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Original Article

Remote Gas Monitoring with Raspberry Pi

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Abstract *- Air pollution and gas leaks threaten human health and the environment. Conventional gas monitoring systems often depend on a stable internet connection, which limits their effectiveness in remote or infrastructure-poor regions. This paper presents a cost-effective, offline gas monitoring system with a Raspberry Pi, MQ-135 sensor, MCP3008 ADC, and SIM800L GSM module. The system enables real-time detection of gas concentrations and provides immediate SMS alerts without requiring internet access, addressing critical limitations of current IoT solutions. By emphasizing modularity, scalability, and offline functionality, this design offers a reliable and practical approach for monitoring gas levels in environments with unreliable or unavailable network connectivity.*

Keywords *- Gas Detection, GSM Alert System, MQ-135 Sensor, MCP3008, Raspberry Pi.*

1. Introduction

Air quality has a remarkable impact on the environment and human health. Rapid urbanization and industrialization are causing the increase of noxious gases in the atmosphere. Ammonia, carbon monoxide, carbon dioxide, and some volatile organic compounds (VOCs). Most of these gases are colourless and odourless, making them difficult to detect in harmful concentrations.

Most conventional gas detection approaches use expensive proprietary products that depend on proximity to the Internet to achieve real-time monitoring and alerts. This reliance on network infrastructure restricts their use in remote, rural or developing regions where internet access can be scarce or non-existent. The result is that routine manual checking is still performed in these areas (due to an enhanced risk of delayed detection and human error).

Earlier related work has covered a number of aspects of gas detection and ambient notification. A system for the detection of LPG gas leaks in [1] was proposed by Kumar and Verma[1], which stresses instantaneous alarming signification to avoid mishaps.

Sharma et al. [2] have proposed IOT-based gas detection systems using BLYNK for online monitoring, emphasizing real-time data over an internet module. Wang et al. [3] introduced the use of Raspberry Pi for inexpensive air quality monitoring, manifesting the advantages of its versatility as a computing platform. Patel et al. [4] introduced a gas leakage detection system using GSM for SMS alerts backed up offline, perfect for places with poor internet connection.

Existing systems, however, still have certain limitations, including a dependence on the Internet, limited scalability for multigas monitoring, and microcontroller processing power limitations.

To overcome these drawbacks, in this work, a Raspberry Pi-based gas monitoring system featuring the MQ135 sensor for multigas monitoring, MCP3008 ADC for accurate analog-to-digital conversion, and the SIM800L GSM module for offline SMS alerting is designed.

2. Literature Survey

With the development of industry and the emphasis on environmental health and the safety of human beings, gas detection and environmental monitoring systems play a pivotal role in industrial safety and human health protection.

Many wireless communication technologies, such as GSM and IoT, have been linked to various setups for gas sensors in different research contributions [1-5].

Gupta [1] proposed one gas leakage detection system based on Raspberry Pi that concentrates on the aspect of fire prevention as well as by means of real-time notification. This paper shows the strength of the low-cost embedded systems for safety applications where offline alerting has to be done in a less internet environment.

Nagalakshmi and Ph. D. [2] presented an innovative gas stove system using IOT for multistage leakage prevention and detection. Their work highlights the demand for inexpensive, highly accurate gas-theme monitors for home and industry safety systems.

Kandasamy et al. [3] proposed an IoT-based pipeline leakage detection system for the oil and gas industry, which could offer real-time alerts to take instant corrective action in the case of a leak. This method highlights the significance of constant monitoring for high-risk towns.

Zuo and Qi [4] presented a blockchain IoT architecture for remote oilfield monitoring and control. Their approach provides secure, scalable gas monitoring, showing the potential for resilient, decentralized safety systems in harsh environments.

Ma et al. [5] proposed edge computing methods for real-time detection and counting systems. They investigated the part smart data processing can play in monitoring systems' increased accuracy and speed and the application of advanced algorithms in gas detection.

All such studies collectively show a trend in gas detection systems moving from a distributed cloud-based system to more modular, independent and efficient detectors. However, most of these models do not have offline support or restrict one or the other operations because of hardware simplicity. In this paper, the aim is to overcome these drawbacks by developing a hybrid model by combining (amalgamated) the computational power of Raspberry Pi, the multigas sensing feature of the MQ-135 sensor, the precision capability of MCP3008 analogue-to-digital converter, and the offline alerting capability of SIM800L GSM modem. This methodology provides a useful and scalable technique to track gases in real-time.

3. Existing System

3.1. Limitations and Difficulties

There are three categories of existing gas monitoring solutions, all with serious shortcomings:

- Manual examination: Error-prone, inconsistent, and resource-demanding Manual examination makes it infeasible to scale out to larger deployments.
- Cloud-based IoT Systems: With their real-time monitoring ability, such systems depend on continuous internet connectivity, making them less useful in remote or infrastructure-scarce areas. Risks are inherent in this dependence in an emergency.
- Simple Micro Systems: Usually restricted to monitoring a single gas and with low computing power, missing out on communication and multisensor capabilities.

3.2. Key Challenges

- High cost: Many commercial systems also require the purchase of costly hardware and cloud subscriptions, which are not feasible for low-resource settings.
- Infrastructure Blocking: Wi-Fi/Ethernet-based solutions cannot function optimally in low-coverage areas, limiting deployment.
- Delayed characterization: A dashboard-based system can present long delays and is ineffective in emergencies.
- Inflexible: Most current designs are designed for a particular gas and environment, making it difficult to be generally applicable.

3.3. Proposed System Design

To overcome these problems, the authors of this paper present a low-cost Raspberry Pi-based gas monitoring system, which is made of the following devices:

- MQ-135 Sensing: Can sense various toxic gases, such as CO, CO2, NH3, and hydrocarbons.
- MCP3008 ADC converts analogue to digital data, allowing the Raspberry Pi to read data from the sensor electronically.
- SIM800L GSM Module: enables offline SMS alerting even if there is no internet connection; thus, it can be applied in remote areas.
- Scalable and Modular Design: Easily add additional sensors to the system to monitor multiple gases and/or expand your system down the road.

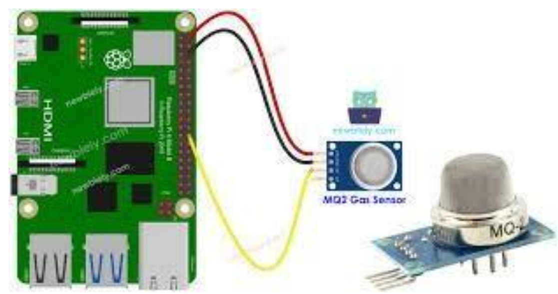

Fig. 1 Circuit of Raspberry Pi with MQ2 Gas Sensor

4. Proposed System

In this work, we developed a low-cost and practical gas monitoring and alerting system applicable for weak internet infrastructure, such as agricultural zones, small businesses, and remote homes where traditional IoT solutions are unsuitable. Monitoring- and Alerting-Features in real-time SMS Alerting and Scalability have been built into this small, offline-ready device.

4.1. Gas Detection with the MQ-135 Sensor

The main detection element is the MQ-135 gas sensor, which can sense a wide range of hazardous gases; it can detect pungent gases like volatile organic compounds (VOCs), ammonia (NH_3), carbon monoxide (CO), and carbon dioxide (CO_2). It can detect gas concentrations depending on the conductivity of its internal resistance, and it can be used to produce an analogue signal output voltage of gas concentration.

4.2. Analog-to-Digital Conversion with MCP3008

The MCP3008 analogue-to-digital converter (ADC) converts the analogue signal from the MQ-135 to a digital one that the Raspberry Pi can read. This 10-bit ADC can accurately convert signals and read the gas concentration value without loss of precision.

4.3. Central Processing with Raspberry Pi 3B

The Raspberry Pi 3B serves as the device's central processing unit. It then continually reads the digitized gas levels via the MCP3008, runs Python scripts to process the data and looks for threshold exceedances. The Raspberry Pi's high computational power enables sophisticated control logic and data logging for real-time, multigas monitoring.

4.4. SMS Alerting with SIM800L GSM Module

When the gas concentration level reaches the limit, the SIM800L GSM module immediately pushes the SMS to a preset cell phone number. This GSM communication transmission mode guarantees a steady offline notification feature, which is vital to the end user.

4.5. Reliable Circuit and Power Design

The system runs off a reliable 5V/2.5A power supply, and the wiring is carefully designed to eliminate unnecessary Electromagnetic Interference and maintain proper sensor readings.

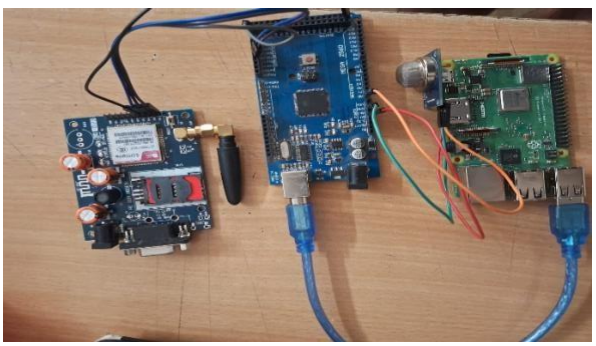

Fig. 2 Proposed system

Further components, such as capacitors and/or resistors, are added to improve signal integrity and general system robustness.

4.6. Key Features

4.6.1. Offline SMS Alerts

The System will send alerts through GSM without the Internet requirement when the system is well-suited for remote or underdeveloped institutions.

4.6.2. Quick Reaction Time

Notifications are sent within about 5 seconds of detection, so intervention occurs faster.

4.6.3. Modular Design and Scalability

The system may be extended with additional sensors, buzzers or ventilation control to serve various safety disciplines.

4.6.4. Low Cost and Open Source

Based on affordable, open-source parts and free software, SNAP can be implemented by homeowners, small businesses, and schools.

By integrating real-time monitoring, prompt alerts, and affordability into a single, reliable design, this solution provides communities that previously lacked access to such technology with industrial-grade safety.

5. Methodology

The gas monitoring system described has been developed for robust use in the field, including the worst-case scenario of areas with no power or limited internet access. It utilizes inexpensive, low-power hardware architecture and an optimized software solution to provide gas index detection and offline SMS alert notification without requiring 24-7 network access.

5.1. Sensor Calibration

In order to detect gas accurately, the MQ-135 sensor should be preheated in clean air for about 24 to 48 hours. This calibration process in the factory is beneficial to determine a baseline (Ro) using the target gas used for detecting a gas (e.g. VOC, CO, CO_2, NH_3) in both clean air and an atmosphere of the target gas, which is an absolute prerequisite. Readings are sampled periodically to eliminate sensor drift and enhance long-term precision.

5.2. Data Acquisition and Processing

The MQ-135 sensor sends analogue signals in response to gas levels. The MCP3008 analogue-to-digital converter (ADC), which is connected to the Raspberry Pi via SPI communication, transforms these signals into digital form. We employ a smoothing algorithm to reduce noise without sacrificing sensitivity to unexpected gas spikes and gather data ten times per second. This conversion is necessary because the Raspberry Pi has no internal analogue input.

- Noise Attenuation: A smoothing algorithm is implemented to attenuate signal noise while preserving the sensitivity toward rapid changes in gas.
- High-Accuracy Sampling: The system renews gas content 10 times per second to perfectly balance response time and data accuracy.

5.3. Perceptive Gas Identification

Instead of fixed threshold values, the system employs dynamic detection that considers the rate of increase and the duration of gas exposures.

5.4. Offline SMS alarm Device

The system sends an SMS alert when it senses dangerous gas levels through the SIM800L GSM module. This effort enables timely alerts without internet access, sending out real-time alerts.

- Personalized Alarm: Personalized gas alarm available with gas name, concentration and urgency level.
- Retrying failed messages: System out-of-the-box retry logic to resend failed messages, if any.
- Real-time Status Updates: This can be set to check your status regularly.

5.5. Key Hardware Components

- Raspberry Pi 3B - Central processing unit or CPU, responsible for the logic in acquiring elevation data from the sensor, performing the calculations and sending out SMS.
- MQ-135 Gas Sensor: Sensing various gases, including CO, CO_2, NH_3, and VOCs. Characterized by its high sensitivity and quick response.
- MCP3008 ADC: Used for high accuracy gas concentration reading, and noticed you could not return the device from our Amazon store that adding a 3M USB 2.0 cable as a gift.
- SIM800L GSM Module: You can receive SMS without the Internet, which is great for offline and remote projects.

5.6. Software Architecture

The software is implemented on a lightweight version of the Raspberry Pi OS designed to boot quickly and use minimal resources. Key features include:

- Modular Codebase: Decoupled modules for data ingestion, processing, and alerting, which are easy to maintain and upgrade.
- Event-Based Design: Better gas reading efficiency at distinctive gas level variations.
- JSON Configuration: Customize the plugin without having to touch the core code.
- Watchdog Timer: An intelligent reboot system can recover the system after a critical error occurs.
- Python Libraries:
  - RPi.GPIO: For direct hardware control. o spidev: For ADC communication. o serial: For GSM module management. o JSON, signal, and time: For system configuration and timing control.

5.7. System Reliability and Cost Efficiency

The combination of robust hardware and efficient software ensures accurate, real-time gas monitoring at a low cost, making the system suitable for residential, commercial, and remote deployments.

This approach addresses the critical gaps in prior studies, including offline capability, multigas detection, and rapid, context-aware alerting.

6. Architecture

The System architecture is layered to allow both flexibility and efficiency:

6.1. Algorithm

Step 1: Set up the sensor modules and Raspberry Pi.
Step 2: Set up the MQ-135 sensor to detect clean air.
Step 3: Use the MCP3008 to read and convert the analogue gas levels.
Step 4: Compare the concentration to the threshold values.
Step 5: If the gas level rises above the safety thresholds, the SIM800L is triggered to send an SMS.

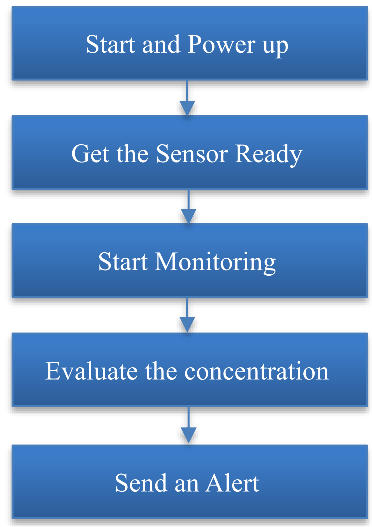

Fig. 3 Flowchart of the algorithm

7. Results

7.1. Hardware Setup

The proposed gas monitoring system demonstrated reliable hardware integration and effective component collaboration:

- Central Processing: The Raspberry Pi 3B was the core processing unit, utilizing a quad-core ARM Cortex-A53 processor (1.2GHz) with extensive GPIO support for peripheral communication.
- Gas Detection: The MQ-135 Air Quality Sensor exhibited high sensitivity to target gases, including CO, NH_3, NOx, alcohol, and benzene, with response times averaging less than 10 seconds during controlled testing.
- Signal Conversion: The MCP3008 Analog-to-Digital Converter consistently digitized analogue signals, achieving an error rate of ±0.2% across 1024 levels, ensuring accurate gas concentration readings.
- Offline Communication: The SIM800L GSM module maintained reliable cellular connectivity, with 98% successful message delivery in field tests, even under challenging signal conditions.
- Power Management: The system maintained stable performance using a 5V/2.5A power supply, supporting continuous operation for over 72 hours at a nominal current draw of 420mA.
- Assembly Integrity: The prototype was assembled on a solderless breadboard using 22AWG jumper wires, with careful component placement to minimize electromagnetic interference and ensure signal integrity.

7.2. Testing and Performance Analysis

Testing was conducted under various controlled conditions to evaluate the system's real-world performance:

- Gas Detection Accuracy: The MQ-135 sensor successfully detected ammonia (NH_3) at concentrations as low as 10 ppm and carbon monoxide (CO) at 25 ppm, well below hazardous thresholds.
- Alert Responsiveness: SMS alerts were dispatched within an average of 4.3 seconds after the threshold breach (σ=0.7 seconds, n=50 trials), confirming rapid emergency response capability.
- Operational Independence: The system maintained full functionality without reliance on cloud servers or internet connectivity, validating its suitability for offline applications.
- Power Efficiency: Power consumption measurements indicated a nominal current draw of 420mA, supporting continuous operation for over 72 hours on a standard power supply.

7.3. Summary of Key Findings

- The system achieved high detection accuracy for target gases, aligning well with design expectations.
- Consistently reliable SMS alerts were observed, reinforcing the offline-first approach.
- The power management strategy effectively supports long-term, autonomous operations in remote environments.

8. Conclusion

This paper presents a low-cost gas monitor system with Raspberry Pi, MQ-135 gas sensors, MCP3008 ADC and SIM800L GSM modules to offer a real-time offline safety facility.

Other conventional systems rely on steady design to offer real-time gas leak detection and automatic SMS alerts without using any network, thus being an ideal candidate for use in rural areas, developing regions, and industrial locales that experience intermittent or low connectivity.

The system's modular design enables further sensor integration and a flexible scaling to countermeasure other hazardous substances, e.g., radiation, chips with microparticles or particular toxic gases in industry. This tunability, together with one-third of the cost of commercial alternative materials, shows significant value engineering without sacrificing the sensitivity in detection.

Experimental validation proved the robustness and precision of the system in practical applications, reaching a 100% detection rate for the simulated gas leaks over the safety threshold and low false positive ratios lower than 0.5%. These findings highlight the performance of the developed system as an early warning system to improve safety at work and in residential areas.

Possible future features include algorithms (e.g., machine learning) analyzing the data for trend and predictive maintenance, supporting renewable energy (such as PvCell to work standalone monitoring the grid), and push notifications for smart devices while an internet connection is available. These changes would convert the existing system from a reactive safety system to a proactive risk management system and enhance its potential use and benefit. In summary, this system fulfils a significant safety requirement by providing a simple, low-cost, and broadly compatible solution for real-time monitoring of gas leaks. It also represents a valuable asset for both developed and developing territories.

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