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A Smart Manhole Monitoring and Detection System

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Abstract: An intelligent manhole cover management system is a crucial foundation in a smart city to effectively prevent frequent accidents related to manhole covers. Proper management of the drainage system is essential for ensuring the safety of residents. Regular inspections alone can lead to flooding and blockages in the drainage system. The displacement, relocation, and deterioration of manhole covers pose serious risks to personal safety, which contradicts the goals of smart city development. The system incorporates multiple sensors to monitor the status of manholes, including detecting lid openings, cover theft, and temperature variations. Additionally, this paper aims to analyze real-time levels of toxic gases. If the gas levels exceed the predetermined threshold, alerts will be sent to the authorized individuals through their connected mobile devices, even if they are remotely located.
Keywords: IOT (Internet of Things), smart city, manhole, sensors.

I. INTRODUCTION

Technology has significantly impacted various fields today. In modern cities, critical systems like the electrical grid, network, and drainage are located underground. Manhole covers are installed in pavements to facilitate access to these systems. However, accidents resulting from the displacement, loss, and damage of manhole covers are common, endangering lives and safety as vehicles and individuals may fall into these uncovered holes [1]. This undermines the fundamental purpose of smart cities. To ensure the well-being of sanitation workers who face health risks, an IoT system and network have been developed to detect harmful gases, including methane (CH4), carbon monoxide (CO), ammonia (NH4), and SO2, among others. Failure to properly decontaminate sewage when it reaches hazardous levels can lead to accidents and illnesses, such as influenza and dysentery, caused by prolonged exposure to toxic gases and pollutants.

Additionally, the status of manhole covers, including damage or loss, is typically assessed through periodic inspections conducted by government officials and reports from individuals on the road. However, these inspections require significant human resources to cover a large number of manhole covers in a city, and they do not provide real-time performance [2].

Addressing the issue of manhole cover theft is challenging without a monitoring mechanism for conventional covers. Moreover, since different types of manholes may belong to different governmental organizations, thefts not only result in public property losses but also increase the risk of exposed holes. These pressing challenges have prompted the development of intelligent systems to manage all manhole covers in a city, particularly in smart cities [3],[4].

An effective intelligent manhole cover management system should possess the following features:

1) Self-perception: Each manhole cover should have the ability to detect if it is slanted, damaged, or displaced, as well as determine its location.
2) Active real-time alerts: Manhole covers should be capable of actively alarming in real time when they are tilted, damaged, or relocated.
3) Real-time response: The intelligent management system should promptly respond to manhole cover alerts and enable real-time scheduling of repair personnel.
4) Low management expenses: The intelligent system aims to reduce costs associated with human resources, bandwidth, and energy consumption.
5) Short average repair time: The primary objective is to minimize the risk of falling into uncovered manholes by significantly reducing the average repair time for tilted, damaged, or displaced covers.

The aforementioned approach enables minute-by-minute tracking and monitoring of variables, ensuring comprehensive electronic surveillance of gases, sewage pollutants, and discharge through gutters. This robust system contributes to efficient sanitation management, addressing the shortcomings of previous solutions.

II. LITERATURE REVIEW

In the existing literature, several smart drainage systems have been proposed. For instance, V. Vani [5] introduced an IoT and Zigbee WSN based system that utilizes ultrasonic and flow sensors to detect drainage leakage and overflow. One of the advantages of this system is its ability to detect water clogging in pipes in advance, thereby preventing public issues and reducing revenue loss for the government. Notably, this system does not require human labor for clog detection.

Another model discussed in Ref. [6] addresses the problem of diseases caused by obstructed drains in various locations in Bangladesh. The proposed system utilizes both GSM and WiFi modules, and the threshold values can be adjusted based on the size and water flowing capacity of the manhole system in different areas.

In Ref. [7], a model focuses on accurately locating manholes by utilizing a GPS system and GSM module for alert messages through the cellular network. The system employs an ARM7 microcontroller and various sensors.

Ref. [8] proposes a model that continuously monitors environmental parameters within the drainage system. When sensor values exceed the threshold limit, an alarm is triggered to indicate unsafe working conditions for the workers. The collected data is also transmitted through a communication channel, significantly reducing the threat to the lives of sewage workers.

According to Muragesh SK and Santhosha Rao [9], sensors and networks are critical components of IoT systems, and they are implemented in underground engineering drafting and manhole monitoring systems (UDMS) used in IoT applications.

Ref. [10] presents a model for monitoring smart cities to enhance management and development. The system comprises sensors that collect various types of data, which are then transferred to the Raspberry Pi3 controller. The output from the controller is sent to the control room via email and displayed on a personal computer.

In Ref. [11], different methods for monitoring and managing underground drainage and manhole systems are proposed. Real-time monitoring and updates of parameters such as temperature, toxic gases, flow, and water level are achieved using the Internet of Things.

Ref. [12] introduces a method for localizing and monitoring all manholes using 3D surveillance with the help of traffic cameras.

A system based on IoT for sewage blockage detection is proposed in Ref. [13]. This system continuously monitors the water level of sewage using ultrasonic sensors and also measures the level of H2S gas with an alert threshold of 100 ppm. Data from the system's microprocessor is transmitted to the host using LoRa.

In the project titled "Web-Based Realtime Underground Drainage or Sewage Monitoring System Using Wireless Sensor Networks" [14], the focus is on implementing a system that gathers data on temperature, gaseous concentration, and the condition of manhole lids.

Ref. [15] presents a model that monitors ownerless manhole covers through RFID, tracking their tilt and other aspects. This approach aims to mitigate the increasing theft of manhole covers by transmitting the location of manholes through the nearest communication tower, thereby ensuring constant confirmation of their whereabouts.

The detection and monitoring of clogged pipelines using an acoustic analysis method is proposed in Ref. [16]. The frequency response of the pipeline is analyzed using common techniques like Fast Fourier Transform (FFT) to extract relevant features. This approach provides highly accurate data by filtering out irrelevant information.

In Ref. [17], a machine learning method is proposed to specifically address the challenge of lid opening detection in manholes and its monitoring.

Table 1: Summary of Literature Literatures

References	Advantages	Limitations
[1]	Detection of Human presence near open manhole helps in prevention of accident	The system has high electricity demand, which make it less desirable in developing countries.
[2]	In built replaceable battery with life up to 3-5 years, Self-Perceptive RFID	Response time is much higher than the prior versions

[3]	Correct scene state of manhole covers can be estimated by MCIMT algorithm and the response time is quicker (under 3s)	Communication distance of the system was very less.
[4]	Assisting sewage employees to check blockage through camera attached to Raspberry PI	Sensor's life was exponentially decreased due to continuous exposure to corrosive nature of sewage.
[5]	Clogs in drainage pipes can be detected as soon as its formed.	--
[6]	Harmful gases, Drainage overflow were monitored with website which can be accesed by local people also to avoid corruption	--
[7]	Cost effective for sewer pipeline maintenance	It focus only on sewer pipeline damage and not on other problems of smart monitoring system
[8]	Monitoring system is OCR and pysttsx3 based which is made considering blind people	It doesn't focuses on manhole cover monitoring
[9]	Addresses all phases of the practical development of an underground Drainage and Manhole System (UDMS)	Due to widening variety of applications, it is difficult to define common requirements for the WSN modes
[10]	Multiple usages in smart city perspectives like garbage level detection, water distribution supply	
[11]	System also consists of GPS sensor which help in locating the accurate manhole	System uses only GSM Module , there is no Wi-Fi module it means there must always be network connectivity
[12]		Only mapping was proposed
[13]	Use of LoRa(Long Ranged) protocol which can have range upto 100km	Multiple gateway of communication using LoRa can cause interferenc
[14]	Low Power Usage and effective algorithm is used	Light Sensor is used for layout of manhole,is of no use during night time
[15]	Ownerless Manhole covers to be constantly monitored via real time pictures and alarm to know whenever a manhole disappeared or removed.	High maintenance cost.

[16]	FFT technique was used to extract features from the frequency response of the pipeline. Data was highly accurate and inconsiderable data were removed.	Only covered the concern of clogged pipelines and not others issues.
[17]	Recurrent Neural Network (RNN) is implemented which has high accuracy rate of 98% and high false negative detection.	High setup and maintenance cost for small scale implementation.

III. PROPOSED M

The IOT-based system mainly records four values (as shown in Fig. 1): Tilt value, temperature values, gas detection, and finally water level. The system uses an ultrasonic sensor to detect the water level, a gas sensor (MQ9) to detect the concentration of the harmful gas carbon monoxide, a temperature sensor (DHT 11) to detect the humidity and temperature, and an accelerometer to monitor the tilt values.

A circuit diagram (as shown in Fig. 4) is created to check the working of IOT based model. The connections are made as per the real hardware model to check for its working. The data collected by the sensors is sent wirelessly to the central control system using two technologies: GSM and WiFi using a GSM module and an Esp 8266 WiFi module (as shown in Fig. 3).

WiFi is used for continuous monitoring and control of data. Data is sent from the sensors over a WiFi network to a local device, which can be a cell phone or a server. For the proposed system, we have used Blynk IOT server.

When the WiFi module is connected to the Internet, it can send data to the Blynk IOT server by using a special set of rules called Blynk API. The module uses the API to communicate with the server and sends data in small pieces called packets, so sometimes there is a delay in the information. However, in our proposed system, this delay is carefully reduced to a minimum. The Blynk server fetches the data and sends it to the relevant authority in the form of both an app and a website. This means that monitoring is possible anywhere if an internet connection is available.

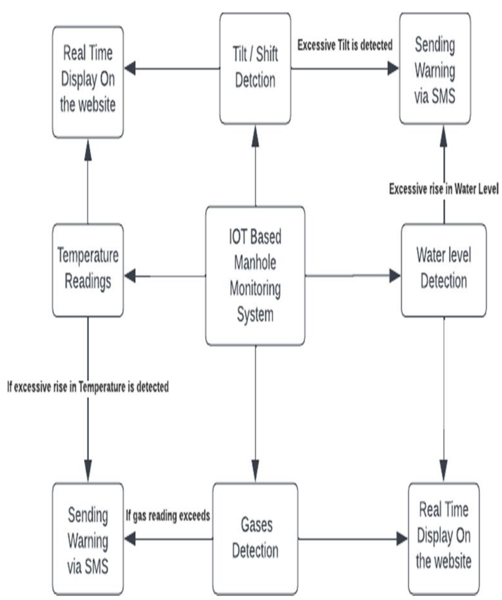

Fig. 1 Block Diagram of the System

The GSM module is used to transmit data via a mobile network. Data is first collected by the microcontroller unit (MCU) and then sent to the GSM module through a serial communication interface. In the proposed system, the GSM module is only used to display warning messages when the values set for each sensor exceed their limit.The exceeding of the sensor values also triggers a buzzer so that the cleaners working nearby can take the necessary actions themselves. The data is also displayed on LCD connected to the main unit, which makes it easier for workers to monitor it.

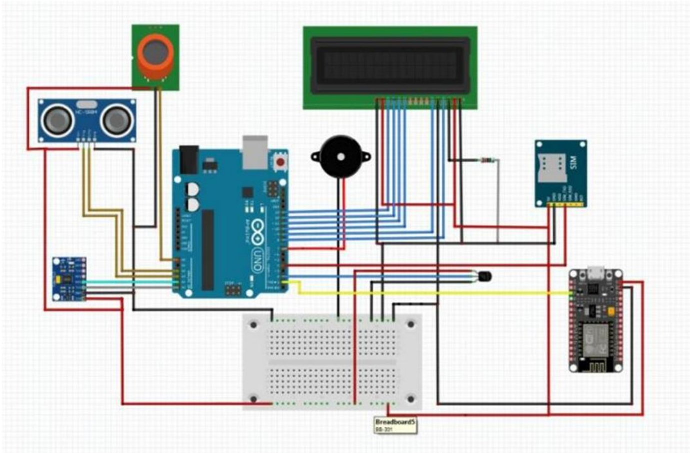

Fig. 2 Circuit Diagram of the System

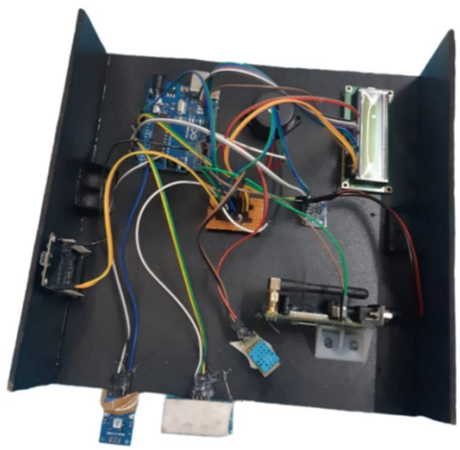

Fig. 3 IOT based Manhole System

IV. EXPERIMENTAL RESULTS

Once the system is connected to the power supply, LCD immediately begins to display the various values of the environment. There are four parameters displayed on LCD (temperature, humidity, gas concentration and water level value) (see Fig. 4).

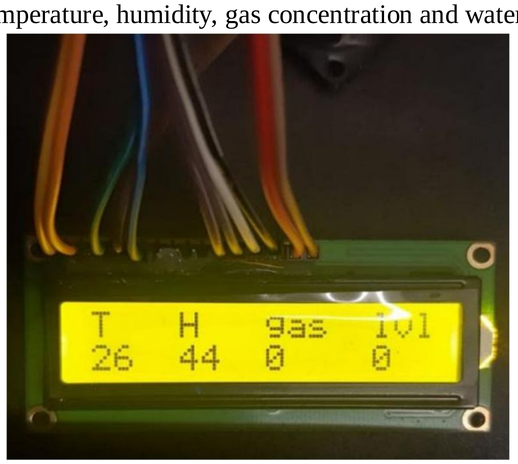

Fig. 4 LCD display shownig various readings

Whenever a threshold is reached for a particular parameter, we receive a warning SMS (as shown in Fig. 5). The tilt sensor operates between -5 degrees and +5 degrees without warning, and the overflow warning is detected when the water level exceeds 50%.

Fig. 5 Alert Messages through SMS

Whatever the changes, they are also displayed via the Blynk IOT app with very little delay (as shown in Fig. 6 and Fig. 7). In both images, one from LCD and the other from the Blynk IOT app, exactly the same values are displayed.

Fig. 6 LCD display shownig various readings

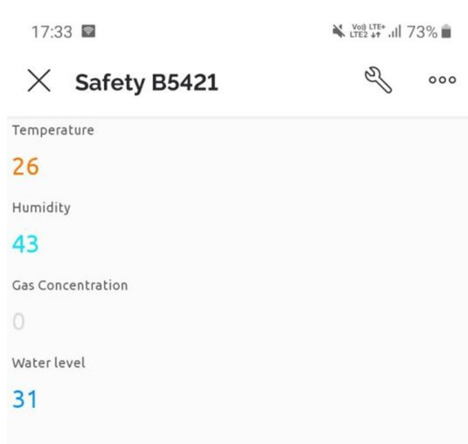

Fig. 7 Realtime Values over Blynk IOT app

V. DATA TABLE

Table 2: Datasets for GAS concentration

GAS LEVEL	SMS
0 < value <= 100	No
100 < value <= 300	No
Value > 500	Yes

If the level of gas changes, then value will be changed in real-time over the Blynk App and if the less than 700 its normal, GSM will not send any SMS. But if the level is more than 700(as shown in Table 2), then GSM will send SMS to the authority .

Table 3: Datasets for Water level

Water Level(in %)	SMS
value = 0	No
0 < value <=50	No
Value > 50	Yes

If the sewage water level is zero, GSM will not send any SMS and it will show the zero level at the Blynk server. The distance is calculated in cms.If the water level exceeds the 50% mark(as shown in Table 3) it will trigger the buzzer and also will send a SMS to the concerned authority via GSM module.

VI. CONCLUSION

Our developed IOT-based manhole monitoring and detection system has the potential to bring about revolutionary changes to both the environment and people's daily lives. In many areas, the existing sewage system poses a significant hygiene problem and contains numerous harmful gases, including CO, CH_4, NH_3, and others. To address this issue, we have designed and implemented a device that effectively controls and reports sewage overflow incidents. By detecting and addressing situations where dirty water spills out from drains and pollutes the surrounding areas, this device plays a crucial role in mitigating human suffering. Additionally, we have integrated a Wi-Fi component into the system, enabling nearby authorities to receive daily updates regarding any rise in sewage levels. Furthermore, we have implemented stringent access controls to ensure that only authorized personnel have control over the system.

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