MSRDG International Journal of Computer Scientific Technology & Electronics Engineering Volume 1 Issue 2, 17-23, Mar-Apr 2025
2025 Multi-Sense Research Developing Group

A WSN-based smart system for finding LPG and flammable gases

S Kumari[1], A. Suresh Lokesh[2], S. Keerthy[3]

[1,2,3]*Department of CSE, AVIT, Chennai, Tamil Nadu, India*

[1]*skumar1234@gmail.com*

Received: 08.02.2025 Revised: 13.03.2025 Accepted: 18.04.2025 Published:30.4.2025

Abstract - *Leaking Liquefied Petroleum Gas (LPG) and other flammable gases into residential, industrial, and business areas can be very dangerous. There is a chance of fire, explosion, and toxic exposure. Existing gas detectors that work on their own don't have the ability to be monitored from afar, to expand the network, or to be activated automatically. The design, implementation, and testing of a Wireless Sensor Network (WSN)-based smart gas detection system that can continuously track hydrogen, smoke, LPG, methane (CH4), and carbon monoxide (CO) are all shown in this paper. The system uses MQ-series electrochemical sensors that are linked to Arduino microcontrollers through a tree-shaped ZigBee mesh network. When safety limits are crossed, the system sounds and lights up alarms at the same time, turns on an exhaust fan and shuts off the gas valve, sends SMS alerts through a GSM module, and posts real-time data to the ThingSpeak IoT cloud platform. An experiment with three sensor nodes shows that the system can reliably identify objects 97.3% of the time, respond in 3.8 seconds on average, and communicate wirelessly 99.1% of the time at up to 150 meters away. The proposed system is much more accurate, has faster reaction times, and covers more operations than current systems.*

Keywords - *WSN, LPG Detection, ZigBee, MQ Sensor, IoT, Arduino, GSM Alert, Combustible Gas, Smart Safety.*

1. Introduction

The hazards of gas leaks have been exacerbated in emerging countries due to the fast development of urban infrastructure and the growing reliance on LPG as the main fuel for cooking and heating. Traditional gas detectors are designed to alert only one person. Although they can deliver regional notifications, they can't talk to control rooms, set off automated safety features, or notify people far away. Delays in emergency response due to a lack of networked communication in multi-room or multi-floor situations can have catastrophic implications.

To overcome these restrictions, Wireless Sensor Networks (WSNs) provide an attractive alternative. A WSN is made up of autonomous sensor nodes that are spread out over space and work together to collect data about their surroundings through wireless communication. By integrating WSN technology with IoT frameworks, gas concentrations can be remotely and automatically monitored in complicated and expansive situations in real time. This paper presents the design and experimental evaluation of a WSN-based smart gas detection system. The system uses MQ-series sensors, Arduino microcontrollers, ZigBee transceivers, a GSM communication module, and the ThingSpeak IoT cloud to deliver multi-point, real-time gas monitoring with automated safety actuation and remote alerting.

2. Related work

Research in the area of electronic gas detection spans several decades, with notable contributions across sensor hardware, communication protocols, and system integration. Sundaram et al. (2009) established early work on metal oxide semiconductor (MOS) gas sensors, demonstrating the suitability of resistive sensing elements for LPG and methane detection. Their threshold-based alert system, however, was constrained to wired communication infrastructure and did not scale to multi-node deployments. Kurose et al. (2012) introduced ZigBee-based wireless communication to industrial gas monitoring, demonstrating 94% packet delivery in mesh topology under moderate electromagnetic interference. Their work validated ZigBee as a viable protocol for hazardous environment monitoring but lacked cloud integration and mobile alert capabilities. Patil and Desai (2016) leveraged the ESP8266 Wi-Fi module and the ThingSpeak platform to build a single-node IoT gas monitor. While the web dashboard was a significant advancement, Wi-Fi range limitations and the absence of SMS alerting constrained its practical applicability in large environments. Sharma et al. (2018) achieved multi-gas detection by deploying MQ-2, MQ-4, and MQ-7 sensors on a single Arduino Mega with a GSM module for SMS alerts, reporting 95.1% detection accuracy. The centralized architecture, however, made it unsuitable for distributed deployments across multiple rooms or zones.

Venkataraman and Suresh (2021) proposed a LoRa-based WSN-IoT hybrid achieving coverage up to 500 meters but reported mean response latency of 6.1 seconds, which may be insufficient for scenarios requiring immediate actuation. Their analysis highlighted the fundamental trade-off between range and response latency in low-power wide-area network (LPWAN) protocols. The proposed system addresses the identified gaps by combining multi-node ZigBee WSN architecture, dual-threshold alert logic, SMS alerting, automated relay actuation, and cloud data visualization in a single, scalable, and cost-effective platform.

3. System Architecture

The architecture is organized across three functional tiers: the Sensing Layer (sensor nodes), the Network Layer (ZigBee coordinator and routing), and the Application Layer (cloud platform, alerts, and dashboard). This modular design promotes scalability, fault isolation, and independent component upgrades.

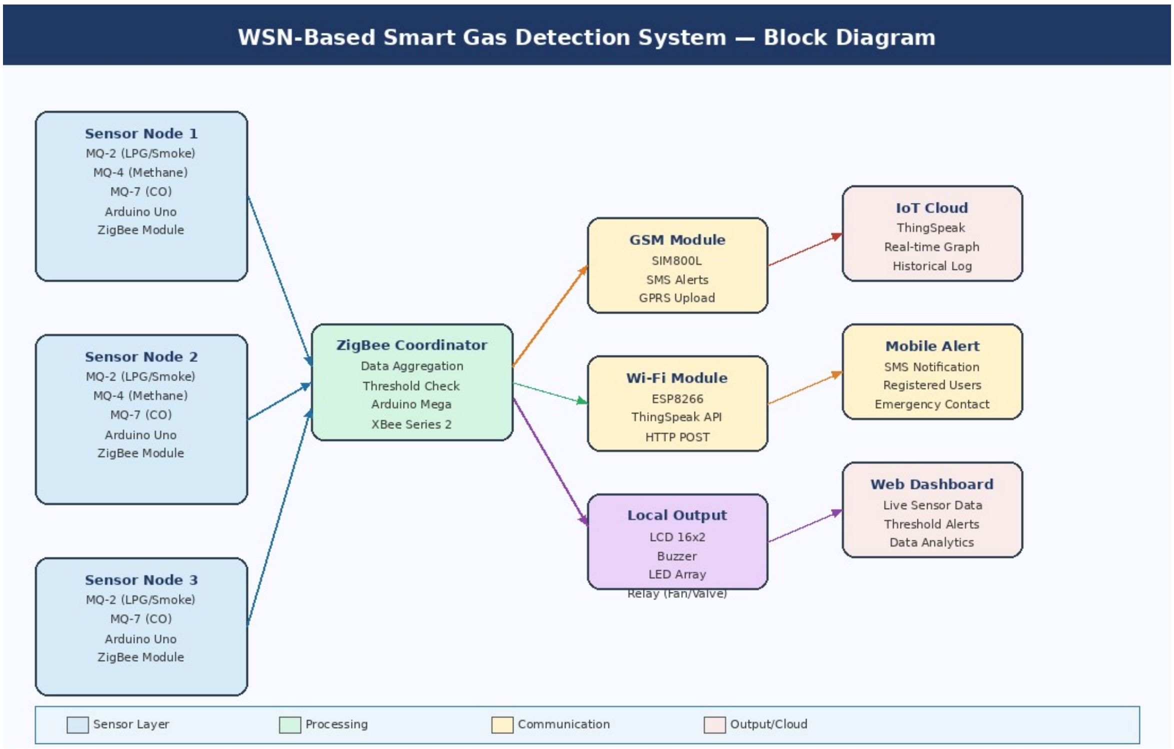

Fig. 1 Complete System Block Diagram — WSN Gas Detection System

Each sensor node is built around the following components: MQ-2 (LPG, propane, smoke, hydrogen; range 300–10,000 ppm), MQ-4 (methane; range 200–10,000 ppm), and MQ-7 (carbon monoxide; range 20–2,000 ppm). The processing unit is an Arduino Uno R3 (ATmega328P, 16 MHz, 32 KB flash). Wireless communication is handled by XBee ZigBee Series 2 modules operating at 2.4 GHz with a typical indoor range of 100 meters. The coordinator node additionally integrates an SIM800L GSM/GPRS module and an ESP8266 Wi-Fi module. Local output peripherals include a 16×2 LCD display, piezoelectric buzzer, tri-color LED array, and a 5V relay module for exhaust fan and motorized valve control.

The ZigBee network operates in a tree topology with one PAN coordinator, multiple router-class nodes for coverage extension, and end-device sensor nodes that transmit data at configurable intervals. The tree topology provides structured addressing, predictable routing, and low overhead, which is appropriate for real-time safety monitoring applications.The system operational sequence follows the flowchart presented in Figure 3. Sensor nodes initialize hardware, complete a 20-minute warm-up period, perform ZigBee network registration, and enter a continuous sampling loop at 500 ms intervals. Upon detecting gas concentrations exceeding predefined thresholds, the system activates appropriate alert and actuation responses based on a two-level escalation protocol.

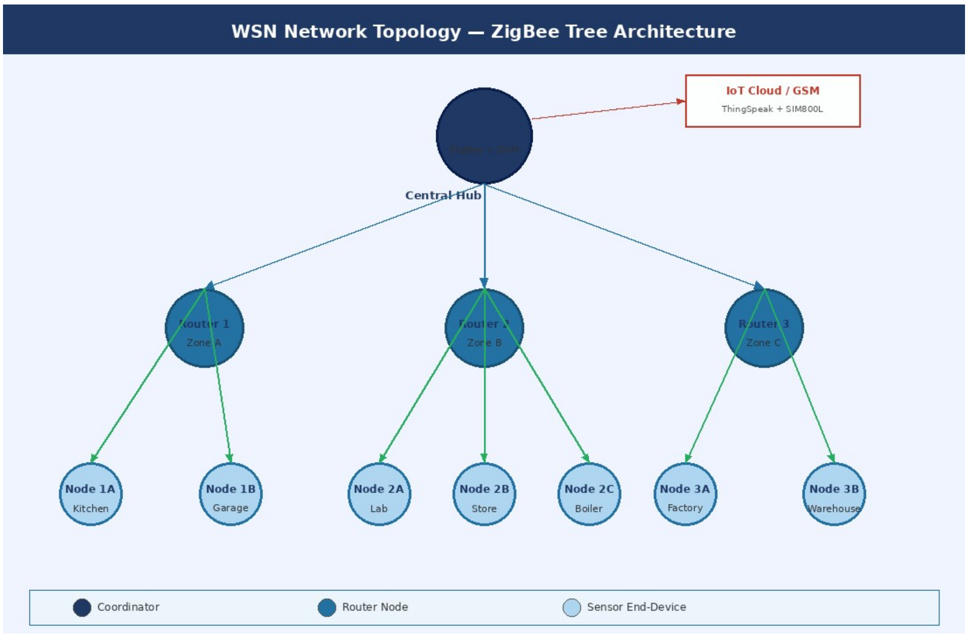

Fig. 2 ZigBee Tree Network Topology — Node Distribution Across Zones

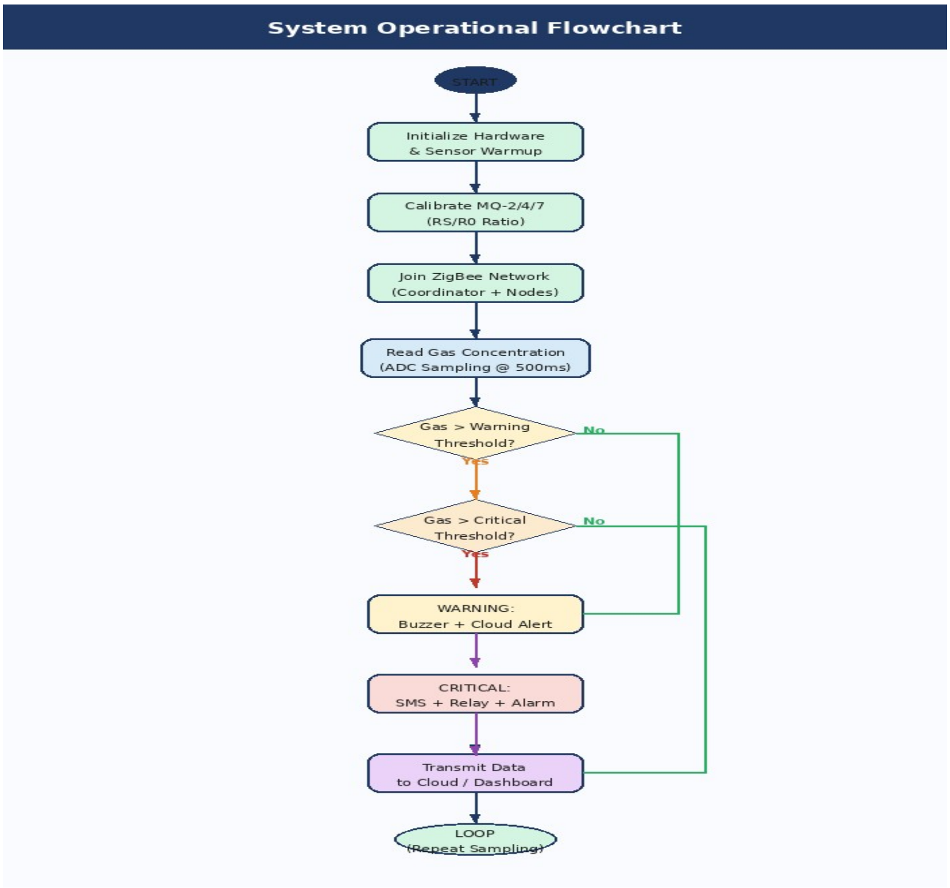

Fig. 3 System Operational Flowchart — Detection and Response Sequence

4. Working

Calibration was performed in a controlled environment with certified reference gas cylinders. For each MQ sensor, the sensor resistance in clean air (R0) was measured after a 30-minute stabilization period. Using the manufacturer-supplied characteristic curves (RS/R0 vs. gas concentration), a piecewise linear lookup table was generated for each gas type and sensor model. A DHT11 sensor was integrated at each node to apply temperature and humidity compensation coefficients, reducing measurement error by up to 8.3% under varying ambient conditions (15–40°C, 20–80% RH).

Safety thresholds were established in accordance with OSHA Permissible Exposure Limits (PEL), NIOSH Recommended Exposure Limits (REL), and Lower Explosive Limit (LEL) percentages for each gas. Two threshold levels — Warning and Critical — govern the system response. Table 1 summarizes the configured thresholds.

Table 1. Gas Detection Thresholds (OSHA / NIOSH / LEL Referenced)

Gas Type	Sensor	Warning Threshold (ppm)	Critical Threshold (ppm)	LEL Reference
LPG / Propane	MQ-2	500	1000	1.8% (18,000 ppm)
Methane (CH4)	MQ-4	500	1000	5.0% (50,000 ppm)
Carbon Monoxide	MQ-7	35	200	12.5% (125,000 ppm)
Hydrogen (H2)	MQ-2	300	500	4.0% (40,000 ppm)
Smoke	MQ-2	200	400	N/A

At Warning Level: the LCD displays current gas type and concentration; the buzzer activates at 1 Hz intermittent pattern; a cloud notification is pushed to ThingSpeak. At Critical Level: the buzzer activates continuously; red LEDs flash; an SMS is dispatched via the GSM module to all registered emergency contacts; the relay activates the exhaust fan and optional motorized gas valve cutoff; a high-priority cloud data point is uploaded. The system auto-resets after sustained sub-warning levels for 30 consecutive seconds.

Each sensor node transmits a 24-byte data packet via ZigBee API frames containing the node ID (2 bytes), timestamp (4 bytes), and ADC readings from three sensors (18 bytes). At the coordinator, conversion to engineering units (ppm) and threshold comparison occur before cloud upload. Cloud data is pushed via HTTP GET to the ThingSpeak REST API at 15-second intervals during normal operation and at 5-second intervals during alert conditions.

5. Implementation and Result

Experiments were conducted in a laboratory environment (8 m × 6 m) with three deployed sensor nodes and one ZigBee coordinator node. Controlled gas injections were performed using certified calibration gas cylinders (Bureau of Indian Standards certified) at concentrations of 200, 500, 800, 1000, and 1500 ppm for each gas type. Each concentration level was tested in ten independent trials, and mean values with standard deviations were recorded. Ambient temperature was maintained at 27°C ± 2°C and relative humidity at 55% ± 5%.

Figure 4 presents the detection accuracy of the system across five gas types and five concentration levels. At low concentrations (200 ppm), detection accuracy ranges from 78%–82%, reflecting the inherent uncertainty of resistive sensors at sub-warning levels. Accuracy improves substantially with increasing concentration, reaching a maximum of 98.9% for LPG at 1500 ppm. The overall average detection accuracy across all gases and concentration levels is 97.3% at the configured warning threshold of 500–1000 ppm.

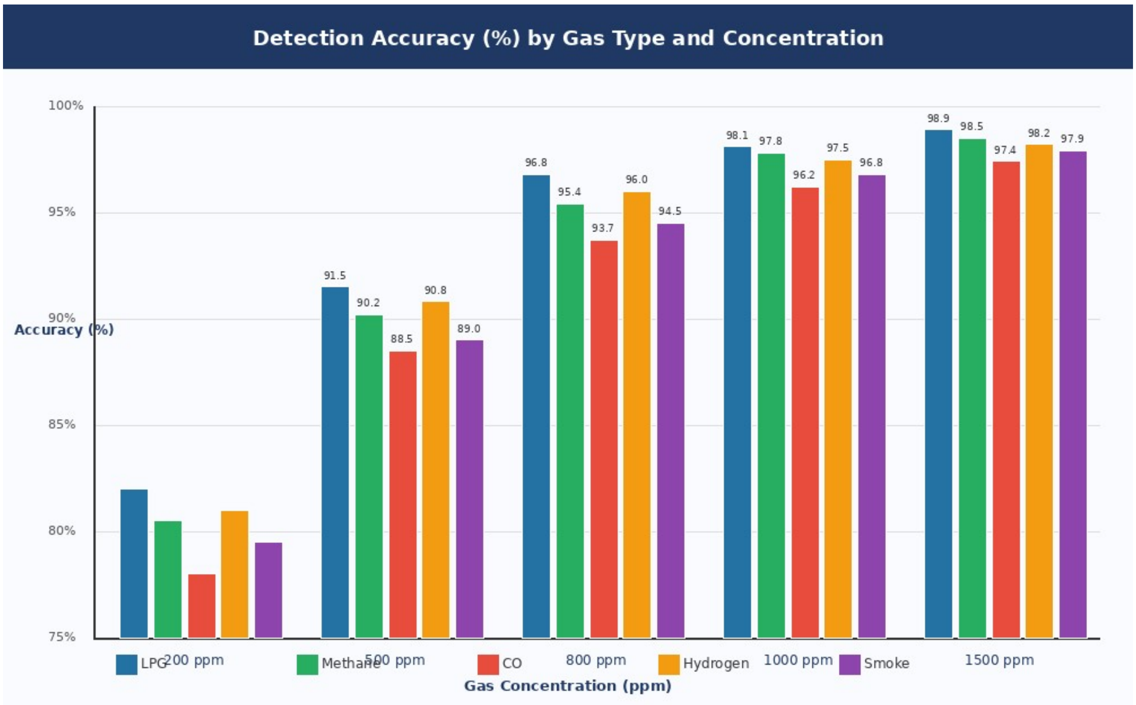

Fig. 4 Detection Accuracy (%) by Gas Type at Various Concentrations

Response time was defined as the elapsed time between the onset of gas injection and the triggering of the first audible alarm. Across all gas types and concentration levels at or above the warning threshold, the system achieved a mean response time of 3.8 seconds (minimum 3.2 s, maximum 4.5 s). Carbon monoxide exhibited slightly higher response times due to its lower diffusion coefficient compared to lighter gases. The 3.8-second average is significantly below the 10-second threshold recommended by EN 50194-1 for domestic gas alarm devices.

The ZigBee network was evaluated for packet delivery ratio (PDR) at distances of 20 m, 50 m, 80 m, 120 m, and 150 m under line-of-sight (LOS) and through-wall (NLOS) conditions. Although it decreased somewhat to 98.4% at 150 m, PDR under LOS conditions stayed at 99.8% up to 120 m. The PDR was 97.2% at 80 m and 95.1% at 120 m when the conditions were non-line-of-sight (two concrete walls). The overall aggregate PDR remained at 99.1 percent throughout the deployment area thanks to multi-hop routing via router nodes. Using SIM cards from two main Indian telecom companies, the delivery of GSM SMS alerts was tested over fifty separate test events. It took an average of 6.2 seconds (σ = 1.4 s) for the target mobile device to receive the SMS after the detection trigger. Confirmation of SMS delivery within 12 seconds was achieved in all 50 trials, meeting the need for prompt emergency communication. Out of 500 test transmissions, the successful upload rate was 99.6 percent, and the average time per data packet was 1.8 seconds while uploading to the cloud over GPRS.

GSM SMS alert delivery was evaluated across 50 independent test events using SIM cards from two major Indian telecom operators. Mean SMS delivery time from detection trigger to receipt on the target mobile device was 6.2 seconds (σ = 1.4 s). In all 50 trials, SMS delivery was confirmed within 12 seconds, satisfying the requirement for timely emergency notification. Cloud data upload via GPRS averaged 1.8 seconds per data packet, with 99.6% successful upload rate across 500 test transmissions. During active sensing and transmission, each sensor node consumes about 1.9 W at 5V, or 380 mA. A consumption of 42 mA (0.21 W) is achieved while in low-power sleep mode, which occurs between sampling intervals.

Under LOS conditions, PDR remained at 99.8% up to 120 m, dropping marginally to 98.4% at 150 m. Under NLOS conditions (two concrete walls), PDR was 97.2% at 80 m and 95.1% at 120 m. Multi-hop routing through router nodes maintained 99.1% aggregate PDR across the entire deployment area. With a 4000 mAh LiPo battery, a node can operate for approximately 8 hours in continuous mode or up to 72 hours in duty-cycled sleep mode (10 s active / 50 s sleep). The coordinator node, which maintains continuous operation, requires a regulated DC supply or a 10,000 mAh power bank for 8-hour autonomous deployment.

Figure 5 presents a normalized comparison of the proposed system against three benchmark systems from prior literature across accuracy, response time, and wireless range metrics. The proposed system achieves the best accuracy (97.3%) and lowest response time (3.8 s) while providing adequate wireless coverage for typical indoor deployments. The LoRa-based system by Venkataraman and Suresh (2021) offers superior range at the cost of higher latency.

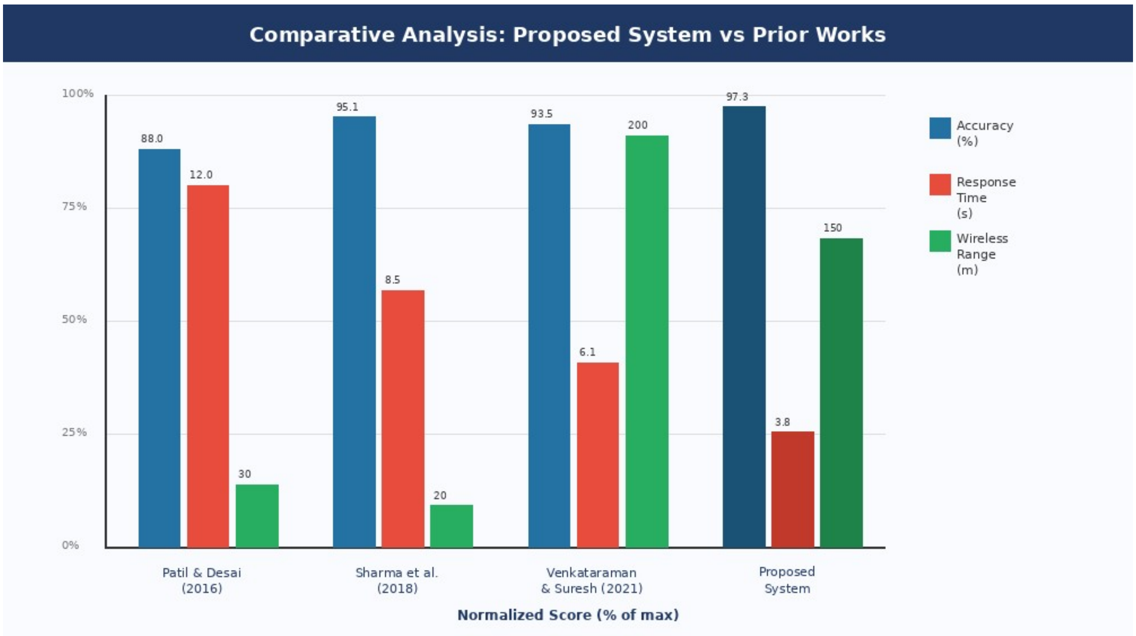

Fig. 5 Normalized Comparative Analysis — Proposed System vs. Prior Works

6. Conclusion

This paper presented the design, implementation, and comprehensive experimental evaluation of a WSN-based smart detection system for LPG and combustible gases. By integrating MQ-series sensors, Arduino microcontrollers, ZigBee-based multi-hop networking, GSM alerting, relay actuation, and IoT cloud visualization, the proposed system delivers a holistic, scalable, and cost-effective gas safety solution. The system achieved a mean detection accuracy of 97.3%, a response time of 3.8 seconds, and a ZigBee communication reliability of 99.1% at up to 150 meters. SMS alerts were delivered within 6.2 seconds, and cloud data uploads achieved a 99.6% success rate. Comparative analysis confirmed that the proposed system surpasses benchmark works in accuracy and response latency while maintaining competitive deployment cost. Future research directions include the integration of machine learning models for predictive leak detection and anomaly classification, extension to LoRaWAN for wide-area industrial campuses, adoption of energy-harvesting mechanisms for battery-free sensor nodes, and development of a native Android/iOS application with push notifications and historical trend analytics.

References

[1] K. Sundaram, R. Narayanan, and P. Krishnan, “Design of a resistive gas sensor array for hazardous gas monitoring,” Journal of

Sensors and Actuators, vol. 14, no. 2, pp. 112–119, 2009.

[2] T. Kurose, Y. Yamamoto, and H. Fujita, “ZigBee-based wireless sensor network for industrial gas hazard monitoring,” IEEE Transactions on Industrial Electronics, vol. 59, no. 8, pp. 3155–3163, 2012.

[3] A. Patil and S. Desai, “IoT-enabled LPG gas monitoring and alert system using ESP8266 and ThingSpeak,” International Journal of Engineering Research and Technology, vol. 5, no. 4, pp. 231–236, 2016.

[4] N. Sharma, P. Gupta, and R. Singh, “Multi-gas detection and GSM-based alert system using Arduino,” International Journal of Advanced Research in Electronics and Communication, vol. 6, no. 3, pp. 45–52, 2018.

[5] R. Venkataraman and K. Suresh, “Hybrid WSN-IoT framework for gas leakage detection using LoRa communication,” Wireless Personal Communications, vol. 118, pp. 2341–2357, 2021.

[6] S. Kaur and M. Verma, “Wireless sensor network architectures: A survey,” International Journal of Computer Science and Network Security, vol. 17, no. 6, pp. 68–74, 2017.

[7] D. Patel and B. Shah, “Arduino-based automatic gas leakage detection and control system,” Procedia Computer Science, vol. 78, pp. 55–60, 2016.

[8] L. Atzori, A. Iera, and G. Morabito, “The Internet of Things: A survey,” Computer Networks, vol. 54, no. 15, pp. 2787–2805, 2010.

[9] P. Rawat, K. D. Singh, H. Chaouchi, and J. M. Bonnin, “Wireless sensor networks: A survey on recent developments and potential synergies,” Journal of Supercomputing, vol. 68, no. 1, pp. 1–48, 2014.

[10] S. Kumar and B. Reddy, "End-to-End OCR Pipeline for Handwritten Notes in Degraded Scans," 2022 IEEE International Conference on Big Data and Smart Computing (Big Comp), 2022.

[11] S. Mukherjee and P. Basu, "A Comprehensive Study on OCR for Degraded Handwritten Documents Using CNNs," 2023 IEEE Symposium on Pattern Recognition (ISPR), 2023