"IoT Based Manhole Monitoring System"

REPORT

Abstract

In modern urban environments, the maintenance and monitoring of municipal infrastructure are critical for ensuring public safety and efficient city management. One such infrastructure component is the manhole, which provides access to underground utility networks. Traditional methods of monitoring manholes are labour-intensive, costly, and often reactive rather than proactive. This paper presents an IoT-based Manhole Monitoring System designed to address these challenges by providing real-time data on the status of manholes.

The proposed system leverages Internet of Things (IoT) technology, including a network of sensors, wireless communication modules, and cloud-based data analytics. Sensors placed within the manholes monitor key parameters such as water levels, toxic gas concentrations and any tilt in the manhole cover. This data is transmitted to a central authority through an e-mail notification to detect potential issues such as blockages, flooding, hazardous gas leaks, and security breaches.

The system features a user-friendly dashboard accessible via web and mobile applications, providing real-time alerts and comprehensive reports to municipal authorities. By enabling proactive maintenance and rapid response to incidents, the IoT-based Manhole Monitoring System enhances urban infrastructure management, reduces maintenance costs, and improves public safety.

The implementation of this system demonstrates the potential of IoT in transforming traditional municipal services, offering a scalable and efficient solution for smart city initiatives. The paper discusses the architecture, implementation, and performance evaluation of the system, highlighting its benefits and potential for future enhancements.

Keywords-*IoT, Manhole Monitoring, Smart Cities, Real-time Monitoring, Urban Infrastructure, Sensor Networks, Cloud Computing, Public Safety***.**

INTRODUCTION

Urban infrastructure management is a cornerstone of modern city governance, with manholes serving as critical access points to subterranean utilities such as sewage, stormwater drainage, and communication networks. Effective monitoring and maintenance of these manholes are essential to prevent issues such as drainage overflow, toxic gas accumulation, and unauthorized access or tampering. Traditional manual inspection methods are often inadequate due to their reactive nature, high labor costs, and inefficiency.

To address these challenges, this paper introduces an advanced IoT-based Manhole Monitoring System specifically designed to monitor drainage overflow, detect toxic gases, and sense any tilt in the manhole cover. This innovative system aims to transform the conventional approach to manhole maintenance by enabling real-time monitoring and automated notifications.

The system employs a network of IoT sensors strategically placed within manholes. These sensors continuously measure critical parameters, including water levels to monitor overflow conditions, gas concentrations to detect the presence of hazardous gases, and the angle of the manhole cover to identify any tilt or displacement. The collected data is transmitted wirelessly to a central authority.

When the system detects anomalies such as drainage overflow, dangerous gas levels, or unauthorized tampering indicated by a tilted cover, it triggers an automated email notification to the central authority. This immediate alert mechanism ensures that municipal authorities can respond promptly to potential hazards, thereby mitigating risks to public health and safety.

A user-friendly dashboard, accessible via web and mobile applications, allows authorities to monitor the status of all connected manholes in real time, receive alerts, and generate comprehensive reports. This proactive approach not only enhances the efficiency and effectiveness of manhole maintenance but also contributes to the broader goals of smart city initiatives by leveraging technology to create safer and more resilient urban environments.

This introduction provides an overview of the motivation behind developing the IoT-based Manhole Monitoring System and outlines its key functionalities. The subsequent sections will detail the system architecture, implementation, and performance evaluation, highlighting the significant benefits and future potential of this technological advancement in urban infrastructure management.

PROBLEM STATEMENT

Urban infrastructure management faces significant challenges in effectively monitoring and maintaining manholes, which are essential access points to underground utilities such as sewage, stormwater drainage, and communication networks. Traditional methods, reliant on periodic manual inspections, are inadequate due to their labor-intensive nature, high costs, and reactive approach. These limitations result in delayed responses to critical issues such as drainage overflow, toxic gas accumulation, and unauthorized tampering or displacement of manhole covers. The lack of real-time monitoring and automated notification systems hinders the ability of municipal authorities to proactively address these hazards, posing risks to public health, safety, and the overall efficiency of urban operations. An innovative solution is required to provide continuous, real-time monitoring and immediate alerts, enabling prompt and effective intervention.

PROJECT SCOPE

The scope of this project involves the design, development, and implementation of an IoT-based Manhole Monitoring System that provides real-time monitoring of drainage overflow, toxic gas levels, and any tilt in manhole covers. The system will deploy advanced sensors to measure water levels, detect hazardous gases, and monitor the position of manhole covers. Data collected by these sensors will be transmitted wirelessly to a central server for processing and analysis. The system will feature an automated email notification mechanism to alert central authorities of any detected anomalies, ensuring prompt and effective response. Additionally, a user-friendly dashboard will be developed for real-time monitoring, accessible via web and mobile applications. The project includes requirements analysis, hardware and software development, system integration, testing, deployment in selected pilot areas, performance evaluation, and user training, with comprehensive documentation and support to ensure long-term functionality and scalability.

METHODOLOGY

The methodology for developing a manhole monitoring system using NodeMCU ESP8266, MQ-2 gas sensor, ultrasonic sensor, and tilt sensor, with email notification, involves several key steps. First, the system design is established by defining the requirements for monitoring drainage overflow, toxic gas detection, and cover tilt. The hardware setup includes selecting and connecting the MQ-2 gas sensor, ultrasonic sensor, and tilt sensor to the NodeMCU ESP8266, ensuring proper circuit design and assembly. Firmware is developed for the NodeMCU to read sensor data, process it, and transmit it wirelessly to a central server. The server stores the data and triggers email notifications to authorities when anomalies such as high gas levels, water overflow, or cover displacement are detected. A web-based dashboard is created for real-time monitoring and alert management. The integrated system is rigorously tested through unit, integration, and field tests to ensure accuracy and reliability. The system is then deployed in selected manholes, with proper installation and configuration, followed by user training for municipal staff. Performance is continuously evaluated and optimized based on feedback and real-world data, ensuring the system's effectiveness and scalability. Comprehensive documentation and ongoing support are provided to maintain long-term functionality.

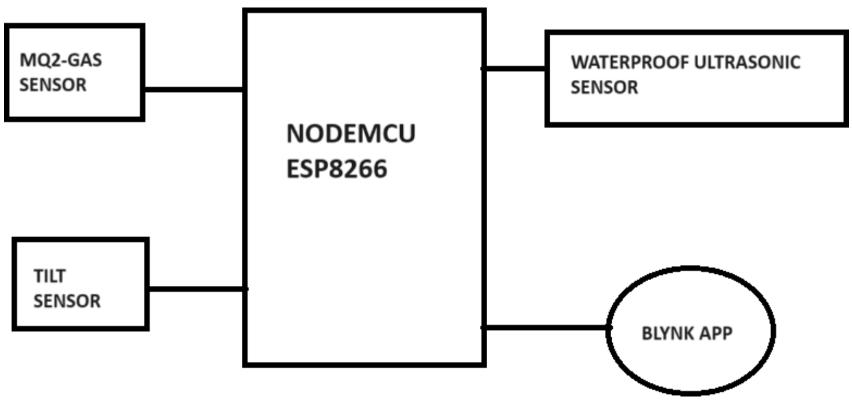

Fig 1- Block Diagram

COMPONENTS REQUIRED

1. NodeMCU ESP8266
2. MQ-2 Gas Sensor
3. JSN SR-04T Waterproof Ultrasonic Sensor
4. KY-017 Mercury Tilt Switch Module
5. Breadboard
6. Jumper Wires

CIRCUIT DIAGRAM AND EXPLANATION

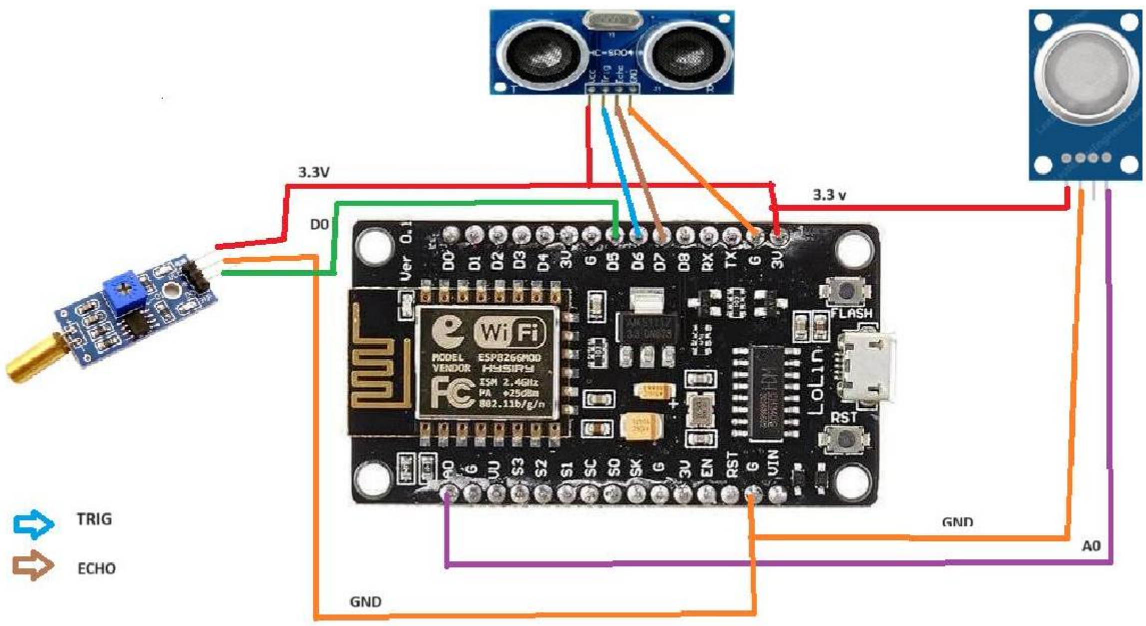

Fig 2- Circuit Diagram

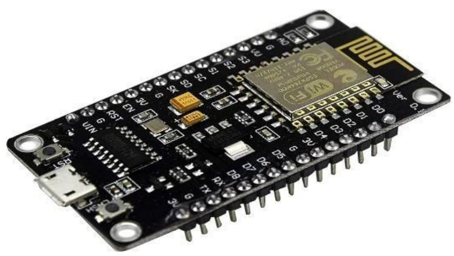

Fig 3- ESP8266 NodeMCU

The ESP8266 WiFi Module is a self-contained SOC with integrated TCP/IP protocol stack that can give any microcontroller access to your WiFi network. The ESP8266 is capable of either hosting an application or offloading all WiFi networking functions from another application processor. Each ESP8266 module comes pre-programmed with an AT command set firmware, meaning, you can simply hook this up to your Arduino device and get about as much WiFi-ability as a WiFi Shield offers (and that's just out of the box)! The ESP8266 module is an extremely cost effective board with a huge, and ever growing, community.

Fig 4- MQ 2 Gas Sensor

MQ2 is a <u>metal oxide semiconductor</u> type gas sensor. Concentrations of gas in the gas is measured using a <u>voltage divider</u> network present in the sensor. This sensor works on 5V DC voltage. It can detect gases in the concentration of range 200 to 10000ppm.

Fig 5- KY-017 Mercury Tilt Switch Module

A mercury tilt sensor is a switch used to detect the orientation or tilt of an object. It consists of a sealed glass or metal tube containing a small amount of mercury and one or more electrical contacts. When the sensor is tilted, the mercury flows and bridges the contacts, completing an electrical circuit. Known for its simple design and high reliability, this sensor is effective in applications such as older thermostats, consumer electronics, industrial equipment, and safety devices. However, due to mercury's toxicity and environmental hazards, its use has significantly declined, replaced by safer and more modern technologies like MEMS accelerometers and solid-state tilt sensors.

Fig 6- JSN SR-04T Waterproof Ultrasonic Sensor

A waterproof ultrasonic sensor is a device designed to measure distance or detect objects in environments where exposure to water or moisture is a concern. It operates by emitting ultrasonic sound waves and measuring the time it takes for the echo to return after reflecting off an object. The sensor's waterproof housing ensures reliable performance in wet or underwater conditions, making it ideal for applications such as level sensing in tanks, proximity detection in marine environments, and obstacle avoidance in outdoor robotics. Known for its durability and accuracy, the waterproof ultrasonic sensor is essential in industries requiring robust and reliable distance measurement solutions under challenging environmental conditions.

Working Principle

The manhole monitoring system operates by integrating several sensors with a NodeMCU ESP8266 microcontroller to provide real-time monitoring and alerts. The ultrasonic sensor is positioned to measure the water level inside the manhole, detecting overflow conditions. The MQ-2 gas sensor monitors the air quality, sensing the presence of toxic gases such as methane and carbon monoxide. The tilt sensor is attached to the manhole cover to detect any unauthorized movement or displacement. Data from these sensors are continuously read by the NodeMCU ESP8266, which processes and transmits the information wirelessly to a central server. When the system identifies abnormal conditions—such as high water levels, dangerous gas concentrations, or cover displacement—it triggers an automated email notification to the central authority, alerting them to take prompt action. The system also features a web-based dashboard for real-time monitoring, providing authorities with accessible and comprehensive data to ensure efficient maintenance and quick response to potential hazards.

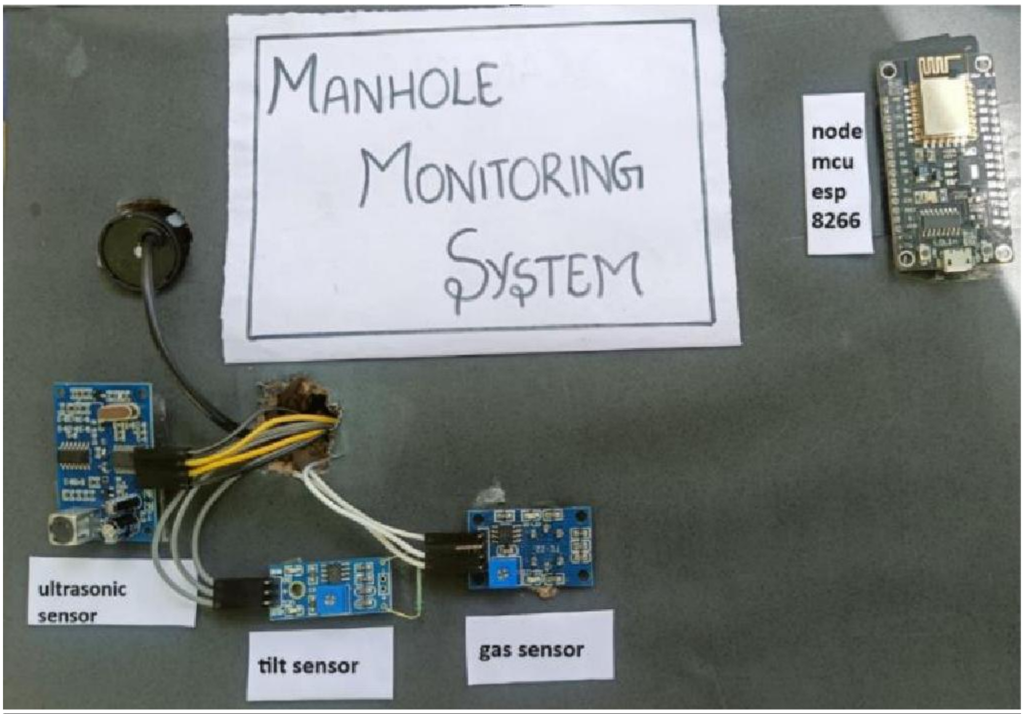

Fig 7 - Circuit connection.

OUTPUT -

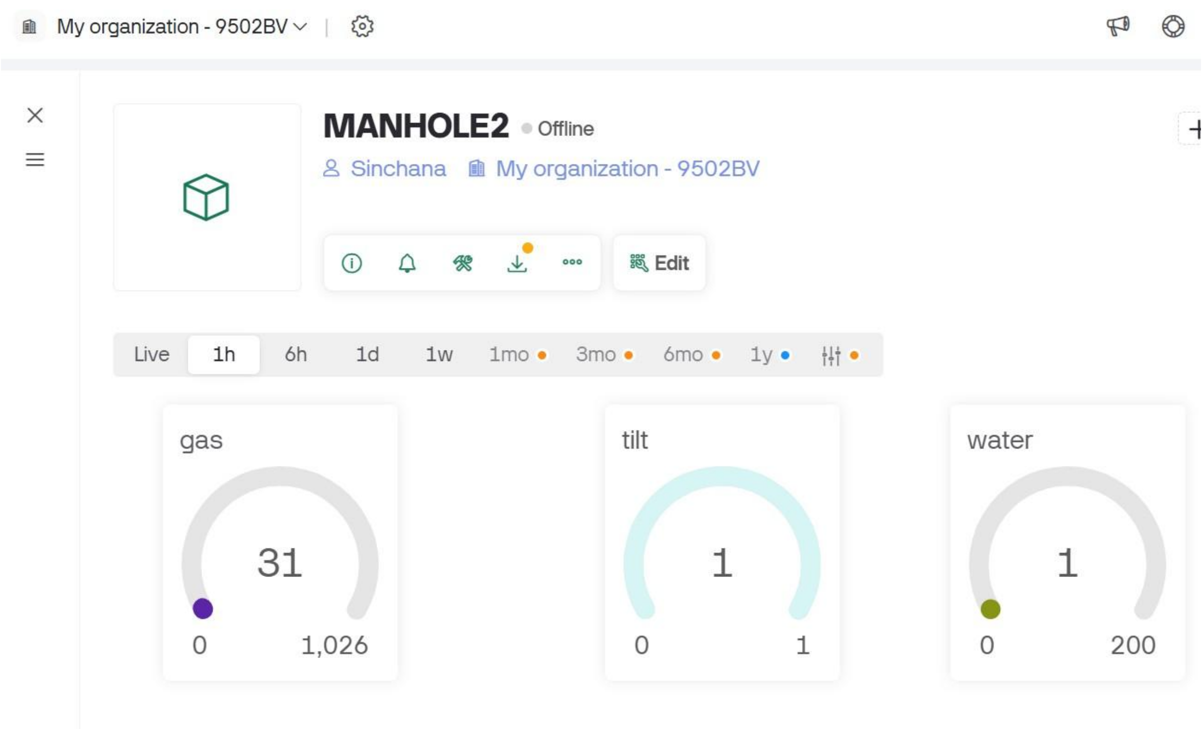

Fig 8- Notification in Blynk App

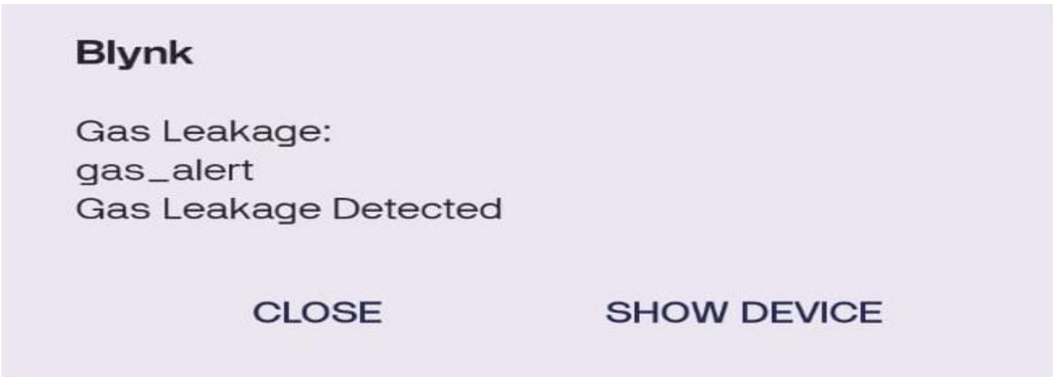

Fig 9- Message Sent to Mobile

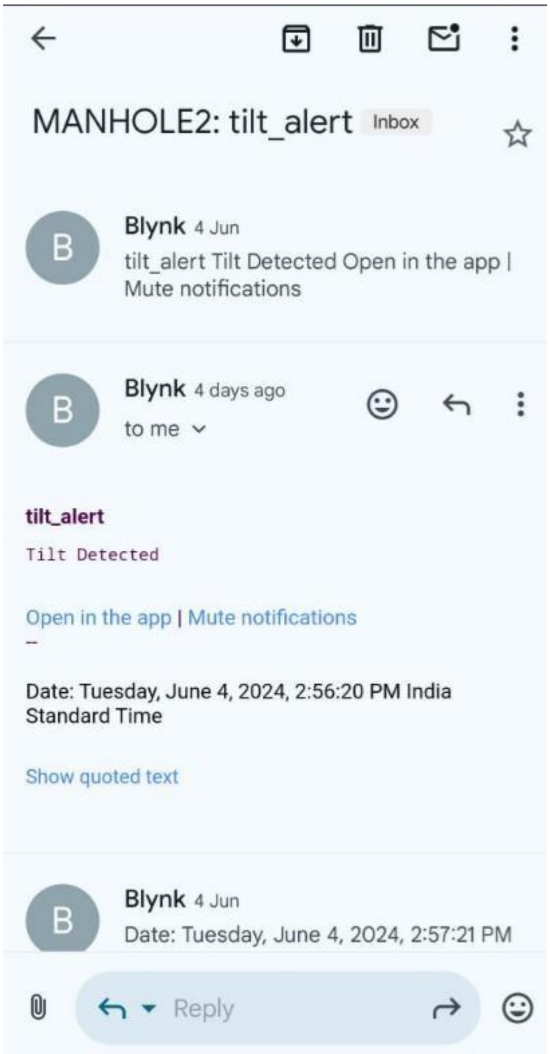

Fig 10- Mail to Mobile

APPENDIX SOURCE CODE

```
#define BLYNK_TEMPLATE_ID "TMPL36e-R2KBa"

#define  BLYNK_TEMPLATE_NAME  "MANHOLE2"

#define BLYNK_AUTH_TOKEN "VrTXzaNZY3kO-XjXqhq3Pr8wg3a8jrEY"

#define BLYNK_PRINT Serial

#include <ESP8266WiFi.h>

#include <BlynkSimpleEsp8266.h>

#include <NewPing.h>  // Library for the ultrasonic sensor


#define sensor D5

#define ECHOPIN D7

#define TRIGPIN D6

int sensorPin = A0;


char auth[] = "VrTXzaNZY3kO-XjXqhq3Pr8wg3a8jrEY";

char ssid[] = "Redmi 9 Power";  // Type your wifi name

char pass[] = "756f9bf538c2";  // Type your wifi password


BlynkTimer  timer;

NewPing sonar(TRIGPIN, ECHOPIN, 200);  // Max distance set to 200 cm

void setup() {

  Serial.begin(9600);

  pinMode(sensor, INPUT);

  pinMode(ECHOPIN, INPUT_PULLUP);

  pinMode(TRIGPIN, OUTPUT);
```

```
 digitalWrite(ECHOPIN, HIGH);
 Blynk.begin(auth, ssid, pass);
 timer.setInterval(2500L, sendSensor);
}
void sendSensor() {
 int readings = digitalRead(sensor);
 int val = analogRead(A0);
 digitalWrite(TRIGPIN, LOW);
 delayMicroseconds(2);
 digitalWrite(TRIGPIN, HIGH);
 delayMicroseconds(15);
 digitalWrite(TRIGPIN, LOW);
 int distance1 = pulseIn(ECHOPIN, HIGH, 26000);
 int distance = distance1 / 58;
 Serial.print("Distance: ");
 Serial.print(distance);
 Serial.println(" cm");
 Blynk.virtualWrite(V0, distance);
 Blynk.virtualWrite(V1, val);
 Blynk.virtualWrite(V2, readings);
 if (readings == 1) {
 Serial.println("Tilt Detected");
  Blynk.logEvent("tilt_alert", "Tilt Detected");
 }
 if (distance <= 20) {
```

```
    Serial.println("Water Level Reached");
    Blynk.logEvent("water_alert", "Water Level Reached");
  }
  if (val > 500) {
    Serial.println(val);
    Serial.println("Gas Detected");
    Blynk.logEvent("gas_alert", "Gas Detected");
  }
}
void loop() {
  Blynk.run();
  timer.run();
}
```

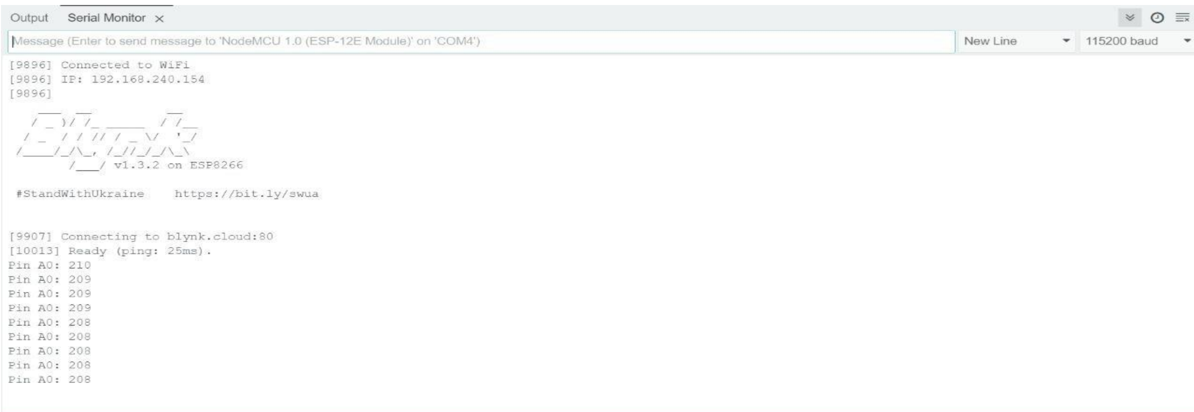

Fig 11- Output seen on Serial Monitor

CONCLUSION

In conclusion, the development and implementation of the IoT-based manhole monitoring system using NodeMCU ESP8266, MQ-2 gas sensor, ultrasonic sensor, and tilt sensor represents a significant advancement in urban infrastructure management. By providing real-time monitoring of drainage overflow, toxic gas levels, and manhole cover displacement, this system enables proactive maintenance and rapid response to potential hazards. The automated email notification feature ensures that central authorities are promptly alerted to any anomalies, thereby enhancing public safety and operational efficiency. The system's user-friendly web-based dashboard offers accessible and comprehensive data for continuous monitoring. Overall, this innovative solution not only addresses the limitations of traditional manhole inspection methods but also contributes to the broader vision of smart cities by leveraging technology to create safer and more resilient urban environments.

PROJECT LIMITATIONS

 Connectivity Issues:

- The system relies on wireless communication via the NodeMCU ESP8266, which may face connectivity issues in areas with poor Wi-Fi coverage or interference, potentially leading to data transmission delays or failures.

 Sensor Durability:

- The harsh environment inside manholes, characterized by moisture, dirt, and extreme temperatures, may affect the longevity and reliability of the sensors. Regular maintenance and replacement may be required.

 Power Supply:

- Providing a continuous and reliable power supply to the sensors and NodeMCU ESP8266 in remote or hard-to-access manholes can be challenging, especially if the system relies on batteries that require frequent replacement or recharging.

 Calibration and Accuracy:

- Sensors such as the MQ-2 gas sensor and ultrasonic sensor may require regular calibration to maintain accuracy. Environmental factors and sensor degradation over time can affect measurement precision.

 Data Security:

- Transmitting sensitive data over wireless networks introduces potential security risks. Ensuring robust encryption and secure data transmission protocols is essential to protect the system from unauthorized access and cyber-attacks.

FUTURE ENHANCEMENTS

Future enhancements for the manhole monitoring system can focus on improving its robustness, efficiency, and scalability. Integrating advanced low-power communication technologies such as LoRaWAN or NB-IoT can address connectivity issues and extend coverage to areas with poor Wi-Fi signals. Enhancing sensor durability through ruggedized designs and materials will increase their lifespan and reliability in harsh environments. Implementing solar-powered modules or energy-harvesting techniques can provide a sustainable power solution, reducing the need for frequent battery replacements. Incorporating machine learning algorithms for data analysis can improve anomaly detection accuracy by learning from historical data and environmental patterns. Expanding the system's capabilities to include additional sensors, such as pressure sensors or cameras, can provide more comprehensive monitoring. Enhancing data security through advanced encryption methods and secure communication protocols will protect against cyber threats. Developing a modular and scalable architecture will facilitate the integration of the system with existing municipal infrastructure and enable easy expansion to cover more manholes. Lastly, creating detailed training programs and user-friendly interfaces will ensure effective adoption and utilization by municipal staff, maximizing the system's impact on urban infrastructure management.

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