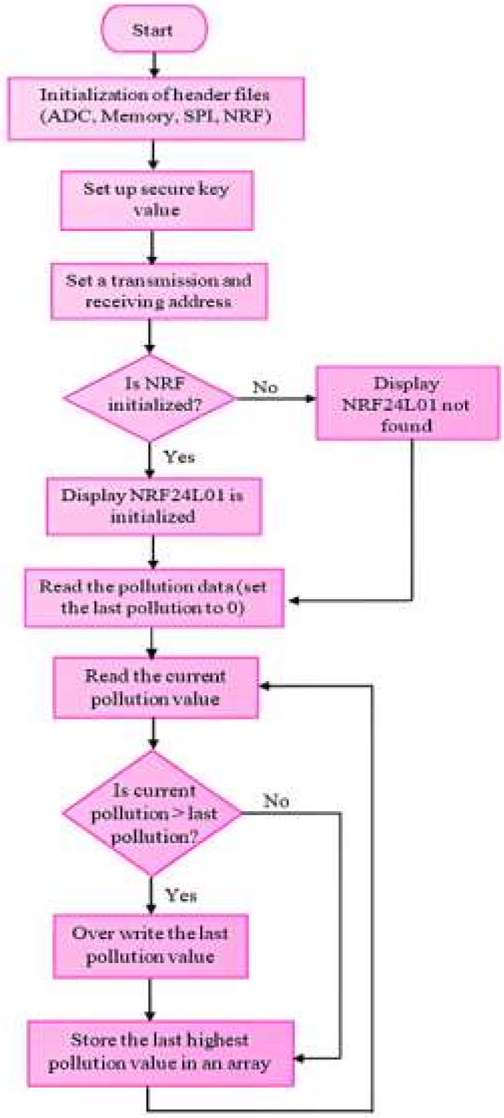


Figure 5. Flow Chart of Transmission Part

When the transmitter is ready, it will be transmitting the data continuously. On the other hand, another Arduino is interfaced with an nRF receiver and LCD Display. Whenever the transmission side nRF module comes in the communication range of the receiving side nRF module, the data will be transmitted from transmitter to receiver.

The Communication between two nRF modules is done using GFSK Modulation. In GFSK (Gaussian Frequency Shift Keying modulation) where baseband pulses (consisting of -1 and 1) are made to pass through the Gaussian filter before the modulation. This Gaussian filter helps to smooth out the pulses and, as a result, reduces the spectrum's breadth, a process known as pulse shaping. After the data is received, the information is sent through GSM Module. GSM is a digital mobile network that is used by mobile phone users throughout the world. GSM is designed to be a safe wireless system. It has considered user authentication via a pre-shared key and challenge-response, as well as over-the-air encryption. Using GSM, it can able to send a message to the respective user if the pollution level exceeds the threshold. To upload the data into the cloud, instead of using the Wi-Fi module, and GSM Module. In this project, we use GSM sim800l to upload data to the cloud because SIM800L supports General Packet Radio Service (GPRS) for internet access via HTTP. AT commands can be used to access the module's built-in TCP/IP stack. This can be very useful for long-term data logging on low-bandwidth networks. The Data is sent to the cloud and the overall work on receiving side is shown in Figure 6.

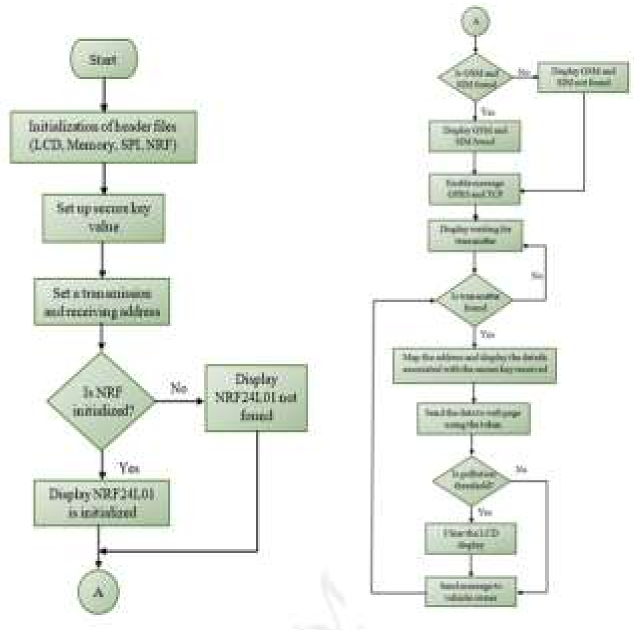


Figure 6. Flow Chart of Receiving Part

4. Result and discussion

4.1. Hardware implementation

In this section, a novel proposed has been described in detail. The significance of the sensor node for real-time analysis of the nodes' filling state will be discussed. MQ-135 gas sensor is used to detect the SO2 and CO gas released from the vehicle. Continuous comparisons are made between the detected gas and the predetermined threshold values. The sensed value and benchmark value are compared using an Arduino controller, and if the sensed value exceeds the threshold value, a warning is sent to the user (GSM Module) and authorities (IOT Technology) with the help of the nRF24L01 trans-receiver. The electrical connection is used to charge the sensor node using its built-in batteries. The sensor node and gateway are combined with the +5 V and +3.3 V voltage converters to supply the necessary voltage.

The Proposed Project was tested. The Proposed System measures the real-time pollution level of various automobiles. The Overall proposed prototype is shown in Figure 7.

Figure 8 depicts the monitoring device, which shows the vehicle's levels of pollution. To track the vehicle's pollution levels, the controller transmits to the server the specifics of the vehicle and the pollutant values.

Figure 7. Simulation setup

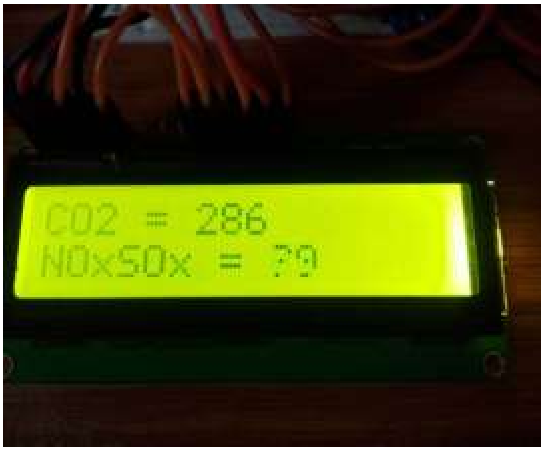


Figure 8. Displaying sensor values on an LCD

Data in general is uploaded to the cloud whenever there is a handshake between the transmission and receiving parts. On the Webpage, the location is indicated to denote the place at which the vehicle crosses the receiver setup Here two data are used to display the pollution range of the vehicle. The first one of the vehicles remains stationary and the second is the vehicle which starts and emits pollution. For a vehicle that remains stationary, the webpage is displayed with a green widget and data is stored in the database as shown in Figure 9.

Figure 9. Display of vehicle data when the vehicle is stationary

The Threshold is set at 50 ppm. When the vehicle starts, it displays 50% and above level on the webpage because testing usually takes an initial value of CO and SO2, which is 50 ppm. The webpage is displayed with a red widget and the pollution level, which is sent to the vehicle owner and advises the pollution level of the vehicle as well as the penalty for causing pollution, as shown in Figure 10.

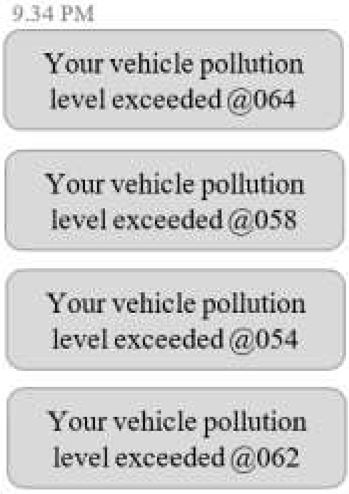


Figure 10. Indication of vehicle owner about the pollution level

Figure 9 illustrates, the display of vehicle data. It displays the date, time, detection location, username, registration number, mobile number, and detection level. In Figure 11 the air pollution monitoring system will place in the vehicle, which indicates 61% of the pollution level when the vehicle is started. All the data is stored in the cloud.

Figure 11. Display of vehicle data when the vehicle is started

The Experimental results are tabulated as shown in Table 1. It gives the pollution level of the various vehicle. Pollution levels were 50 in Raju's vehicle, 55 in Joel's vehicle, 53 in Vishnu's vehicle, and 61 in Naveen's vehicle.

Table 1. Real-Time Results

S. No	Name of the vehicle owner	Pollution level
1	Raju	50
2	Joel	55
3	Vishnu	53
4	Naveen	61

According to Table 2, the high concentration of dots between hours 12 and 15 indicates that the area is particularly polluted during this period. Figure 12's graphical depiction of pollution levels, AQI (Air Quality Index), and time are two examples of sample statistics from Table 2. Pollution levels during normal hours of the day.

The information gathered includes the local temperature and humidity, particulate matter, and the quantity of toxic and harmful gases like CO and SO2. The information gathered outdoors will be in analog format. The data will be routed, digitalized, and then stored on a server from which the controlling and monitoring devices can readily access it using the IoT. The IoT enables the collection and transmission of data in a more readable format to websites or mobile applications, not only increasing people's awareness of pollution levels in their area but also assisting them in understanding when and how to take precautions to protect themselves from various health risks.

Table 2. Sample data

S. No	AQI	Time
1	100	0
2	50	4
3	100	7
4	400	9
5	423	11
6	150	14
7	300	18
8	104	20
9	130	0
10	80	4
11	110	6
12	440	9

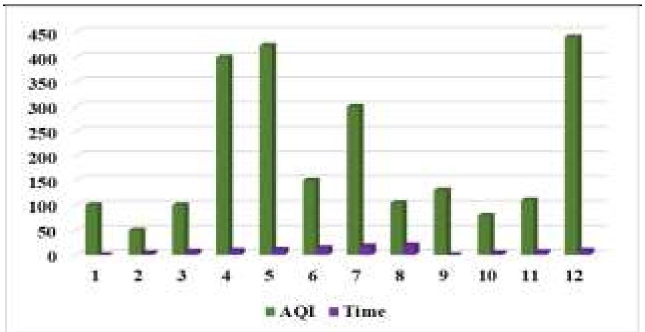


Figure 12. Histogram representing the Pollution Level

3.1. Comparative analysis

The performance of the existing techniques was compared with the performance of the proposed strategy to demonstrate that it is more effective. In a comparative study, the proposed IoT-VGEMS model is compared with existing approaches. Compares the overall performance of the proposed method is shown in Figure 13.

Figure 13 shows the outcomes of the overall accuracy rate. In comparison, the proposed IoT-VGEMS achieve a high accuracy range of 97.98%. It shows that the accuracy obtained by the IoT-based Smart-Air technique, sensor-based embedded system, and AI Technique is 95.34%, 94.39%, and 92.92% respectively. The specificity obtained by IoT-based Smart-Air technique, sensor-based embedded system, and AI Technique is 91.19%, 93.98%, and 93.18%. Precision is obtained by IoT-based Smart-Air technique, sensor-based embedded system, and AI Technique is 90.58%, 93.87%, and 91.49%. Recall is obtained by IoT-based Smart-Air technique, sensor-based embedded system, and AI Technique is 93.51%, 90.59%, and 92.87%. F1 score is obtained by IoT-based Smart-Air technique, sensor-based embedded system, and AI

Technique is 90.31%, 89.98%, and 90.89%. The proposed IoT-VGEMS achieves a higher accuracy rate than the currently used models.

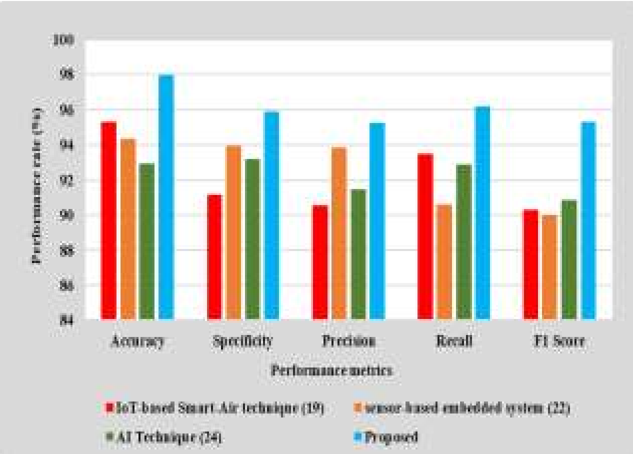


Figure 13. Comparison analysis of the proposed IoT-VGEMS model

5. Conclusion

In this paper, a novel Internet of Things-based Vehicle Gas Emission Monitoring System (IoT-VGEMS) to monitor and control the reduction of gas emissions. The overall work is categorized into two sections: One is Transmission Part, and the other is receiving part. The Transmitting Part consists of Arduino UNO, MQ-135 Sensor, and nRF24L01 transmitter. The Receiving Part consists of Arduino UNO, LCD Display, GSM, and nRF24L01 receiver. Initially, creating code to sense the data from the MQ-135 sensor to the Arduino UNO and store the data in Arduino 1 is fetched to transfer with the help of the nRF24L01 module. Using an Arduino UNO to interface with a GSM module. GSM module that would deliver the warning and intimation messages to the vehicle owner and display them on LCD. Finally, GSM can be able to send a message to the respective user if the pollution level exceeds the threshold. Hence the message from our device will give information about the emission and the user could rectify it. Few people will not take any action even if they receive a warning from transport officials, they will be penalized further. The monitoring system is battery-based. In the future, since sunlight is pure and free of pollutants, we can design small and compact monitoring systems based on solar energy and add other low-cost sensors to detect accidents.

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