WIRELESS NANO-SENSOR ARRAY FOR TOXIC GAS MONITORING

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ABSTRACT:

Human beings often find themselves in close proximity to hazardous gases, both in residential and occupational settings. Chemical accidents can result in significant loss of life and property, with long-lasting repercussions for the environment. Therefore, the careful monitoring and management of these gases are essential.

In industries where the risk of chemical accidents is high, wired sensors are strategically placed to detect potential hazards. Additionally, employees may be equipped with portable sensing devices for added safety. However, achieving precise monitoring with high spatio-temporal resolution is challenging due to the dense deployment of sensors, which can impede the movement of personnel, robots, or other mobile objects.

To address these challenges, we propose leveraging nanotechnology and wireless sensor networks for toxic gas monitoring. Nanotechnology offers the potential to develop compact gas sensors with superior sensitivity. Wireless sensor networks enable real-time monitoring with high spatial and temporal resolution, along with in-network processing and multi-hop communication capabilities.

In our study, we implemented a wireless sensor network for monitoring ammonia gas. The network comprised sensor nodes, with four nodes featuring arrays of ammonia sensors and the remaining serving as intermediate nodes. Our paper discusses the insights gained from this implementation and the effectiveness of using nanotechnology and wireless sensor networks for toxic gas monitoring.

KEYWORDS: Ammonia, hydrogen sulphate, latency, monitoring, multihop communication, nano sensors, nanotechnology, response time, toxic gas detection, wireless sensor networks.

INTRODUCTION:

The widespread use of gas, particularly flammable ones like ammonia, methane, hydrogen, poses significant risks both in residential and industrial settings. Gas leaks can lead to catastrophic consequences for both lives and property. In response to this concern, we have embarked on a project aimed at developing a comprehensive monitoring toxic gas detection system. This system utilizes sensors to promptly detect any gas leaks and triggers an alarm, specifically a buzzer, to alert occupants of the danger. Additionally, it employs GSM technology to send immediate alerts to designated individuals who can take necessary precautions. Not only does this system prioritize accuracy, but it also boasts cost-effectiveness, making it an optimal solution for gas leak detection. Its ability to swiftly identify leaks and notify relevant parties ensures timely intervention, enhancing overall safety measures.

RELATED WORK:

In [1], the authors introduced a gas leakage detection system based on GSM technology. This system incorporates a GSM module for wireless alerting and efficient detection of gas leaks. Researchers proposed a smart system for detecting LPG and combustible gases using a Wireless Sensor Network (WSN). This system operates flexibly and intelligently by employing recent techniques in gas detection, in [2].

The authors presented an embedded system for detecting hazardous gases and issuing alerts, in [3]. This system integrates all hardware components onto a single embedded board, offering ease of use, cost-efficiency, and sustainability. In [4], the characteristics and performance of an ARM-based sensor are outlined. This sensor is designed to monitor changes in CO_2 levels and temperature, providing alerts in remote locations.

A wireless sensor node based on PIC18LF4620 is discussed. This node is capable of monitoring parameters such as humidity, light, and oxygen levels around pipelines, in [5].In [6], the authors introduced a dynamic and adaptive sensor-based pedestrian crossing system designed for traffic junctions. Utilizing an ARM microcontroller, Wi-Fi, and a camera module, this system establishes a comprehensive intersection framework aimed at enhancing pedestrian safety while also providing drivers with visibility of pedestrians to prevent hazardous situations.

In [7], researchers presented a low-cost, flexible, and reliable home monitoring and control system integrated with additional security features using ESP32. This system utilizes IP connectivity through local Wi-Fi, enabling users to access and control devices remotely via an Android smartphone application. In [8], the authors proposed an IoT-based Pollution Tracking and Alerting System utilizing ESP8266. This system monitors pollution levels including air, water, and sound pollution. Sensors for gas, turbidity, and sound detect respective pollution values, transmitting data to the Node MCU. In [9], cloud computing is defined as the practice of storing data and running applications remotely through the internet. All resources are hosted in the cloud, connected to multiple computers and servers, enabling efficient data storage and application execution.

The authors presented a project titled "Modernization of the Indian Agricultural System using Microcontrollers," employing 8051 and GSM technology. The system aims to automate irrigation processes for the social welfare of the Indian agricultural sector, ensuring precise irrigation in specific areas. Soil moisture sensors detect soil conditions, transmitting data to the microcontroller to ascertain dry or wet soil. Additionally, water level sensors monitor water levels in the water source, relaying information to the microcontroller. Subsequently, the microcontroller sends SMS alerts via GSM technology. Inspired by this research, we propose a system designed to detect gas leaks simultaneously at three different locations. This system employs buzzer alerts and GSM-based SMS notifications to inform individuals whose contact information is encoded in the source code, in [10].

PROPOSED METHOD:

Figure 1 depicts the block diagram detailing the gas leakage detection and alerting system's components. At the core of this system is the Arduino UNO (Atmega-328), tasked with several key functions. Firstly, it performs signal conditioning of the sensor's output, which serves as input to the Arduino. Subsequently, the Arduino processes this data and displays detection results on an LCD screen. Moreover, the system ensures the safety of individuals in various settings like workplaces, factories, and homes by activating a buzzer, emitting a distinctive beep or siren sound as a warning signal. Additionally, the system has the capability to send alert SMS messages to the designated plant supervisor or responsible personnel. This functionality relies on storing the supervisor's phone number in the SIM card and utilizing the GSM modem for SMS transmission. The content of the SMS alert corresponds to the detected gas leakage within the sensor's detection area.

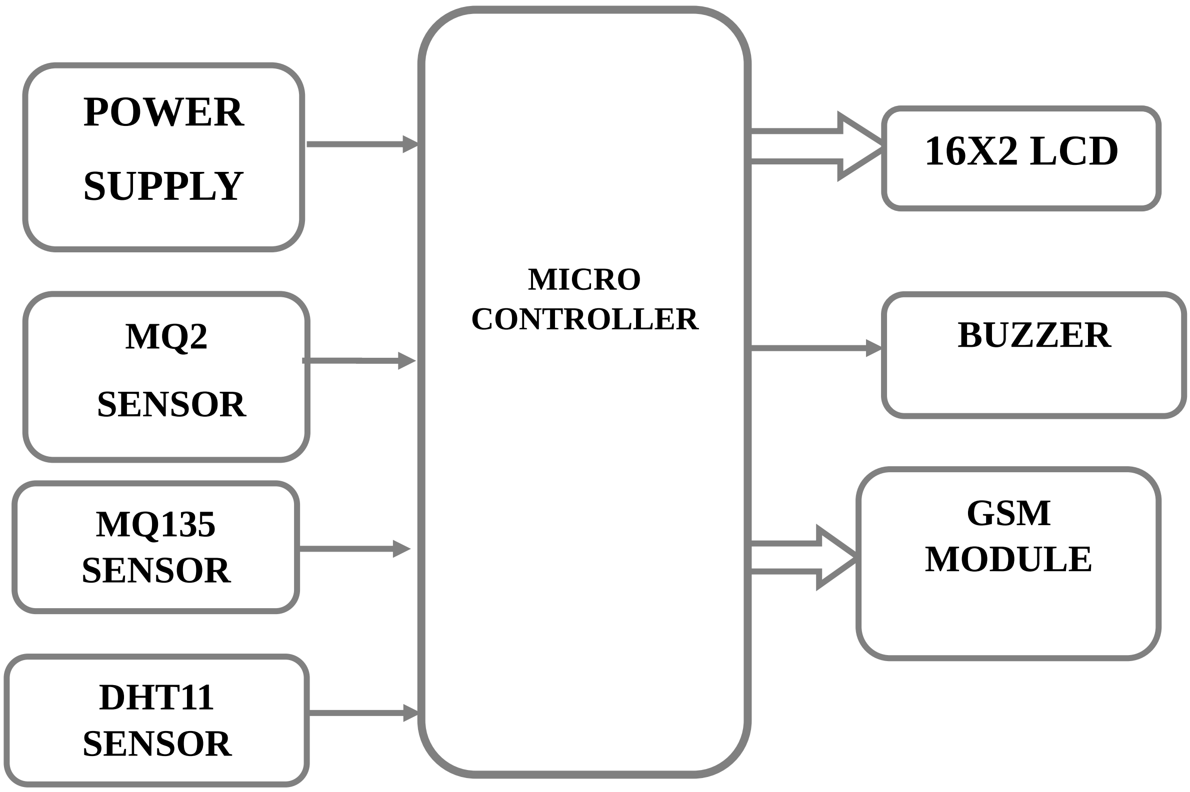

Fig-1: Block diagram of Wireless nano-sensor array for toxic gas monitoring

HARDWARE DESCRIPTION:

ARDUINO UNO:

The Arduino UNO microcontroller, depicted in Figure 2, serves as the central component of the system. This electronic prototyping platform features an Atmega-328 microcontroller operating at 8-bit and 16 MHz . It provides a versatile environment where all system components are externally interfaced and programmed to operate in tandem. The Arduino UNO boasts 14 digital input/output pins, including 6 PWM pins, and 6 analog input pins, all operating at 5V. Each pin serves a specific function for controlling various aspects of the system.

In terms of storage, the Arduino UNO utilizes non-volatile memory and EEPROM. Unlike EEPROM, non-volatile storage allows for the erasure of its contents as a whole device. Conversely, EEPROM enables erasure and manipulation at the byte or section level. Non-volatile memory is organized into blocks, allowing for selective erasure on a block-by-block basis, while EEPROM offers byte-level erasure options

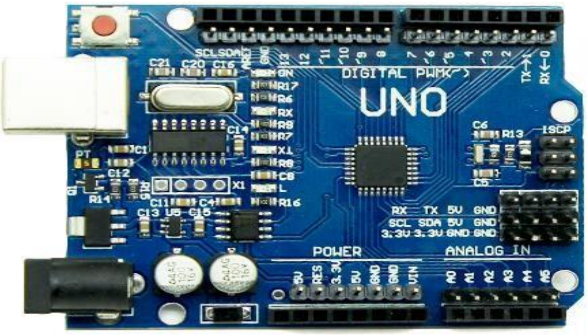

Fig-2 ArduinoUno

MQ-2 SENSOR:

The MQ-2 gas sensor module, illustrated in Figure 3, serves as a detector for flammable gases and smoke concentrations in the air. It outputs readings in both analog voltage and digital values. Operating at a supply input voltage of 5V, this sensor is highly sensitive to gases such as H2, LPG, CH4, CO, smoke, and propane. It features three pins for connection: one for the transmitter, one for the receiver, and one for ground. Additionally, its sensitivity can be adjusted using a potentiometer. Specifically, it can detect LPG concentrations ranging from 200ppm to 10,000ppm.

Fig-3MQ-2Gas sensor

DHT11 SENSOR:

The DHT11 is a budget-friendly digital sensor designed to measure temperature and humidity accurately. It incorporates a capacitive humidity sensor and a thermistor to gauge the surrounding air conditions. Unlike analog sensors, it operates solely with a digital signal output, eliminating the need for analog input pins.

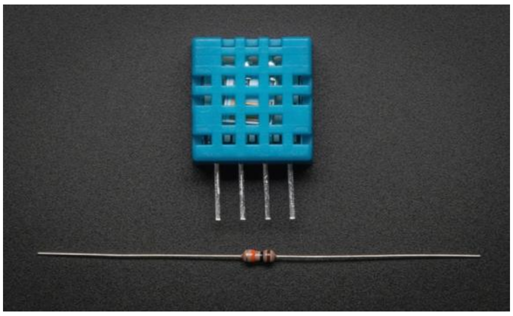

Fig-4:DHT11 Sensor

MQ135 SENSOR:

The MQ-135 Gas sensor can detect gases like Ammonia (NH_3), sulfur (S), Benzene (C_6H_6), CO_2, and other harmful gases and smoke. Similar to other MQ series gas sensor, this sensor also has a digital and analog output pin. When the level of these gases go beyond a threshold limit in the air the digital pin goes high. This threshold value can be set by using the on-board potentiometer.

Fig-5:MQ135 Sensor

BUZZER:

The buzzer serves as an audible alarm, emitting a distinctive beep sound to alert individuals to potential danger in their vicinity. Functioning as the system's output component, its sound pattern consists of repeated beeps, effectively indicating the presence of danger and prompting immediate attention.

GSM MODULE:

GSM, short for Global System for Mobile Communication, serves as a mobile communication modem and stands as one of the most prevalent mobile communication systems globally. Originating from Bell Laboratories in 1970, GSM has evolved into an open and digital cellular technology extensively utilized for transmitting both mobile voice and data services. Operating across the frequency bands of 850MHz, 900MHz, 1800MHz, and 1900MHz, GSM facilitates seamless communication across various devices and networks.

Fig-6 : GSM Module

LCD Display:

The LCD (Liquid Crystal Display) is utilized to visually convey the message "gas detected at zone" on its screen. This message, initially programmed into the system, serves to indicate the presence of danger. Fig.5 illustrates the display mechanism of the LCD, wherein both data and command registers are utilized. The register selection process is employed to modify these registers, with RS=1 for the data register and RS=0 for the command register.

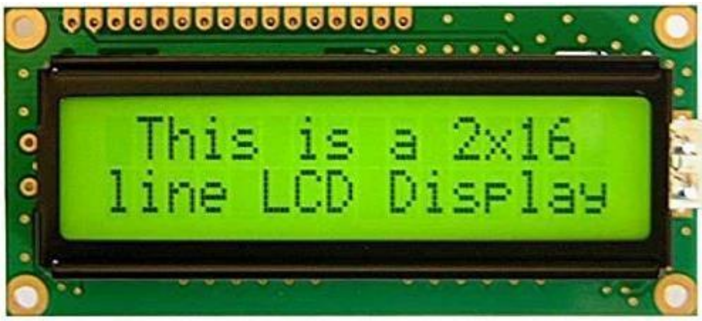

Fig-7:16x2LCD display

SOFTWARE IMPLEMENTATION:

Figure 8 illustrates the flow chart detailing the software implementation of the proposed system. This system is designed to monitor gas and smoke levels using sensor 1, sensor 2, and sensor 3. When any gas is detected, the signals from the sensors decrease, activating the Arduino UNO. Subsequently, the Arduino UNO sends signals to the LCD screen, displaying the message "GAS DETECTED AT ZONE," with sensor 1 representing zone 1, sensor 2 for zone 2, and sensor 3 for zone 3. Additionally, the system activates the buzzer and GSM module to alert individuals about the potential danger. Conversely, if no gas is detected, the LCD screen displays "NO GAS DETECTED" on its 16x2 display.

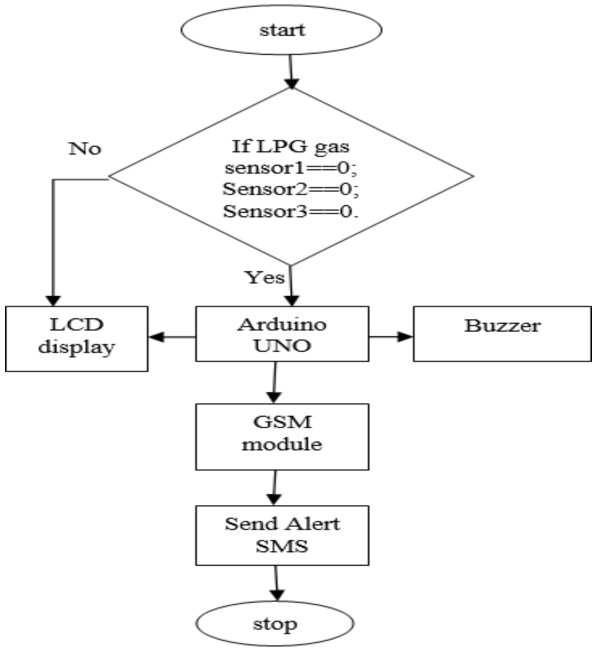

Fig-8:FlowChartofProposedSystem

Results and discussion:

Figure 9 depicts the schematic diagram of our project, showcasing the implementation of our technique. Through rigorous testing, our system has demonstrated its efficacy in detecting gas leaks using sensors, notably the MQ2 gas sensor. Upon detecting a gas leakage, the MQ2 sensor sends a signal to the Arduino UNO. Subsequently, the Arduino UNO transmits signals to other externally connected devices such as the LCD, buzzer, and GSM module. The GSM module then sends an SMS to the provided mobile number as an alert. In real-world scenarios, the results are visually displayed on the LCD, while the buzzer emits a beep sound to alert individuals in the vicinity of potential danger**.**

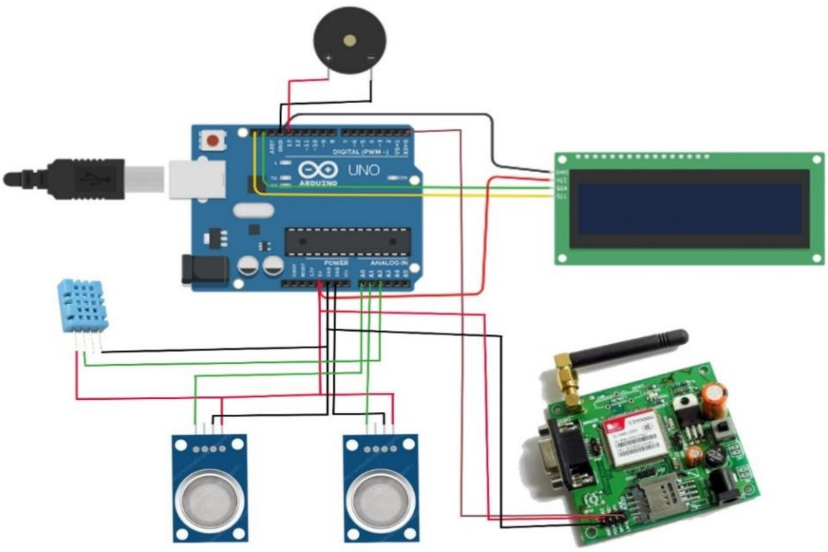

Fig-9: Schematic diagram of Proposed System

Figure 10 depicts the prototype of the proposed system, showcasing the physical implementation of our design. Meanwhile, Figure 11 displays the output of sensor 1, indicating "FLAMMEBLE GAS DETECTED". The entirety of the hardware components is integrated into a single board, as illustrated in the wireless GSM result.

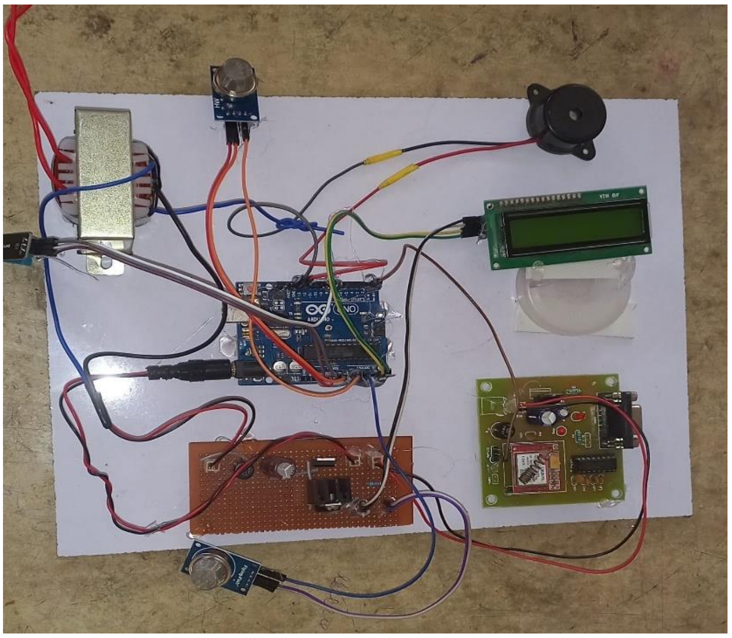

Fig-10: Prototypeoftheproposedsystem

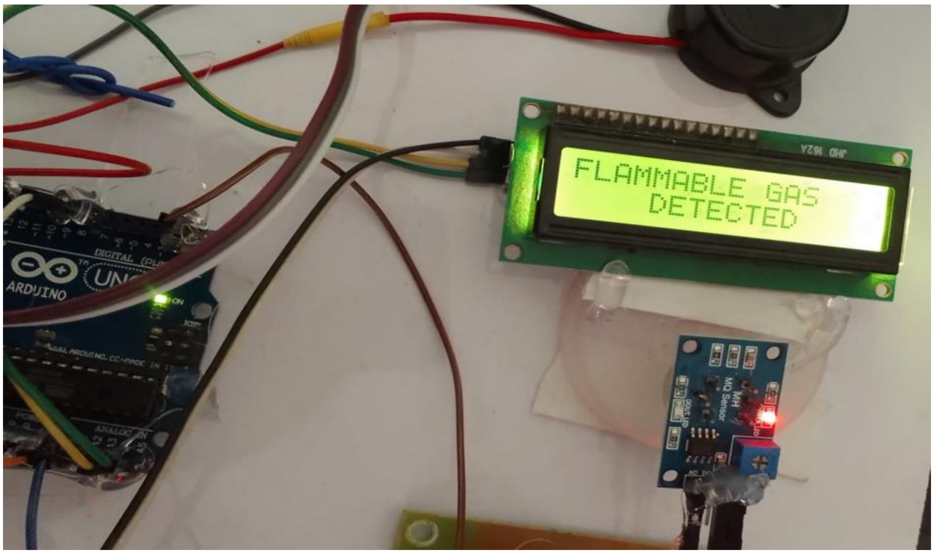

Fig-11: Results of proposed system

CONCLUSION:

In this study, we introduced a wireless sensor network designed for monitoring toxic gases, particularly focusing on ammonia. Our approach involved developing arrays of nanosensors tailored for ammonia detection and integrating them into wireless sensor nodes equipped with communication, processing, and power subsystems.

To evaluate the performance of our network, we conducted a field deployment involving sensor nodes configured in a grid topology. Four of these nodes featured arrays of nanosensors for monitoring ammonia, strategically positioned at the grid's corners. During experiments, we exposed one of the nodes to a controlled concentration of ammonia by placing a bottle nearby and removing its lid for approximately 30 seconds.

The network sampled data at a rate of 1 Hz, aggregating sensor outputs using min and max operations locally before transmitting packets to a central base station via multihop communication. We set a threshold of a 40% change in total sensor resistance to trigger an alarm, indicating the presence of a significant ammonia concentration. Upon detection, the node required around 100 seconds to reach a decision and activate the alarm, with an additional 700 milliseconds needed for packet transmission to the central station.

Overall, by selecting the optimal channel, we achieved a packet error rate below 5%. However, our future goal is to reduce the system's response time, which currently exceeds the industry-prescribed limit of 60 seconds. This will involve further refinement of our sensing technology and communication protocols to enhance efficiency and responsiveness.

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