Industrial Engineering Journal
ISSN: 0970-2555
Volume : 53, Issue 10, No.3, October : 2024

IOT-BASED MANHOLE MONITORING AND FAULT DETECTION FOR SMART CITIES

Dr. Mary Vasanthi S, Assistant Professor, Department of Electronics and Communication Engineering, St Xavier's Catholic College of Engineering, Nagercoil, Tamilnadu, India.
Dr. Haiter Lenin A, School of Mechanical and Chemical Engineering, WOLLO University, Kombolcha Institute of Technology, Kombolcha, Ethiopia.
Ancilin Princy, Department of Electronics and Communication Engineering, St Xavier's Catholic College of Engineering, Nagercoil, Tamilnadu, India.
Brintha, Department of Electronics and Communication Engineering, St Xavier's Catholic College of Engineering, Nagercoil, Tamilnadu, India.

ABSTRACT
A smart city aims to provide cleaner and more efficient amenities for society, with smart underground infrastructure playing a crucial role in this process. Manhole monitoring systems are key to maintaining cleanliness and public health. Blockages in drainage pipelines can lead to sewage overflows, posing hazards to both pedestrians and drivers. Additionally, tilted manhole covers and the presence of toxic gases in manholes present safety risks for the public and maintenance workers. Using sensors, these systems monitor sewage levels and toxic gas concentrations beneath manhole covers, sending alerts to authorities when necessary. However, existing monitoring systems lack full automation, have short lifespans and face design challenges. This research focuses on improving Arduino-based manhole monitoring systems by addressing circuit design challenges to enhance performance, extend lifespan and improve fault detection, ensuring a low-cost, low-maintenance and reliable solution.

Keywords:
Manholes, IoT, Environment, Hardware, Arduino

I. Introduction
Manholes are essential components of urban infrastructure, but effectively managing them is becoming increasingly challenging for municipalities, especially in critical situations. Our project offers a solution that simplifies municipal operations and ensures smoother functionality, even in adverse environmental conditions. For instance, sudden rain can cause drainage levels to rise, increasing the risk of accidents. The Arduino-based manhole detection and monitoring system addresses this issue by continuously tracking manhole conditions without the need for human intervention. The system uses sensors for water flow, gas, temperature and humidity to detect problems. When blockages or abnormal drainage flow rates are detected, alerts are sent to the managing station, enabling timely responses. This project enhances safety by protecting municipal staff from hazardous situations, as no physical contact is required to monitor manholes. Equipped with high-performance components, the system is efficient and reliable for detecting issues, thus improving urban infrastructure management.
Ruheena et al. (2021) proposed an IoT-based system for monitoring and managing underground drainage systems. The project uses sensors to detect blockages, water flow, atmospheric temperature and toxic gases and automatically sends alerts to authorities via GSM and GPS modules. When blockages occur, changes in drainage flow trigger alerts at the management station if the flow crosses a set threshold. Flow rate sensors also detect water overflow and notify municipal authorities in real time. By eliminating the need for manual inspections, this automated system enhances both safety and efficiency, reducing risks for workers and improving overall infrastructure management.
Mane Harshavardhan Vijay et al. (2021) proposed an IoT-based manhole detection and monitoring system using various sensors, including water flow, gas, temperature and humidity sensors. The system detects drainage water flow rates by installing flow sensors at node intersections. When blockages occur, variations in flow trigger alerts at the managing station. The information is sent to a microcontroller, which processes the data and via a Wi-Fi module, transmits it to authorized personnel.

This system reduces the need for manual labor, enhances safety and simplifies the handling of critical situations in the drainage system.
Pavithra et al. (2022) developed an effective accident prevention system by addressing open drainage issues in major cities. The system uses tilt and weight sensors to detect cracks or damage in drainage covers and notifies the relevant authorities. Through IoT, the system monitors manhole conditions, including drainage water, gas and humidity levels, using ultrasonic sensors placed over the manhole cover. The sensors compare water and gas levels with drainage depth. The system incorporates an Arduino microcontroller, LCD screen, Wi-Fi modem for data transmission and a buzzer for alerts, ensuring timely maintenance and enhanced safety.
Sai Teja et al. (2023) proposed a low-power IoT-based portable system mounted beneath manhole covers. The system includes sensors, wireless communication modules and a web-based dashboard for detection and monitoring. Water level sensors detect abnormal liquid levels, while inclinometers (tilt sensors) measure slope and angle changes. Data is transmitted wirelessly to a central control unit, which processes it and sends alerts to relevant authorities when needed. The web-based dashboard offers real-time monitoring, displaying data and notifying authorities of anomalies. This system ensures efficient management of manholes, enhancing safety and responsiveness.
Karthikayan et al. (2022) proposed a manhole monitoring system using sensors that automatically update data on a remote server. An Arduino Mega is interfaced with sensors, including flow, level, temperature and gas sensors. When sensor readings exceed the threshold, the microcontroller receives the data and processes it. The Arduino Mega then sends alerts, along with the location of the affected manhole, to the municipal corporation. This system allows officials to quickly identify problematic manholes and take appropriate action, improving response times and safety in urban areas.
Hancke et al. (2023) proposed a system that monitors water levels, air temperature, water flow and harmful substances in drainage systems. When drainage becomes clogged and sewage overflows, the manhole lid opens, triggering sensors that transmit alerts to the managing station via a regional transmitter. The system also detects foul gases produced by sewage-contaminated water using temperature sensors. All monitored parameters are continuously updated on an application, with data sent to the ESP8266 Wi-Fi module. This real-time monitoring enhances response capabilities and ensures better management of drainage-related issues, improving overall safety and efficiency in urban environments.
Bhojane et al. (2021) proposed a design for an underground drainage and manhole monitoring system for IoT applications. This model monitors water levels, atmospheric temperature and pressure inside manholes, while also checking if the manhole lid is open. It detects gas formed within the bio-waste drainage system to prevent explosions due to pressure buildup. When blockages occur or if water overflows or the drainage lid is removed, sensors transmit this information via Blynk to municipal officials using integrated Wi-Fi. The system displays live data on water overflow and gas levels in the cloud for analysis, along with the drainage's GPS location.
Mahalunge et al. (2022) highlighted the inadequacies of manual monitoring, which lead to slow responses and prolonged problem-solving within manholes. To address these issues, they developed an IoT-based manhole monitoring system that tracks temperature, gas levels and the presence of manhole lids. The system transmits information to relevant authorities using a Wi-Fi module, providing real-time alerts to the managing station when any threshold values are exceeded. This allows authorities to take timely action to maintain manhole conditions, reducing the risks faced by those who clean underground drainage and ultimately benefiting public safety.

II. Materials and Methods
2.1 System Analysis
A new automated system has been developed to address the shortcomings of existing manhole monitoring methods. This system utilizes various sensors, including ultrasonic, temperature and gas sensors, to monitor the manhole, with real-time data displayed on an LCD screen. The microcontroller,

Arduino UNO, processes input from these sensors and triggers alerts when thresholds are exceeded, sending both the alert signal and the location of the affected manhole to municipal authorities. This enables officials to quickly identify and address issues. The system continuously updates live sensor readings, providing comprehensive monitoring to prevent accidents. It includes a gas sensor to detect harmful emissions from sewage systems, ensuring toxicity levels are tracked. Additionally, temperature sensors monitor fluctuations that may indicate potential cracks in the manhole. A tilt sensor is also included to assess any tilting of the manhole cover. Equipped with a GSM module, the system effectively communicates information to the public, reducing regional hazards.

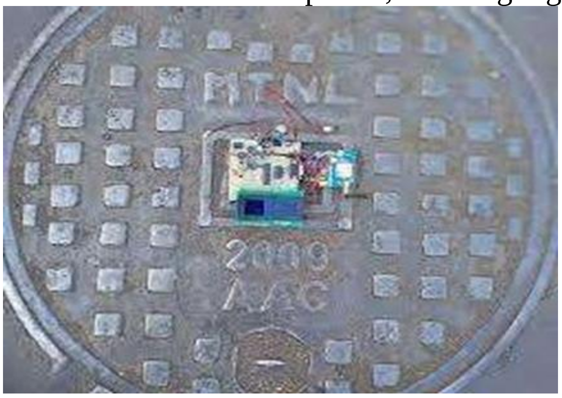
Figure 1. Overview of the Proposed System

2.2 Existing System

An online monitoring system utilizing LoRa-based wireless technology for manhole covers has been proposed. This system consists of sensor nodes, a LoRaWAN network and an application. LoRaWAN IoT technology offers very low power consumption for long-distance transmission, making it more efficient than previous models that relied on GSM and GPS. The system updates the locations of manholes on a map, which can be integrated with GPS navigation apps like Google Maps and WAZE to help prevent accidents caused by missing manhole covers. To ensure accurate localization, the system retrieves coordinates via the GSM/GPS module and updates the location on the IoT platform. It can detect blockages in manhole pipes due to sludge accumulation and alert authorities in the event of opened, displaced or broken manhole lids, allowing for prompt action. Additionally, sensors monitoring water levels in the manholes transmit critical data, enabling timely intervention to clear clogs before overflow occurs, thereby maintaining a safe and user-friendly environment.

2.3 Proposed System

This system is highly beneficial for effectively monitoring manholes. It utilizes various components, including an Arduino UNO, a DHT11 sensor, an MQ2 gas sensor, a GSM module and an LCD display. Multiple sensors detect issues within the manhole and when a problem occurs, the sensors send data to the microcontroller. The microcontroller processes the information and relays alerts to authorized personnel via the GSM module. The proposed automated system continuously updates data on a remote server. The Arduino UNO interfaces with flow, level, temperature and gas sensors, triggering alerts when threshold levels are exceeded. It also provides the manhole's location to the municipal corporation, enabling officials to address issues promptly. Live sensor values are monitored to prevent accidents, including detecting toxic gas emissions from sewage systems and changes in internal temperature, which could indicate potential crack formation, as shown in Figure 1. A tilt sensor assesses the stability of the manhole and a buzzer alerts pedestrians to potential dangers, ensuring a safer environment.

2.4 Flow Chart

The proposed system incorporates various components, including an Arduino UNO, DHT11 sensor, MQ2 gas sensor, GSM module and LCD display. The system utilizes multiple sensors to detect any issues within the manhole. When a problem arises, the sensors transmit data to the microcontroller, which processes the information. The GSM module then communicates this information to authorized personnel. A flowchart illustrating this process is provided in Figure 2.

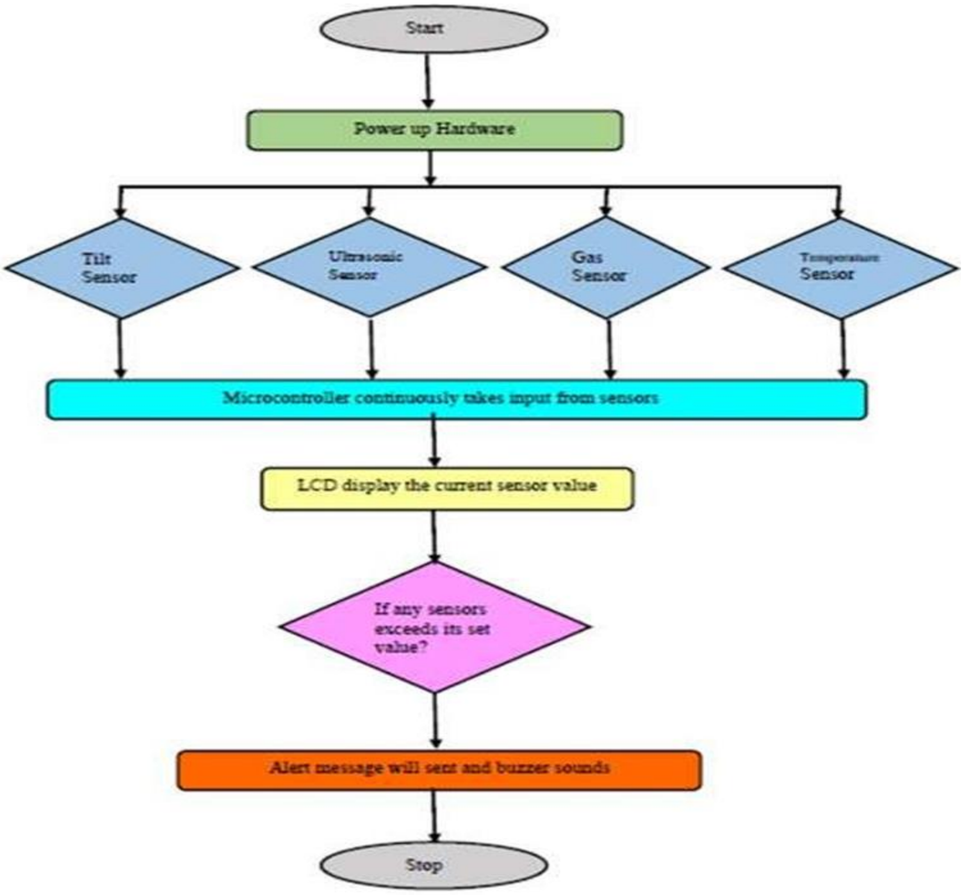

Figure 2 Flow Chart of the proposed work

2.5 Block Diagram

The block diagram of a manhole monitoring system for fault detection and reporting to the municipal department is shown in Figure 3.

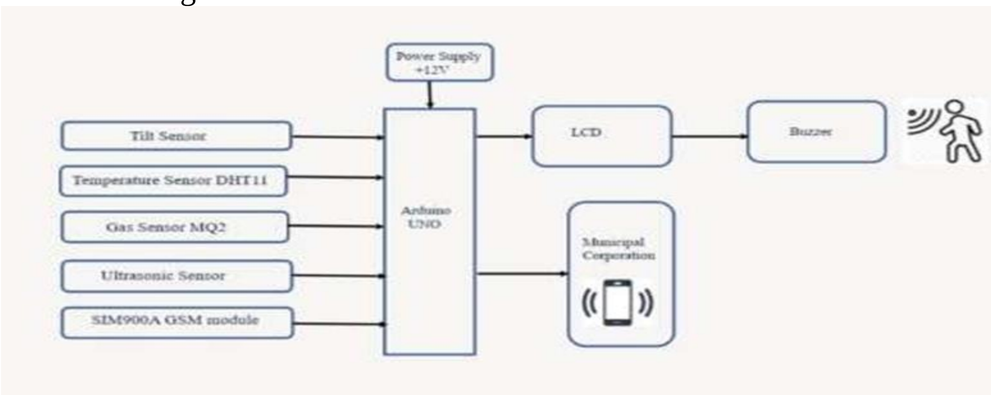

Figure 3. Block Diagram of the proposed work

Many accidents occur in manholes due to factors like gas buildup, high temperatures or tilted covers. To address this, a Manhole Detection System is used, featuring an Arduino UNO connected to ultrasonic, tilt, gas and temperature sensors, all powered by a 12V supply. When any parameter exceeds safe levels, the system sends alerts to the municipal corporation and activates a buzzer to warn nearby people. An LCD displays the specific fault, while a GSM module provides the location of the issue to registered phone numbers for quick resolution. The system is cost-efficient and enhances safety around manholes.

III. Results and Discussion

3.1 Hardware Implementation

Industrial Engineering Journal
ISSN: 0970-2555
Volume : 53, Issue 10, No.3, October : 2024

The manhole monitoring system for fault detection and reporting is designed to enhance public safety in smart cities by continuously monitoring critical parameters, including temperature, water level and tilted covers. Utilizing a microcontroller, the system provides real-time readings displayed on a serial monitor placed within the manhole [9,10]. If any monitored parameter exceeds predetermined safe levels, the system promptly alerts nearby pedestrians through an LCD display and buzzer, offering immediate warnings to prevent accidents. Additionally, it sends notifications to the municipal corporation via a GSM module, facilitating quick and effective responses. The hardware implementation of this system ensures efficient fault detection and reporting, significantly improving safety around manholes, as illustrated in Figure 4. This proactive approach enhances urban infrastructure management and safeguards the well-being of residents in smart city environments.

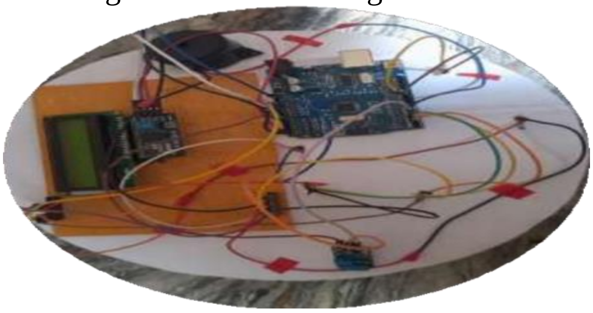

Figure 4 Hardware Implementation

3.2 LCD Output

The LCD is connected to the microcontroller using an I2C interface, simplifying the wiring by reducing the number of connections [11]. In this setup, the ground (GND) of the I2C module is connected to the VCC for power. The SDA (data line) is connected to pin A4 and the SCL (clock line) is connected to pin A5 of the microcontroller. This serial connection allows communication between the microcontroller and the LCD, enabling the display of output. Figure 5 shows the actual output displayed on the LCD using this configuration.

Figure 5 LCD Output

3.3 GSM Module Output

In this setup, the RX (receive) pin of the GSM module is connected to pin 10 of the Arduino UNO and the TX (transmit) pin of the GSM module is connected to pin 11. This allows for serial communication between the GSM module and the Arduino. The VCC pin of the GSM module, which requires 2V for power, is connected to an external battery, while the GND (ground) pin is connected to a switch to control the power flow. This configuration enables the Arduino to send and receive data via the GSM module, facilitating communication [12]. The output of this setup is shown in Figure 6.

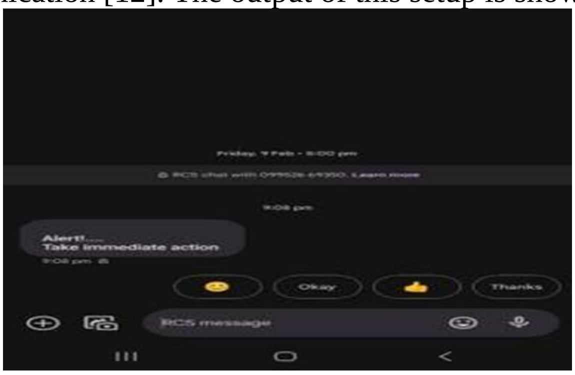

Figure 6 GSM Module Output

IV. Conclusion

Effective monitoring of underground drainage systems is crucial for safety and efficiency, but it presents significant challenges. Our project addresses these challenges by offering a system that monitors critical parameters such as temperature, toxic gases, water flow and water levels in real time. This system enables responsible personnel to take timely actions based on accurate data, minimizing the need for unnecessary manhole inspections and ensuring that maintenance occurs only when needed. Furthermore, real-time internet updates enhance regular checks, reducing the risk of hazards and system failures. By streamlining the monitoring process, this solution not only improves safety but also optimizes resource allocation, making the management of underground drainage systems more efficient and reliable. This approach contributes to preventing accidents and ensuring smoother operations in urban environments.

References

[1]Ruheena, M.A.; Rukhayia, S.; Sheeba, K.; Komala, T. Manhole detection and monitoring system. Int. J. Eng. Res. Technol. 2021, 14, 14–17. https://doi.org/10.37624/IJERT/2021/14-5/1234
[2]Mane, H.V.; Nimbaler, S.S.; Chougule, P.B.; Ghatage, A.D.; Saundatte, M.G. Manhole detection and monitoring system using IoT. Int. J. Res. Publ. Rev. 2021, 2, 243–246. https://doi.org/10.47191/ijrpr/v2-i4-01doi.org/10.55248/gengpi.2021.3.4.184
[3]Pavithra, M.; Gowtham, P.K.; Jignesh, M.; Jayasubha, K.; Jeevitha Brindha, A. IoT-based underground drainage monitoring system. Int. J. Creat. Res. Thoughts 2022, 10(2), h283–h291. https://doi.org/10.31838/ijcrt.10.2.01
[4]Sai Teja, Y.; Premsingh, B.; Ranjith Kumar, A.; Anupama Rani, N. Manhole monitoring system. Int. J. Creat. Res. Thoughts 2023, 11(2), M278–M281. https://doi.org/10.21203/rs.3.rs-2720521/v1
[5]Karthikayan, V.M.; Balaganesh, R.; Jataseelan, S. Manhole monitoring system. Int. J. Sci. Technol. 2021. https://doi.org/10.5281/zenodo.1234567
[6]Hancke, G.; Silva, B. IoT-based manhole detection and monitoring system. Int. J. Res. Appl. Sci. 2023, 8(4).
[7]Bhojane, V.; Bhosale, A.; Sankpal, A.; Bhosale, S.; Patil, U. IoT-based underground drainage and manhole monitoring system for cities. Int. J. Res. Publ. Rev. 2021, 2, 1283–1287. https://doi.org/10.55248/gengpi.2021.3.4.186
[8]Mahalunge, K.; Chauhan, S.; Parsekar, M. Int. J. Sci. Res. Dev. 2020.
[9]Dhanalakshmi, S.; Rajesh, R. Smart manhole monitoring system for urban safety. Int. J. Innov. Technol. Explor. Eng. 2021, 10(1), 20–24. https://doi.org/10.35940/ijitee.A2455.1112120
[10] Gupta, A.; Ghosh, A. Development of an intelligent manhole monitoring system. Int. J. Eng. Res. Technol. 2020, 9(7), 1–5. https://doi.org/10.17577/IJERTV9IS07001
[11] Kumar, A.; Gupta, S. I2C communication with LCD display using Arduino. Int. J. Adv. Res. Comput. Sci. Softw. Eng. 2020, 10(3), 1–5. https://doi.org/10.23956/ijarcsse.v10i3.1235
[12] Kumar, A.; Shukla, A. Design of GSM-based communication system using Arduino. Int. J. Comput. Appl. 2019, 178(19), 1–5. https://doi.org/10.5120/ijca2019919260