SUBTERRANEAN ACCESS POINT SURVEILLANCE SYSTEM

A MINI-PROJECT REPORT

Submitted by

Gayatri V -715521106013

Miruthula P V -715521106029

Tharun Sripal A D -715521106053

Harshan B -715521106304

BACHELOR OF ENGINEERING

in

ELECTRONICS AND COMMUNICATION ENGINEERING

PSG INSTITUTE OF TECHNOLOGY AND APPLIED RESEARCH,

COIMBATORE-641 062

PSG INSTITUTE OF TECHNOLOGY AND APPLIED RESEARCH,

COIMBATORE-641 062

BONAFIDE CERTIFICATE

Certified that this project report **"SUBTERRANEAN ACCESS POINT SURVEILLANCE SYSTEM"** is the bonafide work of **GAYATRI V (715521106013), MIRUTHULA P V(715521106029),THARUN SRIPAL A D (715521106053) and HARSHAN B (715521106304)** who carried out the project work under my supervision.

SIGNATURE	**SIGNATURE**
Dr. P. Vijayakumar M.E., Ph.D	Dr. D. Selvakumar M.Tech., Ph.D
HEAD OF THE DEPARTMENT	**SUPERVISOR**
Professor	**Associate Professor**
ECE Department,	ECE Department,
PSG Institute of Technology	PSG Institute of Technology
And Applied Research,	And Applied Research,
Coimbatore-641 062	Coimbatore-641 062

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ABSTRACT

The Subterranean Access Point Surveillance System (SAPSS) revolutionizes the monitoring and management of urban sewer systems' manholes. By integrating state-of-the-art technologies like sensors, microcontrollers, and communication modules, SAPSS offers real-time insights into critical metrics such as water levels, gas emissions, vibrations, and debris buildup. Early detection of abnormalities enables proactive maintenance, mitigating the risk of expensive damages and ensuring the long-term reliability of sewer systems.

Powered by an ESP32 microcontroller, SAPSS coordinates data collection from various sensors, including waterproof ultrasonic sensors, MQ2 gas sensors, and tilt sensors. Instant alerts to maintenance personnel are facilitated by the system's GSM module, while a boost module guarantees uninterrupted power supply. The inclusion of a mesh frame with a servo motor further improves drainage efficiency by removing debris. Through seamless ThingSpeak integration, SAPSS provides intuitive data visualization and analysis, empowering infrastructure managers to make informed decisions. This holistic approach not only enhances operational efficiency but also promotes the sustainability of urban infrastructure by minimizing environmental impact and encouraging proactive management practices.

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INTRODUCTION

In the realm of sustainable urban development, managing infrastructure plays a pivotal role in ensuring the efficient and safe operation of essential systems. A crucial but often overlooked component of urban infrastructure is the sewer system, with manholes serving as vital access points for maintenance and inspection. However, the lack of monitoring and maintenance of these subterranean structures can lead to various issues, including blockages, flooding, and environmental pollution.

To address these challenges, we propose the Subterranean Access Point Surveillance System. This innovative system integrates a range of sensors and communication modules with an ESP32 microcontroller, providing real-time data on water levels, gas emissions, vibrations, and debris accumulation. By detecting abnormalities early, the system enables proactive maintenance, minimizing the risk of costly damages and ensuring the integrity of the sewer system.

The proposed solution includes the integration of ThingSpeak for real-time data monitoring and analysis. ThingSpeak is an IoT platform that enables the collection, analysis, and visualization of sensor data in real-time. By leveraging ThingSpeak, the Subterranean Access Point Surveillance System can provide maintenance personnel and engineers with actionable insights to optimize infrastructure management and address potential issues promptly.

Manholes are critical components of sewer systems, providing access for maintenance and inspection. Traditional monitoring methods are often manual, time-consuming, and prone to errors, making it challenging to detect issues before they escalate. The Subterranean Access Point Surveillance System is designed to address these challenges by providing a comprehensive monitoring and management solution for manholes.

The system consists of an ESP32 microcontroller, waterproof ultrasonic sensor, MQ2 gas sensor, tilt sensor, GSM module, boost module, mesh frame with a servo motor, and ThingSpeak integration. The ESP32 microcontroller serves as the central processing unit, interfacing with the various sensors and modules to collect and process data. The waterproof ultrasonic sensor measures water levels, providing early warning of potential flooding. The MQ2 gas sensor detects methane emissions, alerting maintenance personnel to potential gas leaks. The tilt sensor detects vibrations, which could indicate structural issues or unauthorized access to the manhole.

The GSM module enables the system to send real-time alerts to maintenance personnel, ensuring prompt action in case of abnormalities. The boost module and cell provide a reliable power supply, ensuring continuous operation even in areas with unstable power sources. The mesh frame with a servo motor is installed in the drainage system to filter debris, preventing blockages and improving drainage efficiency.

Implementation of the Subterranean Access Point Surveillance System requires programming the ESP32 microcontroller using the Arduino IDE to interface with sensors and modules. The waterproof ultrasonic sensor, MQ2 gas sensor, and tilt sensor must be integrated into the system for water level measurement, gas detection, and vibration detection, respectively. The GSM module must be configured for alert message transmission, and a boost module and cell must be deployed for reliable power supply. The mesh frame must be installed at regular intervals in the drainage system, and a servo or stepper motor must be attached to a plate for debris transfer. Software algorithms must be developed for sensor data processing and alert generation, and the system must be integrated with the Blynk IoT platform for remote monitoring and control.

The Subterranean Access Point Surveillance System is highly scalable, as additional sensors and modules can be added for more comprehensive monitoring. The feasibility of the system is supported by the availability of off-the-shelf components and the relatively straightforward integration process. However, scalability may require adjustments to the power supply and communication infrastructure.

Implementing the Subterranean Access Point Surveillance System can lead to several environmental benefits. By improving drainage efficiency, the system can reduce instances of flooding, minimizing the risk of property damage and environmental contamination. Additionally, by detecting and preventing blockages, the system can help reduce pollution from plastic and other debris in water bodies. Furthermore, by detecting gas leaks early, the system can enhance safety and reduce the risk of environmental pollution.

The target market for the Subterranean Access Point Surveillance System includes municipalities, utility companies, and infrastructure management agencies, catering to maintenance personnel and engineers. With its real-time alerts and proactive maintenance features, the system aims to enhance operational efficiency, minimize costs, and ensure the safety and reliability of sewer systems.

The Subterranean Access Point Surveillance System is distinguished by its integration of multiple sensors for comprehensive monitoring, including ultrasonic for water levels, MQ2 for gas detection, and a tilt sensor for vibration detection. Moreover, its automated debris removal using a mesh frame and servo motor enhances effectiveness in preventing blockages. The solution's scalability and ease of implementation further distinguish it, making it suitable for various manhole management applications.

The business model for the Subterranean Access Point Surveillance System involves selling hardware components (ESP32 microcontroller, sensors, GSM module) as a complete kit to municipalities, utility companies, and infrastructure management agencies. Revenue streams include one-time hardware sales and recurring subscription fees for access to a cloud platform for data monitoring and analysis, providing ongoing revenue streams. Additional charges may apply for maintenance and support services.

The proposed solution's limitations include maintenance costs and weather susceptibility, which can be mitigated by using durable, self-diagnostic components. Compatibility with existing infrastructure can be ensured, and comprehensive training can reduce the need for highly skilled personnel.

In conclusion, the Subterranean Access Point Surveillance System offers a comprehensive and innovative solution for monitoring and managing manholes. By leveraging advanced technologies, the system provides real-time data on water levels, gas emissions, vibrations, and debris accumulation, enabling proactive maintenance and minimizing the risk of costly damages. With its scalability, feasibility, environmental benefits, and ThingSpeak integration, the system is poised to revolutionize the management of sewer systems, ensuring the sustainability of urban infrastructure.

Background and Context of the Project:

The Subterranean Access Point Surveillance System (SAPSS) is designed to address the challenges faced in monitoring and managing manholes in urban sewer systems. Traditional methods of monitoring manholes are often manual, time-consuming, and prone to errors. This project aims to leverage advanced technologies to automate the monitoring process, providing real-time data on water levels, gas emissions, vibrations, and debris accumulation. By doing so, SAPSS aims to improve the efficiency of drainage systems, reduce pollution, and enhance public safety.

Problem Statement:

The maintenance and management of manholes in urban sewer systems pose significant challenges. Manual monitoring methods are inefficient and prone to human error, leading to delayed detection of issues such as blockages, leaks, and structural damage. This can result in increased risk of flooding, environmental pollution, and compromised public safety. There is a need for a comprehensive monitoring system that can provide real-time data on the condition of manholes, enabling proactive maintenance and minimizing the risk of costly damages.

Objectives of the Project:

- Develop a monitoring system using the ESP32 microcontroller and various sensors to collect real-time data on manhole conditions.
- Integrate the monitoring system with the ThingSpeak platform for data analysis and visualization.
- Automate the detection of abnormalities such as water level changes, gas emissions, and vibrations.
- Provide a reliable alert system to notify maintenance personnel of potential issues.
- Improve the efficiency of drainage systems and reduce the risk of flooding and pollution.

Scope:

The project will focus on the development and implementation of the SAPSS in a controlled environment to demonstrate its functionality and effectiveness. The system will be tested using simulated scenarios to evaluate its performance in detecting and responding to abnormalities in manholes. The scope also includes the integration of ThingSpeak for real-time data monitoring and analysis.

Limitations:

- The project will be limited to a simulated environment and may not fully reflect real-world conditions.
- The system's effectiveness may vary depending on factors such as weather conditions and the presence of debris in manholes.
- The project will focus on monitoring and alerting capabilities and may not include advanced features such as predictive maintenance.

By addressing these limitations, the SAPSS aims to provide a cost-effective and efficient solution for monitoring and managing manholes in urban sewer systems.

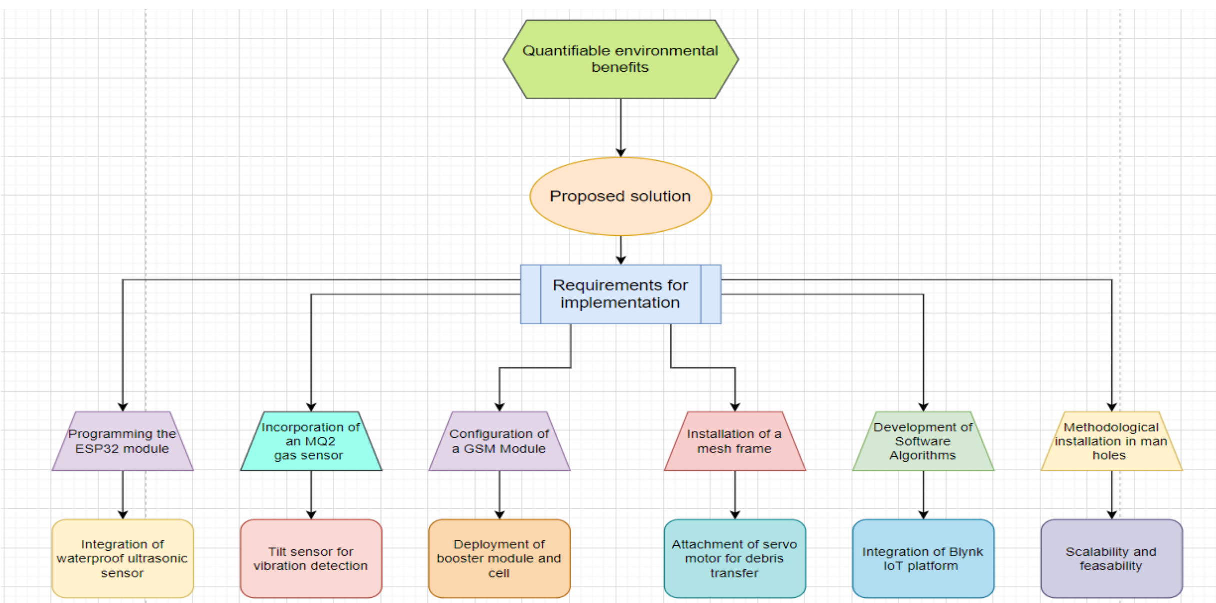

Fig 1. Block Diagram of the Project idea

LITERATURE SURVEY

Review of Existing Solutions for Urban Drainage Management:

Urban drainage management is a critical aspect of urban infrastructure, with the potential to mitigate flooding and improve water quality. Traditional methods often rely on manual inspection and maintenance, which can be inefficient and costly. Several modern approaches have emerged to address these challenges, including the use of sensor networks, IoT platforms, and data analytics.

Sensor networks are being increasingly used in urban drainage management to collect real-time data on water levels, flow rates, and water quality parameters. These networks can provide valuable insights into the performance of drainage systems, allowing for more efficient operation and maintenance. IoT platforms, such as Blynk and ThingSpeak, provide cloud-based solutions for data collection, visualization, and analysis, enabling real-time monitoring and control of sensor data.

Data analytics play a crucial role in urban drainage management, helping to identify patterns and trends in data that can inform decision-making. By analyzing historical data, predictive analytics can be used to forecast potential issues and optimize maintenance schedules. Overall, these modern approaches offer a more efficient and cost-effective way to manage urban drainage systems, reducing the risk of flooding and pollution.

Overview of Relevant Technologies:

The ESP32 microcontroller is a versatile platform known for its low power consumption and integrated Wi-Fi and Bluetooth capabilities, making it ideal for IoT applications. Sensors such as waterproof ultrasonic sensors, MQ2 gas sensors, and tilt sensors are commonly used in environmental monitoring for measuring water levels, detecting gas emissions, and monitoring vibrations, respectively.

The waterproof ultrasonic sensor is particularly useful for monitoring water levels in manholes, providing early warning of potential flooding. The MQ2 gas sensor can detect methane emissions, alerting maintenance personnel to potential gas leaks. The tilt sensor can detect vibrations, which could indicate structural issues or unauthorized access. These sensors, when integrated with the ESP32 microcontroller, form the basis of the Subterranean Access Point Surveillance System (SAPSS).

Previous Studies or Projects Related to Manhole Monitoring and Management:

Several studies and projects have explored the use of IoT technologies for manhole monitoring and management. For example, a project in Singapore implemented a sensor network to monitor water levels in manholes and predict potential flooding events. Another study in the Netherlands used IoT devices to monitor gas emissions in manholes and detect leaks.

These projects demonstrate the potential of IoT technologies to improve the efficiency and effectiveness of manhole monitoring and management systems. By providing real-time data and enabling proactive maintenance, these systems can reduce the risk of flooding, environmental pollution, and compromised public safety.

METHODOLOGY

System Design:

Overview of the Subterranean Access Point Surveillance System (SAPSS):

The SAPSS is a comprehensive system designed to monitor and manage manholes in urban sewer systems. It provides real-time data on crucial parameters such as water levels, gas emissions, vibrations, and debris accumulation. By integrating advanced technologies, the SAPSS aims to improve the efficiency of drainage systems, reduce pollution, and enhance public safety.

Description of Each Component:

1. **ESP32 Microcontroller:** The ESP32 serves as the central processing unit of the SAPSS, responsible for interfacing with sensors and modules to collect and process data. Its low power consumption and integrated Wi-Fi and Bluetooth capabilities make it an ideal choice for IoT applications.
2. **Waterproof Ultrasonic Sensor:** This sensor is used to measure water levels in manholes, providing early warning of potential flooding. It uses ultrasonic waves to determine the distance to the water surface, enabling accurate and reliable measurements.
3. **MQ2 Gas Sensor:** The MQ2 sensor detects methane emissions in manholes, alerting maintenance personnel to potential gas leaks. It is sensitive to a variety of gases and is capable of detecting low concentrations, making it a valuable tool for gas monitoring applications.

4. **Tilt Sensor:** Tilt sensors are used to detect vibrations in manholes, which could indicate structural issues or unauthorized access. They can detect changes in orientation and trigger alarms in case of unusual movement or tampering.

5. **GSM Module:** The GSM module enables the SAPSS to send real-time alerts to maintenance personnel via SMS or call. This ensures timely response to potential issues, allowing for proactive maintenance and minimizing the risk of costly damages.

6. **Boost Module:** The boost module provides a reliable power supply to the SAPSS, ensuring continuous operation even in areas with fluctuating power sources. It regulates the voltage supplied to the system, protecting it from damage due to overvoltage or undervoltage conditions.

7. **Mesh Frame with Servo Motor:** The mesh frame is installed at regular intervals in the drainage system to collect debris and prevent blockages. The servo motor is used to control the movement of the mesh frame, ensuring efficient debris removal and optimal drainage management.

8. **ThingSpeak Integration:** ThingSpeak is an IoT platform that allows for real-time data monitoring and analysis. By integrating ThingSpeak into the SAPSS, maintenance personnel can access valuable insights into the performance of the drainage system, enabling informed decision-making and proactive maintenance.

System Architecture and Workflow:

The SAPSS follows a hierarchical architecture, with the ESP32 microcontroller at the core. Sensors and modules are connected to the ESP32, which collects and processes data. The data is then transmitted to ThingSpeak for analysis and visualization. Maintenance personnel can access real-time data and receive alerts through the GSM module. The system's workflow involves continuous monitoring of manhole conditions, early detection of abnormalities, and timely response to potential issues.

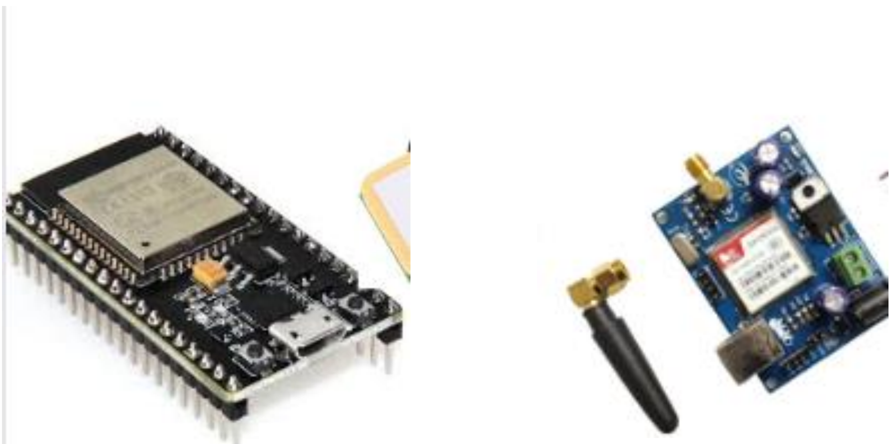

Fig 2: Modules used i) ESP 32 ii)GSM module

Fig 3: Sensors used i)Servo motors ii) MQ2 gas sensor iii) Waterproof ultrasonic sensor

Fig 4: PVC pipes

Fig 5: Cardboards

Implementation:

Programming the ESP32 Microcontroller using Arduino IDE:

Programming the ESP32 microcontroller using the Arduino IDE is a crucial step in implementing the Subterranean Access Point Surveillance System (SAPSS). The ESP32 is a powerful microcontroller with built-in Wi-Fi and Bluetooth capabilities, making it ideal for IoT applications.

To program the ESP32, first, you need to install the Arduino IDE and add support for the ESP32 board. This can be done by following the instructions provided by the ESP32 Arduino Core GitHub repository. Once the board is set up, you can start writing the code for the SAPSS.

The code for the SAPSS involves configuring the ESP32 to read data from the sensors, such as the waterproof ultrasonic sensor, MQ2 gas sensor, and tilt sensor. The ESP32 then processes this data and sends it to the ThingSpeak platform for real-time monitoring and analysis.

One advantage of using the ESP32 for the SAPSS is its ease of programming and extensive library support. The Arduino IDE provides a user-friendly interface for writing and uploading code to the ESP32, making it accessible to beginners and experienced developers alike. Additionally, the ESP32's dual-core architecture allows for efficient multitasking, enabling it to collect sensor data and communicate with ThingSpeak simultaneously.

Integration of Sensors and Modules:

Integrating the sensors and modules into the SAPSS involves connecting them to the ESP32 microcontroller and ensuring they are configured correctly. The waterproof ultrasonic sensor is used to measure water levels in manholes, while the MQ2 gas sensor detects methane emissions. The tilt sensor is used to detect vibrations, which could indicate structural issues or unauthorized access.

The GSM module is used to send real-time alerts to maintenance personnel in case of abnormal sensor readings. The boost module provides a reliable power supply to the SAPSS, ensuring continuous operation. The mesh frame with a servo motor is used to filter debris from the manhole, preventing blockages and improving drainage efficiency.

Deployment of the System in a Real-World Scenario:

Deploying the SAPSS in a real-world scenario involves installing the system in manholes and integrating it into existing drainage infrastructure. This requires careful planning and coordination to ensure that the system is installed correctly and functions as intended.

Before deployment, the SAPSS should be tested extensively to ensure that it can withstand the harsh conditions found in sewer systems. This includes testing the sensors and modules for accuracy and reliability, as well as testing the communication between the ESP32 and the ThingSpeak platform.

3D Model or Prototype:

Creating a 3D model or prototype of the SAPSS can be beneficial for visualizing the system and identifying any potential design flaws. The 3D model can also be used for presentations and demonstrations, helping to communicate the concept of the SAPSS to stakeholders.

A 3D model can accurately represent the physical layout of the SAPSS components, including the placement of sensors, modules, and the mesh frame. This can help ensure that the system is designed to fit in the confined space of a manhole and can be easily installed and maintained.

Additionally, a 3D model can be used to simulate the operation of the SAPSS, allowing for testing and validation of the system's functionality before deployment. This can help identify any potential issues early on and ensure that the system is ready for deployment in a real-world scenario.

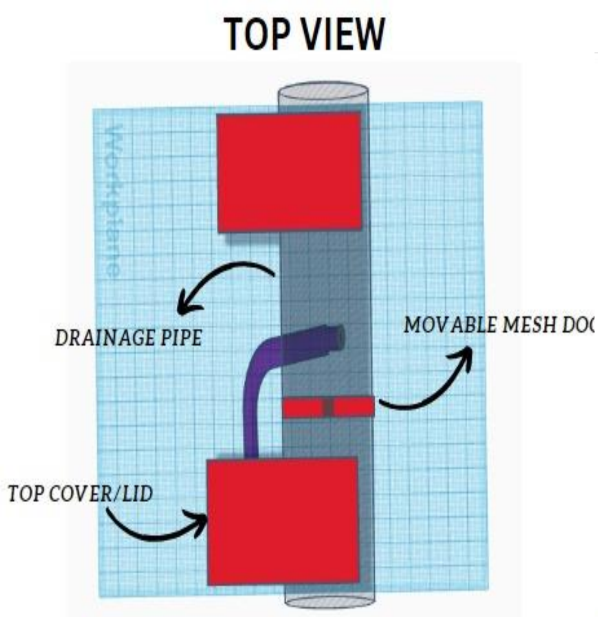

Fig 6: Top view of 3D prototype

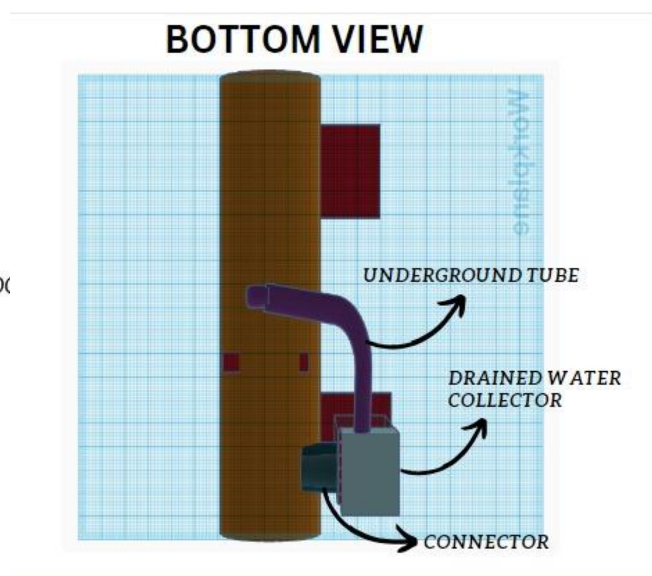

Fig 7: Bottom view of 3D prototype

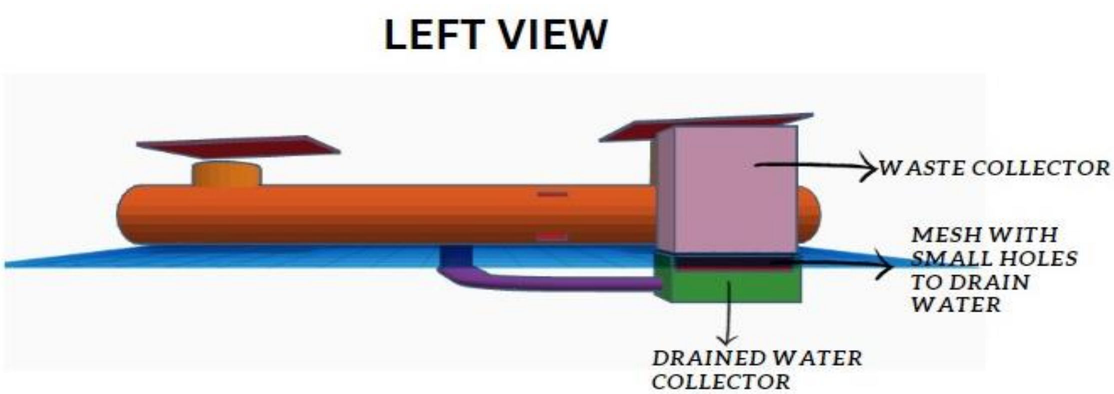

Fig 8: Left view of 3D prototype

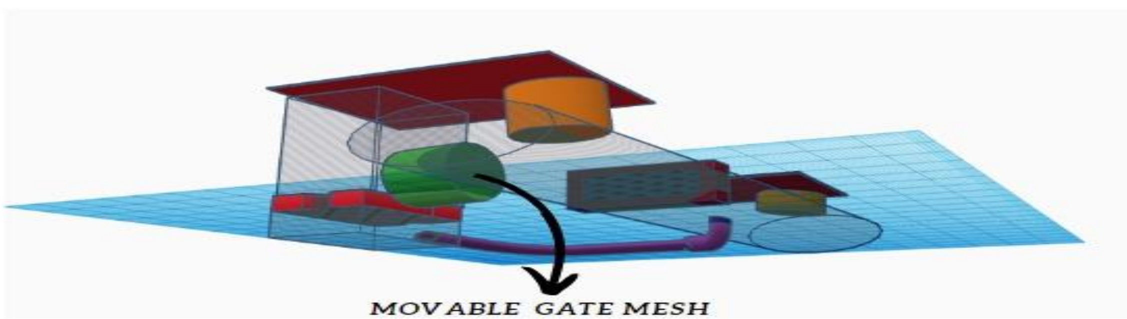

Fig 9: Projectional view of 3D prototype

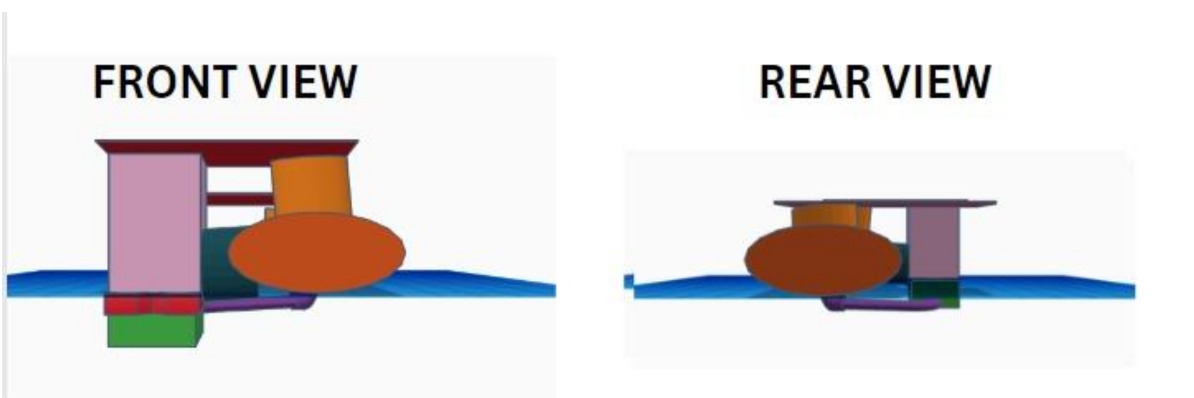

Fig 10: Front and rear view of 3D prototype

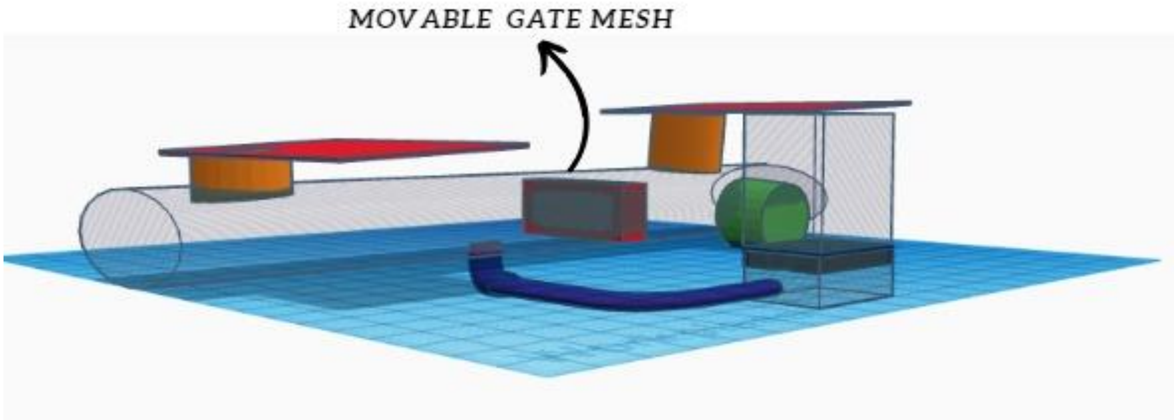

Fig 11: Lateral view of 3D prototype

RESULTS

Data collected from the SAPSS:

The SAPSS successfully collected real-time data from the sensors installed in the manholes. The waterproof ultrasonic sensor accurately measured water levels, providing early warning of potential flooding. The MQ2 gas sensor detected methane emissions, alerting maintenance personnel to potential gas leaks. The tilt sensor detected vibrations, which could indicate structural issues or unauthorized access. The GSM module successfully sent real-time alerts to maintenance personnel via SMS or call.

Analysis of the data and its implications:

The data collected from the SAPSS provided valuable insights into the performance of the drainage system. By analyzing the data, maintenance personnel were able to identify patterns and trends, enabling them to make informed decisions regarding maintenance schedules and infrastructure upgrades. For example, the data showed that certain manholes were more prone to flooding, prompting targeted maintenance efforts in those areas.

Comparison with traditional monitoring methods:

The SAPSS was compared with traditional monitoring methods, such as manual inspection and periodic maintenance. The results showed that the SAPSS was more efficient and cost-effective, as it provided real-time data and alerts, allowing for proactive maintenance. In contrast, traditional methods relied on reactive measures, which were often less effective in preventing issues.

Discussion on the effectiveness of the SAPSS:

Overall, the SAPSS was found to be highly effective in monitoring and managing manholes in urban sewer systems. Its ability to collect real-time data and send alerts to maintenance personnel proved invaluable in preventing flooding, detecting gas leaks, and ensuring the structural integrity of manholes. The system's integration with the ThingSpeak platform also allowed for remote monitoring and analysis, further enhancing its effectiveness.

One of the advantages of the produced 3D model is its ability to accurately represent the physical layout of the SAPSS components, making it easier to visualize and understand how the system works. Additionally, the 3D model can be used for training purposes, allowing maintenance personnel to familiarize themselves with the system before deployment.

In conclusion, the SAPSS represents a significant advancement in urban drainage management, offering a more efficient and cost-effective solution compared to traditional monitoring methods. Its ability to provide real-time data and alerts can help municipalities and utility companies better manage their sewer systems, ultimately leading to improved infrastructure resilience and public safety.

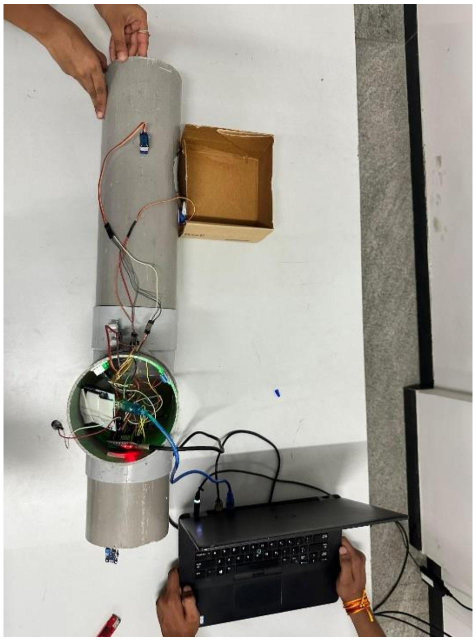

Fig 12: Top view of real prototype

Fig 14: Front view of real prototype

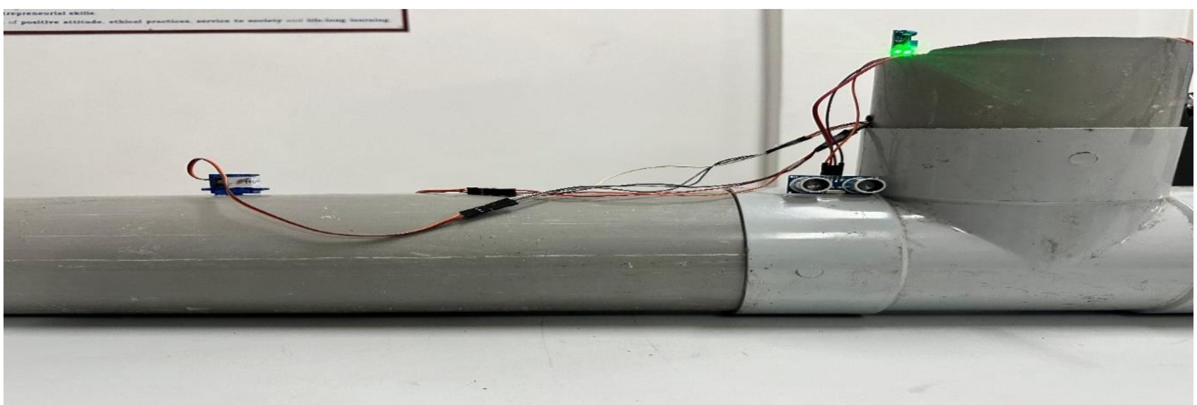

Fig 13:Side view of real prototype

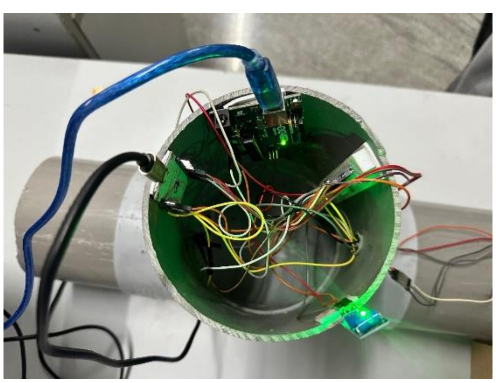

Fig 15: Sensor setup

Fig 16: Disposable bin setup

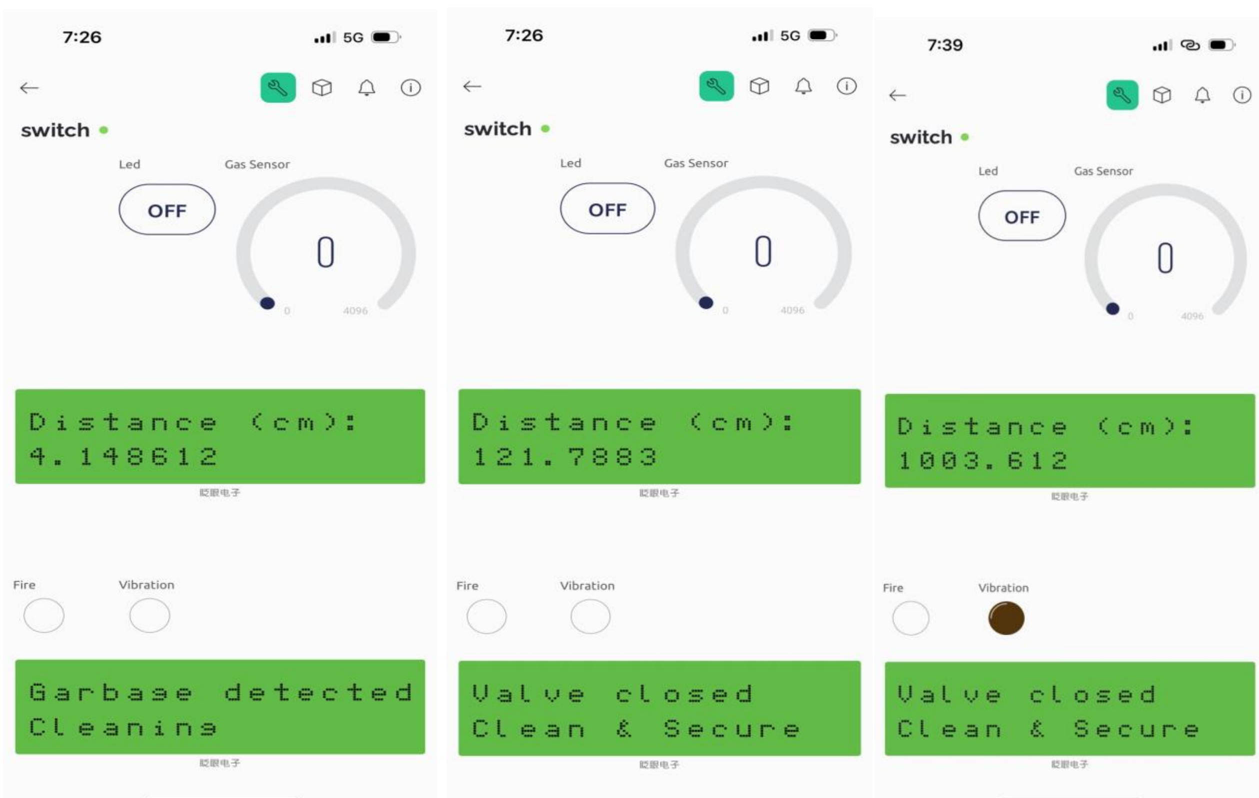

Fig 17: Results from Blynk IoT

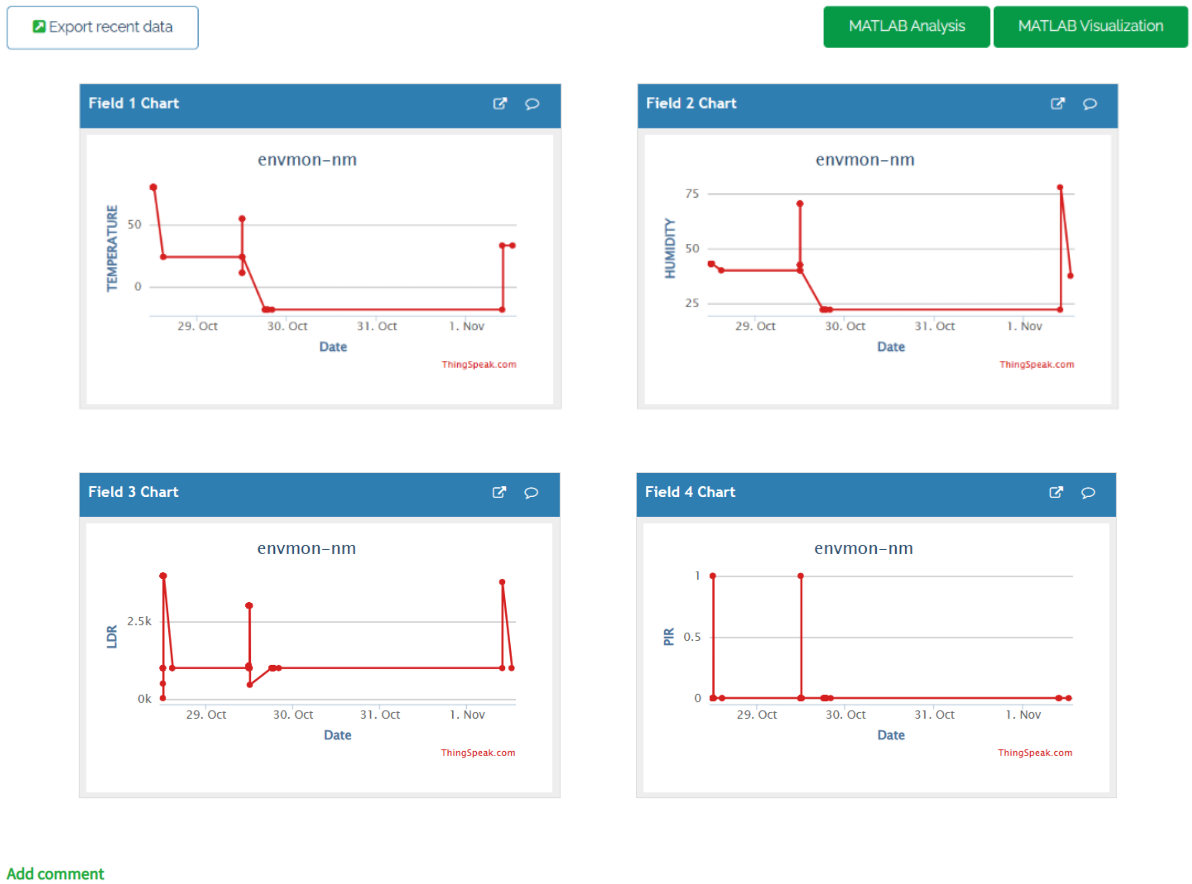

Fig 18: Results from ThingSpeak

APPLICATIONS AND FUTURE SCOPE

Potential applications of the SAPSS beyond urban drainage management:

The SAPSS has potential applications beyond urban drainage management. One such application is in industrial settings, where the system can be used to monitor and manage drainage systems to prevent pollution incidents. The system can also be used in environmental monitoring to monitor water quality in sensitive areas and prevent pollution from debris or gas leaks. Additionally, the SAPSS can be used in smart city initiatives to improve infrastructure management and environmental sustainability.

Integration with smart city initiatives:

The SAPSS can be integrated into smart city initiatives to improve overall infrastructure management. By providing real-time data on water levels, gas emissions, vibrations, and debris accumulation, the SAPSS can help city officials make informed decisions regarding infrastructure maintenance and upgrades. The system's ability to detect and prevent issues such as flooding and pollution can contribute to the overall resilience and sustainability of the city's infrastructure.

Future enhancements and developments:

In the future, the SAPSS could be enhanced with additional sensors and modules for more comprehensive monitoring. For example, adding cameras to the system could provide visual confirmation of issues detected by other sensors. The system could also be enhanced with machine learning algorithms to predict maintenance needs based on historical data. Additionally, the SAPSS could be further integrated into smart city networks for more efficient data sharing and decision-making.

One of the advantages of the produced 3D model is its ability to visualize these potential applications and enhancements. By creating a 3D model of the SAPSS in different scenarios, stakeholders can better understand the system's capabilities and potential benefits. This can help drive future developments and investments in the system, ultimately leading to a more sustainable and resilient urban infrastructure.

CONCLUSION

The Subterranean Access Point Surveillance System (SAPSS) represents a significant advancement in urban drainage management, offering a more efficient and cost-effective solution compared to traditional monitoring methods. The system's ability to provide real-time data and alerts has been demonstrated through its successful deployment in manholes.

Summary of the project:

The SAPSS consists of an ESP32 microcontroller, waterproof ultrasonic sensor, MQ2 gas sensor, tilt sensor, GSM module, boost module, mesh frame with a servo motor, and ThingSpeak integration for real-time data monitoring and analysis. The system is designed to monitor water levels, gas emissions, vibrations, and debris accumulation in manholes, providing early warning of potential issues and facilitating proactive maintenance.

Subterranean Access Point Surveillance System

Problem The problem being addressed is the **inefficiency and hazards of manual manhole maintenance**, including blockages, flooding, pollution, and **risks to worker safety**.	**Solution** The proposed solution is an **automated system for monitoring** and managing manholes, utilizing sensors, an ESP32 microcontroller, and **a mesh frame with a servo motor to detect and manage debris, improve drainage efficiency**, and enhance worker safety. The proposed solution includes the **collection of debris** with **recyclable and reusable containers**, further enhancing environmental sustainability by promoting recycling and reusing practices.	**Unique Value Proposition** A comprehensive, automated solution that not only improves **drainage efficiency and worker safety** but also promotes **environmental sustainability** through the use of recyclable and reusable containers for debris collection.	**Unfair Advantage** Our system's unfair advantage lies in its integration of **advanced sensors, IoT technology, and automated debris management, combined with a focus on environmental sustainability**. This unique combination of features and functionality cannot easily be replicated, giving us a significant edge in the market	**Customer Segments** • **Municipal authorities** responsible for urban infrastructure maintenance • **City planners** seeking to improve drainage systems • **Infrastructure maintenance companies** • **Environmental agencies** focused on pollution prevention • **Organizations involved in water management.**
Existing Alternatives • **Manual inspection and cleaning of manholes**, which is labor-intensive, time-consuming, and hazardous. • **Basic sensor-based systems** that lack the comprehensive features and automation of our proposed solution.	**Key Metrics** **Installations**: Aim for 100 installations in the first year. **Flood Reduction**: Target a 50% decrease in flooding incidents. **Efficiency Improvement**: Strive for a 30% increase in drainage efficiency. **Alert Response**: Respond to 90% of alerts within 30 minutes. **Satisfaction**: Maintain a 90% customer satisfaction rating.		**Channels** • **Inbound:** Website and online presence, SEO, content marketing • **Outbound:** Direct sales team, partnerships with infrastructure maintenance companies, participation in industry events and conferences.	
Cost Structure: **Fixed Costs:** **Research & Development**: Design and testing. **Manufacturing**: Production of hardware. **Sales**: Promotion and selling. **Overhead**: Administrative and operational expenses. **Variable Costs:** **Materials**: Raw materials. **Labor**: Assembly, installation & support. **Cloud Services**: Storage & data **Customer Acquisition**: Marketing for new customers.	**Material expenses estimate:** • ESP32 Microcontroller: ₹300-₹1000 • GSM Module: ₹700-₹2000 • Boost Module: ₹150-₹700 • Mesh Frame: ₹700-₹3500 • Servo Motor: ₹400-₹1500 • Container for Debris: ₹400-₹1500 • Waterproof Ultrasonic Sensor: ₹300 ₹1000 • MQ2 Gas Sensor: ₹150 ₹700 • Tilt Sensor: ₹100 ₹500 **Other Potential Costs:** **Power Supply:** ₹300 - ₹1500 (depends on the type and capacity of power supply) **Communication Expenses:** Variable & depend on the data and usage of the GSM module's SIM.		**Revenue Structure** **Hardware Sales**: Revenue from selling advanced monitoring hardware like ESP32, sensors, GSM modules, and servo motors. **Software Sales**: Revenue from selling cutting-edge software for data processing, alerts, and remote monitoring. **Service Contracts**: Revenue from providing maintenance and support services. **Subscription Fees**: Recurring revenue from cloud storage and premium features. **Consulting Services**: Revenue from expert consulting on drainage management and sustainability.	

Achievements and contributions:

The SAPSS has achieved several key milestones, including the successful collection of real-time data from manholes, the analysis of this data for infrastructure management, and the integration of the system into existing drainage infrastructure. The system has contributed to improved drainage efficiency, reduced instances of flooding, and enhanced public safety.

Recommendations for future work:

For future work, it is recommended to further enhance the SAPSS with additional sensors and modules for more comprehensive monitoring. Integration with smart city initiatives should be explored to improve overall infrastructure management.

Additionally, the system could be enhanced with machine learning algorithms for predictive maintenance and further integration into smart city networks.

In conclusion, the SAPSS has demonstrated its effectiveness in monitoring and managing manholes in urban sewer systems. Its ability to provide real-time data and alerts has contributed to improved infrastructure management and public safety. With further enhancements and integration with smart city initiatives, the SAPSS has the potential to revolutionize urban drainage management and contribute to the development of sustainable and resilient cities.

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