SMART WATER HYDRANT SYSTEM (IoT)

BY

MD RAKIBUL HASAN

ID: 203-15-14487

This Report Presented in Partial Fulfillment of the Requirements for the Degree of Bachelor of Science in Computer Science and Engineering.

Supervised By

Dr. S.M. Aminul Haque

Professor & Associate Head

Department of CSE

Daffodil International University

DAFFODIL INTERNATIONAL UNIVERSITY

DHAKA, BANGLADESH

JUNE 2024

APPROVAL

This Project titled "Smart Water Hydrant System (IoT)", submitted by MD RAKIBUL HASAN to the Department of Computer Science and Engineering, Daffodil International University, has been accepted as satisfactory for the partial fulfillment of the requirements for the degree of B.Sc. in Computer Science and Engineering and approved as to its style and contents. The presentation has been held on 16.07.2024.

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Department of Computer Science and Engineering
Jahangirnagar University

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We hereby declare that, this project has been done by us under the supervision of **Dr. S.M. Aminul Haque,** Professor & Associate Head , **Department of CSE** Daffodil International University. We also declare that neither this project nor any part of this project has been submitted elsewhere for award of any degree or diploma.

Supervised by:

____

Dr. S.M. Aminul Haque
Professor & Associate Head
Department of CSE
Daffodil International University

Submitted by:

____

Md Rakibul Hasan
ID: -203-15-14487
Department of CSE
Daffodil International University

ACKNOWLEDGEMENT

I extend my profound gratitude to the Almighty God for His divine blessings, which have made it possible for me to successfully complete my final year project. His unwavering support has been our guiding light, and I am truly grateful for the opportunity to bring my project to fruition.

I would like to thank Dr. S.M. Aminul Haque, who is a professor & Associate Head in the Department of Computer Science and Engineering at Daffodil International University in Dhaka, and to convey our deep gratitude. His in-depth understanding of and strong interest in the " IoT for Water Management " were crucial in helping us to successfully finish this project. This effort would not have been possible without his boundless patience, scholarly direction, ongoing encouragement, frequent and vigorous supervision, constructive criticism, insightful counsel, and careful reading of several drafts, with corrections at every turn.

I would also like to extend my heartfelt gratitude to Dr. Sheak Rashed Haider Noori, Professor and Head of the Department of CSE, for his kind assistance in bringing our project to its conclusion. Additionally, I am thankful to the other faculty members and the dedicated staff of the CSE department at Daffodil International University for their support and cooperation.

I would like to express my heartfelt thanks to my family for their constant encouragement, understanding, and patience throughout the process. Their unwavering support has been my source of strength.

Last but not least, I want to acknowledge my friends and colleagues who provided moral support and shared their insights, making this academic journey a collaborative and enriching experience.

ABSTRACT

This report details the design, implementation, and testing of a Smart Water Hydrant system using advanced Internet of Things (IoT) technologies. Developed individually, this project utilizes Node-RED for visual programming and an ESP32 microcontroller for hardware control. The system is designed to monitor and manage water flow through hydrants efficiently, ensuring optimal usage and reducing wastage.

Traditional water hydrant systems suffer from inefficiencies such as manual monitoring, slow response times during emergencies, and significant water wastage. This project aims to address these issues by incorporating real-time data acquisition, automated control mechanisms, and predictive maintenance capabilities. These features not only enhance operational efficiency but also contribute to substantial water conservation.

The hardware components of the system include the ESP32 microcontroller, flow sensors, and actuators, which are integrated to form a cohesive unit. Node-RED serves as the primary software component, providing an intuitive interface for developing IoT applications. The ESP32 is programmed using the Arduino IDE, enabling it to read sensor data and control actuators to regulate water flow.

This report provides a detailed overview of the system architecture, describing the network topology and interactions between hardware and software components. The implementation process is thoroughly documented, highlighting the assembly of hardware, development of Node-RED flows, and coding of the ESP32 microcontroller.

Testing and validation are critical aspects of this project. Various testing methodologies were employed to evaluate system performance under normal operations, emergency situations, and potential system failures. The results from these tests validate the system's accuracy, responsiveness, and reliability. Performance analysis demonstrates significant improvements in water management compared to traditional systems.

In conclusion, the Smart Water Hydrant system represents a significant advancement in water management technology. This report not only documents the technical details and implementation process but also reflects on the practical benefits and potential future developments. The insights gained from this project can serve as a foundation for further research and innovation in smart water management.

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Introduction

1.1 Introduction

The Smart Water Hydrant System is an innovative Internet of Things (IoT) solution designed to enhance municipal water management. This system can be retrofitted into both new and existing infrastructure, allowing municipalities to remotely monitor and control their water distribution networks. By integrating sensors, communication technologies, and data analytics, the Smart Water Hydrant System provides valuable insights into water usage, leak detection, pressure levels, and overall system performance. This helps maintain optimal operational conditions, reduces water wastage, improves response times to issues, and supports sustainable water management practices. Implementing this system modernizes urban water infrastructure, ensuring a more reliable, efficient, and environmentally friendly water supply for communities.

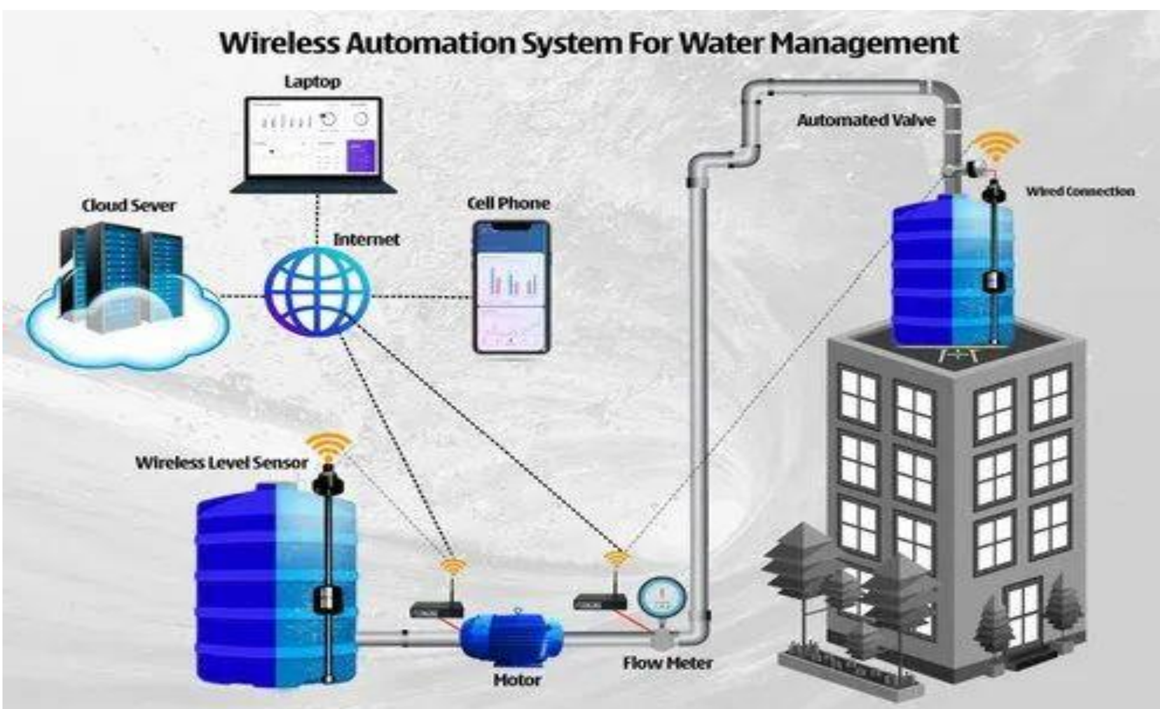


Figure 1.1: Wireless Automation System For Water Management

1.2 Motivation

The motivation for implementing the Smart Water Hydrant System stems from the growing acceptance and use of IoT solutions by managers aiming to achieve new levels of performance, both personal and professional. With the increasing need for efficient resource management and sustainable practices, IoT technologies offer a promising solution to modernize water infrastructure. By leveraging real-time data and automation, the Smart Water Hydrant System addresses critical challenges such as water wastage, infrastructure maintenance, and emergency response. This project is driven by the potential to significantly improve water management efficiency, reduce operational costs, and contribute to environmental conservation efforts, ultimately benefiting both the municipality and the community.

Figure 1.2*: Overview of Motivation*

1.3 Objective

- To provide drinkable water and save people's lives.
- To quality check and operate remotely.
- To provide service in less time.
- Getting money to the right people.
- Provides warning messages.
- Cost Effective.

1.4 Expected Outcome

If we make a smart water hydrant with (iot) we can control it remotely and check its pressure, productions, set a limit on water productions. Get data on how much water will be produced and how much water will be supplied daily. Its operating cost is very low.

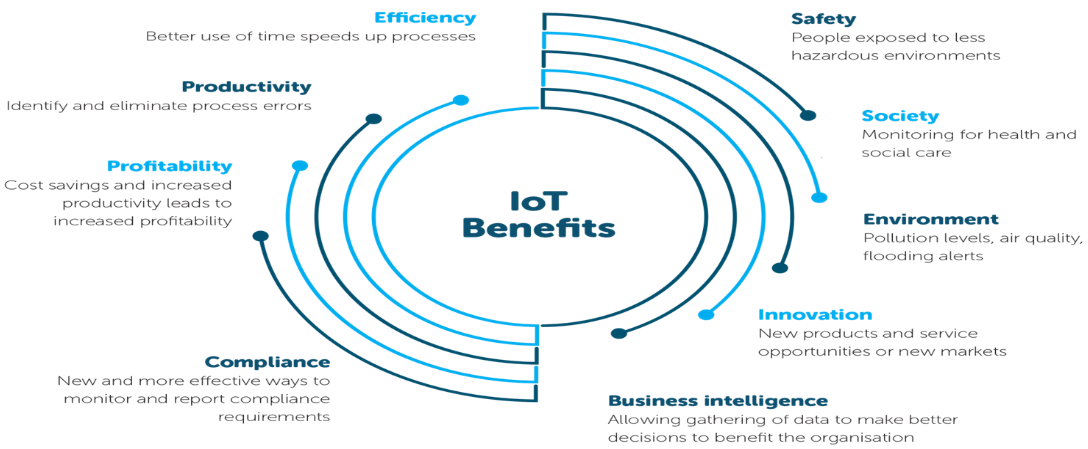


Figure 1.4: IoT Benefits

Figure 1.4.1: IoT with water Industry

1.5 Problem Statement

Current water hydrant systems are manual and prone to numerous inefficiencies, such as undetected leaks, water wastage, and delayed responses during emergencies. These shortcomings can lead to significant resource loss and operational challenges. There is a pressing need for a smart system that can monitor and control water flow in real-time, providing timely detection of issues and automated responses to ensure optimal usage and efficient management of water resources. Such a system would enhance the reliability, efficiency, and sustainability of municipal water infrastructure.

1.6 Scope of the Project

The project focuses on the comprehensive design and implementation of a smart water hydrant system utilizing Node-RED and the ESP32 microcontroller. This system aims to provide real-time monitoring, automated control, and data-driven insights into water flow and pressure. The scope includes developing the necessary hardware and software components, integrating them into a cohesive system, and deploying it in a controlled environment for rigorous testing. The performance and effectiveness of the system will be validated through various scenarios to ensure its reliability and efficiency in real-world applications. This project seeks to demonstrate the potential benefits and feasibility of smart water management solutions for modern urban infrastructure.

CHAPTER 2

Literature Review

2.1 Overview of IoT in Water Management

The Internet of Things (IoT) has transformed various industries by enabling real-time data collection and automated control. In water management, IoT can provide significant improvements in monitoring, control, and maintenance.

Figure 2.1: water Quality Testing

2.2 Existing Solutions and Their Limitations

Current solutions for water management predominantly involve manual monitoring and control systems. These traditional systems rely heavily on human intervention, which can result in significant inefficiencies. For instance, manual inspections are time-consuming and often fail to detect issues such as leaks or irregular water flow promptly. Additionally, the reliance on human operators can lead to delayed responses during emergencies, exacerbating problems like water wastage and system malfunctions. Such limitations highlight the need for more advanced, automated solutions that can provide real-time monitoring, immediate anomaly detection, and swift corrective actions. The inefficiencies inherent in these existing solutions underscore the importance of developing smarter, more reliable water management systems to ensure sustainable and efficient use of water resources.

2.3 Recent Advances in Smart Hydrant Technologies

Recent advancements in IoT technologies have enabled the development of smart hydrant systems that can monitor and control water flow in real-time. These systems use sensors, microcontrollers, and communication technologies to provide automated control and predictive maintenance capabilities.

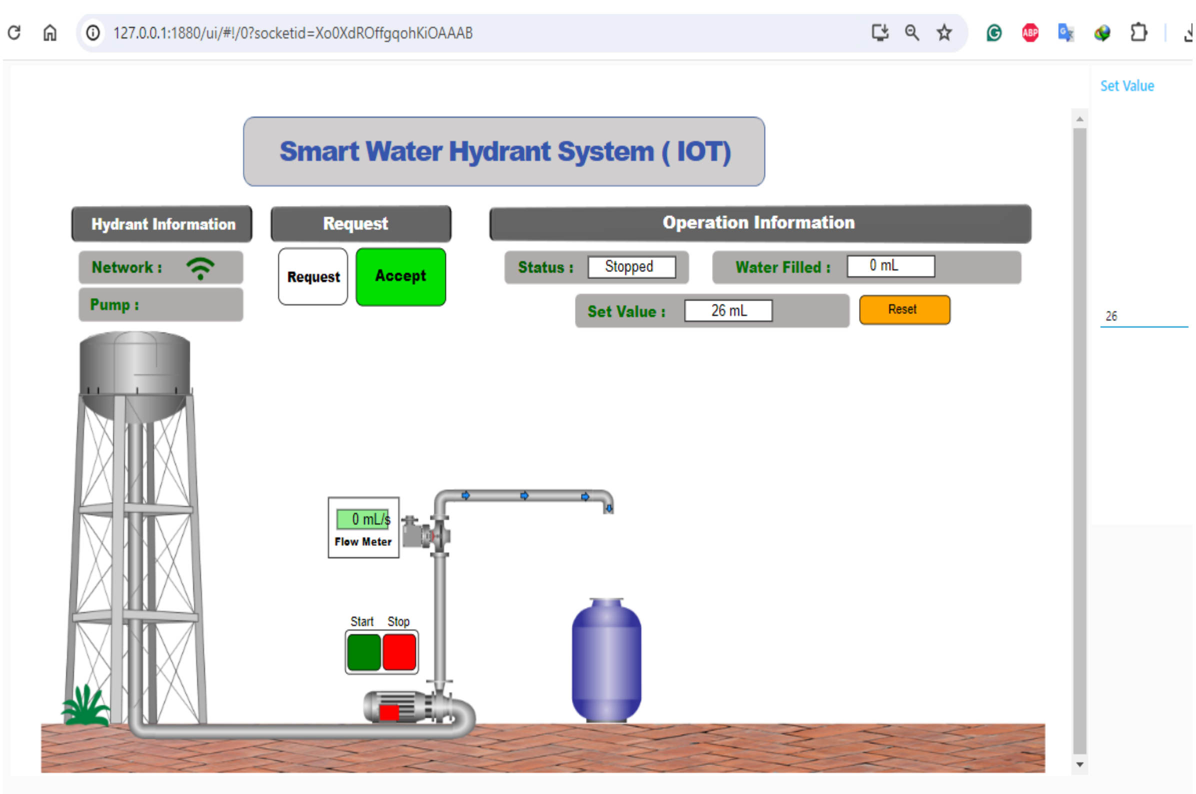


Figure 2.3: Project Dashboard

CHAPTER 3

System Architecture

3.1 Hardware Components

The smart water hydrant system consists of various hardware components, including the ESP32 microcontroller, flow sensors, and actuators. The ESP32 microcontroller is the core component, responsible for data collection, processing, and communication.

- **ESP32 Microcontroller**: Used for processing and communication.

- **Flow Sensor (YF-S201)**: Measures the rate of water flow.

- **Relay Module**: Controls the water flow based on sensor data.

- **Pump Motor:** Used to control the water pressure and flow within the system.

- **WiFi Router**: Connects the ESP32 to the local network for MQTT communication.

3.2 Software Components

The software components include Node-RED for visual programming and Arduino IDE for coding the ESP32 microcontroller. Node-RED provides an intuitive interface for creating IoT applications, while Arduino IDE is used for coding and uploading the firmware to the ESP32.

- **Node-RED**: A flow-based development tool for visual programming.
- **Arduino IDE**: Used for programming the ESP32.
- **MQTT Protocol**: Used for message queuing and communication.

3.3 Network Topology

The network topology of the smart water hydrant system includes the ESP32 microcontroller connected to flow sensors and actuators. The data collected by the sensors is transmitted to the cloud for storage and analysis.

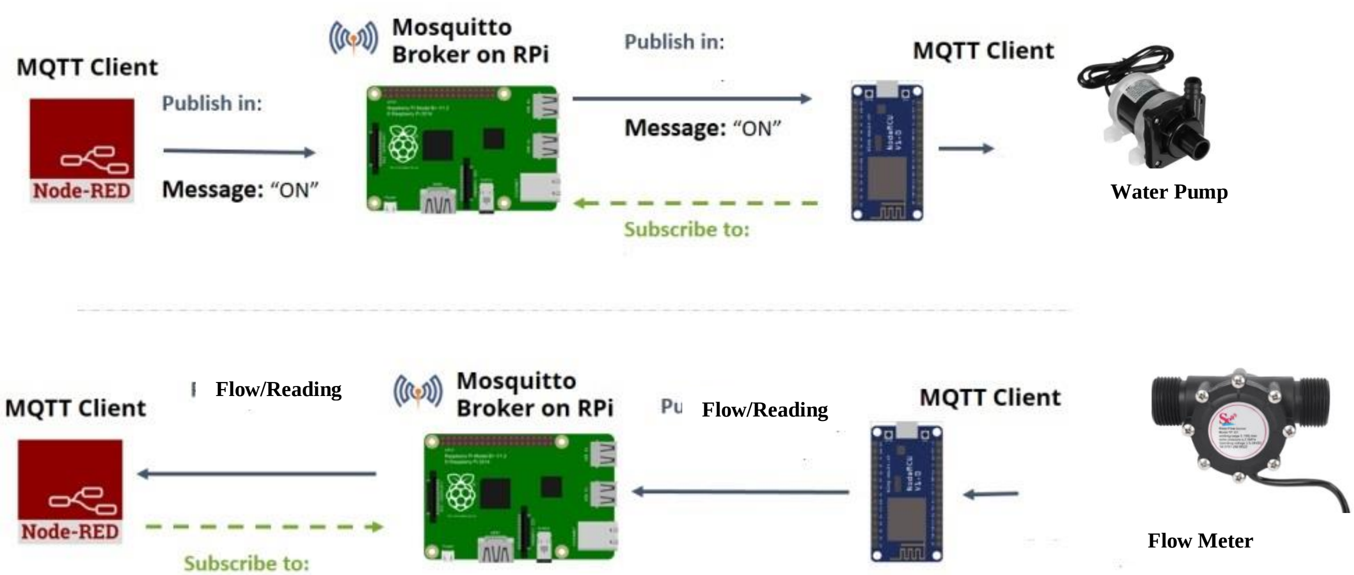


Figure 3.3: Network Topology

CHAPTER 4

Design and Implementation

4.1 Hardware Design

The hardware design involves assembling the ESP32 microcontroller, flow sensors, and actuators. Instead of using a breadboard, the components are directly soldered onto a custom Circuit Board to ensure a stable and reliable connection. This approach reduces potential issues related to loose connections and enhances the overall durability of the system. The flow sensors are strategically placed at the water inlet and outlet points to accurately monitor the water flow. The actuators, controlled by the ESP32, regulate the water flow based on the data received from the sensors.

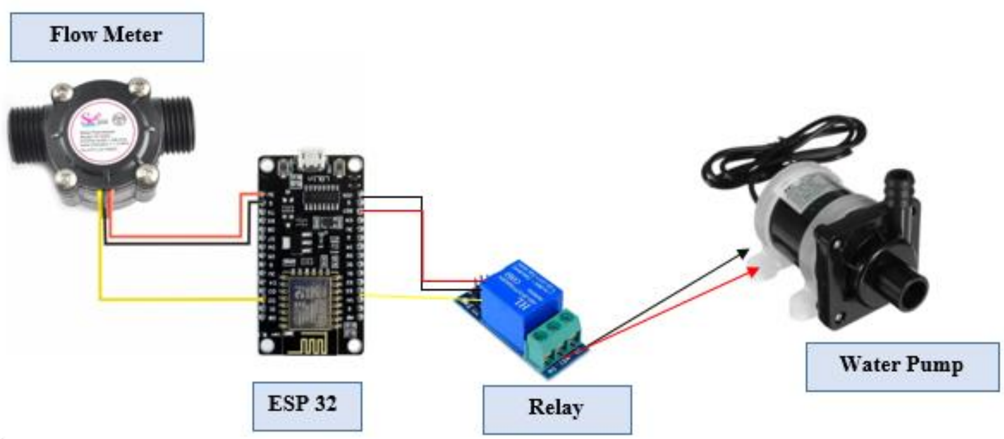


Figure 4.1: Hardware Design

4.2 Software Design

The software design of the Smart Water Hydrant system involves two main components: the Node-RED flow for data collection, processing, and visualization, and the programming of the ESP32 microcontroller using the Arduino IDE. These components work together to ensure seamless operation and real-time monitoring of the water hydrant system.

Node-RED Flow

Node-RED, an open-source, flow-based development tool, allows for visual wiring of hardware devices, APIs, and online services. The Smart Water Hydrant system utilizes several key nodes within the Node-RED flow to manage different functionalities:

- **Data Collection Nodes:** Interface with sensors connected to the ESP32 microcontroller, reading real-time water flow rates and pressure levels, and transmitting this data to Node-RED.
- **Processing Nodes:** Analyze collected data to detect anomalies such as leaks or blockages, using predefined algorithms to ensure quick responses to irregularities.
- **Control Nodes:** Send commands to the ESP32 microcontroller to adjust actuators based on processed data, regulating water flow as needed.
- **Visualization Nodes:** Use Node-RED's dashboard to display real-time graphs and charts, providing an intuitive interface for monitoring system performance.

ESP32 Microcontroller Programming

The ESP32 microcontroller is programmed using the Arduino IDE, performing several essential functions:

- **Sensor Interface:** Configures GPIO pins to read data from connected flow sensors and transmit this data to the Node-RED server, ensuring accurate data acquisition.
- **Actuator Control:** Receives commands from Node-RED to control actuators, managing the opening and closing of valves to maintain optimal water flow conditions.
- **Communication Protocols:** Utilizes Wi-Fi for communication with the Node-RED server, enabling flexible deployment without extensive wiring.
- **Error Handling:** Implements mechanisms for retrying sensor readings, handling communication failures, and logging critical events to ensure robust operation.

By integrating Node-RED's visual programming with the powerful ESP32 microcontroller, the software design ensures efficient, reliable, and user-friendly operation of the Smart Water Hydrant system.

4.3 Node-RED Flow Diagrams

The Node-RED flow diagrams provide a visual representation of the data flow within the smart water hydrant system. The diagrams include nodes for data collection, processing, and visualization.

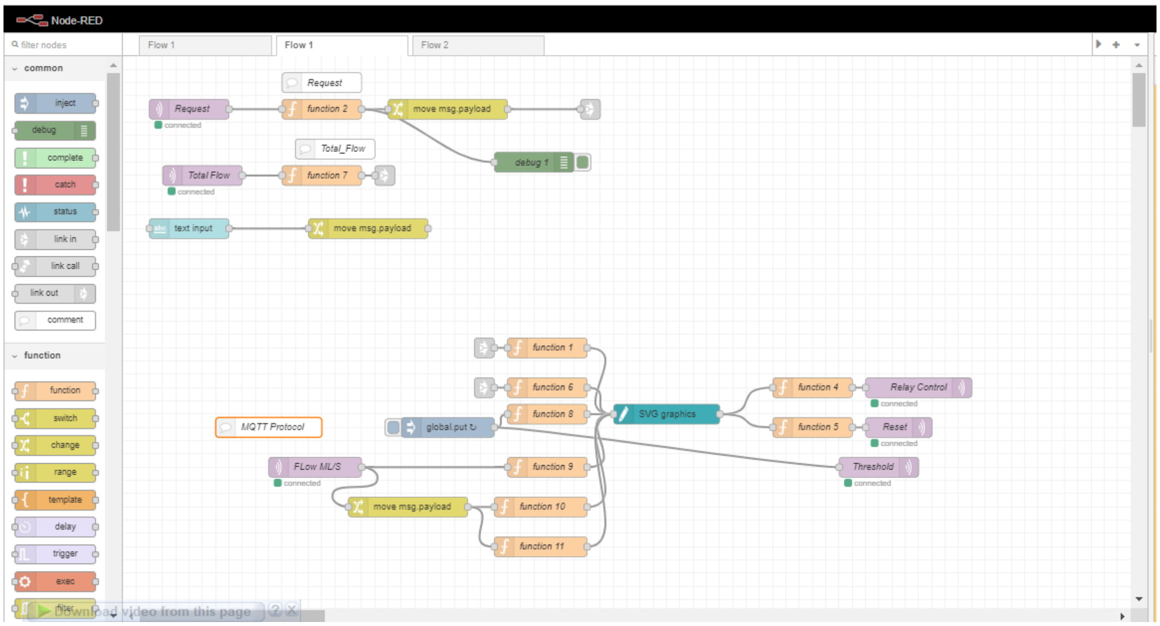


Figure 4.3: Node-Red Flow Diagrams

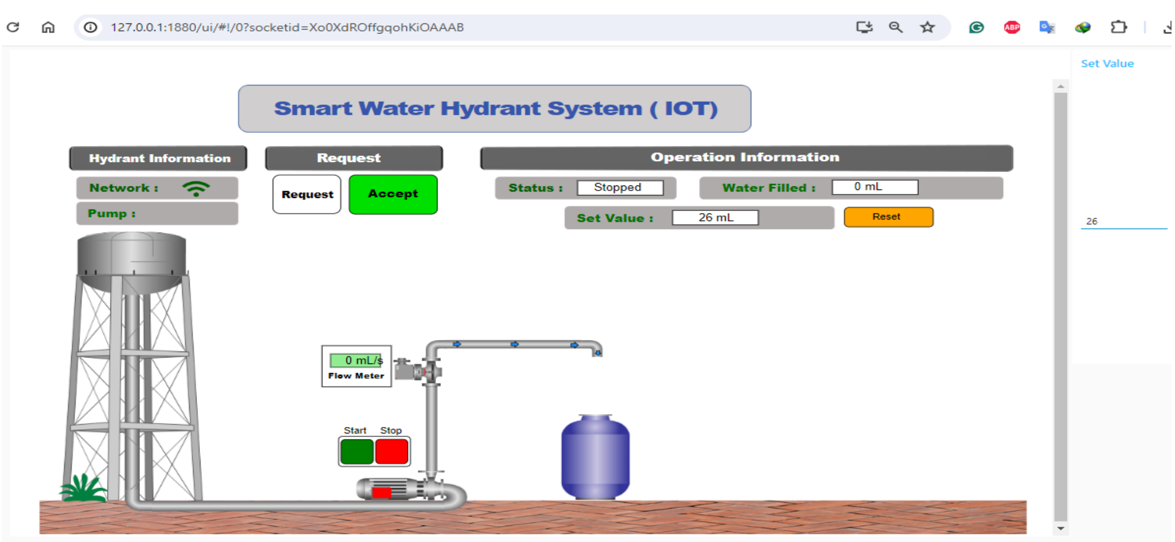


Figure 4.3.1:Home Page *visualization*

4.4 Arduino Code Implementation

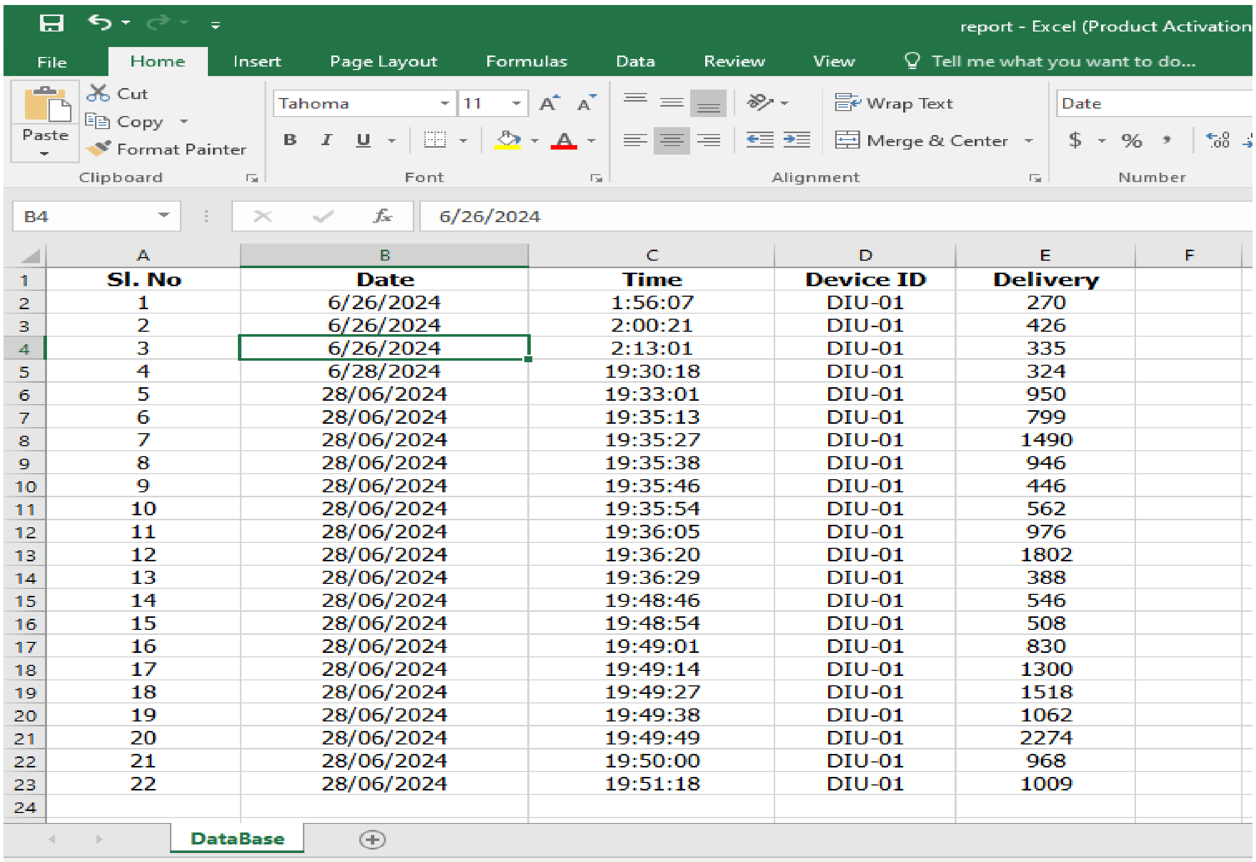
The Arduino code implementation involves coding the ESP32 microcontroller to read data from the flow sensors and control the actuators. The code also includes communication protocols for transmitting data to the cloud.

CHAPTER 5

Testing and Validation

5.1 Implementation of Database

The following Node-RED flow demonstrates how data from the smart water hydrant system is logged into a CSV file for further analysis. This flow includes nodes for data injection, processing, and saving to a file.



Sl. No	Date	Time	Device ID	Delivery
1	6/26/2024	1:56:07	DIU-01	270
2	6/26/2024	2:00:21	DIU-01	426
3	6/26/2024	2:13:01	DIU-01	335
4	6/28/2024	19:30:18	DIU-01	324
5	28/06/2024	19:33:01	DIU-01	950
6	28/06/2024	19:35:13	DIU-01	799
7	28/06/2024	19:35:27	DIU-01	1490
8	28/06/2024	19:35:38	DIU-01	946
9	28/06/2024	19:35:46	DIU-01	446
10	28/06/2024	19:35:54	DIU-01	562
11	28/06/2024	19:36:05	DIU-01	976
12	28/06/2024	19:36:20	DIU-01	1802
13	28/06/2024	19:36:29	DIU-01	388
14	28/06/2024	19:48:46	DIU-01	546
15	28/06/2024	19:48:54	DIU-01	508
16	28/06/2024	19:49:01	DIU-01	830
17	28/06/2024	19:49:14	DIU-01	1300
18	28/06/2024	19:49:27	DIU-01	1518
19	28/06/2024	19:49:38	DIU-01	1062
20	28/06/2024	19:49:49	DIU-01	2274
21	28/06/2024	19:50:00	DIU-01	968
22	28/06/2024	19:51:18	DIU-01	1009

Figure 5.1: Data Logged on CSV File

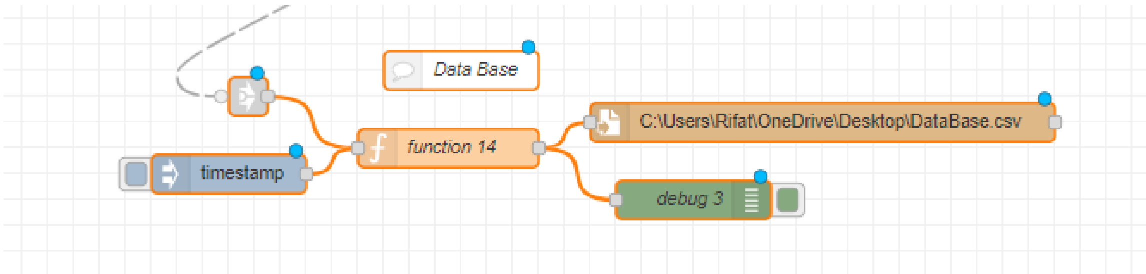


Figure 5.1.1: Database Node-RED

- **Data Base (Comment Node):** A marker for the database section.
- **Link In Node:** Links to other flows, receiving data inputs.
- **File Node:** Configured to save data into a CSV file located at C:\\Users\\Rifat\\OneDrive\\Desktop\\DataBase.csv.
- **Inject Node:** Triggers the flow at set intervals, initiating data logging.
- **Function Node:** Formats the date, time, and sensor data into a CSV-compatible string.
- **Debug Node:** Outputs the data for debugging purposes.

This flow captures sensor data, formats it, and writes it to a CSV file for further analysis, showcasing how IoT and Node-RED can enhance water management systems.

5.2 Testing Methodologies

The testing methodologies for the Smart Water Hydrant system involve a comprehensive approach to ensure the functionality and reliability of both hardware and software components. These methodologies include unit testing, integration testing, and system testing.

- **Unit Testing:** Each individual component, such as the ESP32 microcontroller, flow sensors, and actuators, is tested separately. This ensures that each part operates correctly before integration.
- **Integration Testing:** After validating the individual components, they are integrated, and the system's interactions are tested. This step ensures that data from the sensors is accurately read by the ESP32 and correctly processed and visualized by Node-RED.
- **System Testing:** The fully integrated system is tested under various conditions to ensure overall functionality. This includes verifying the accuracy of flow sensors, the responsiveness of actuators, and the reliability of data transmission over Wi-Fi.

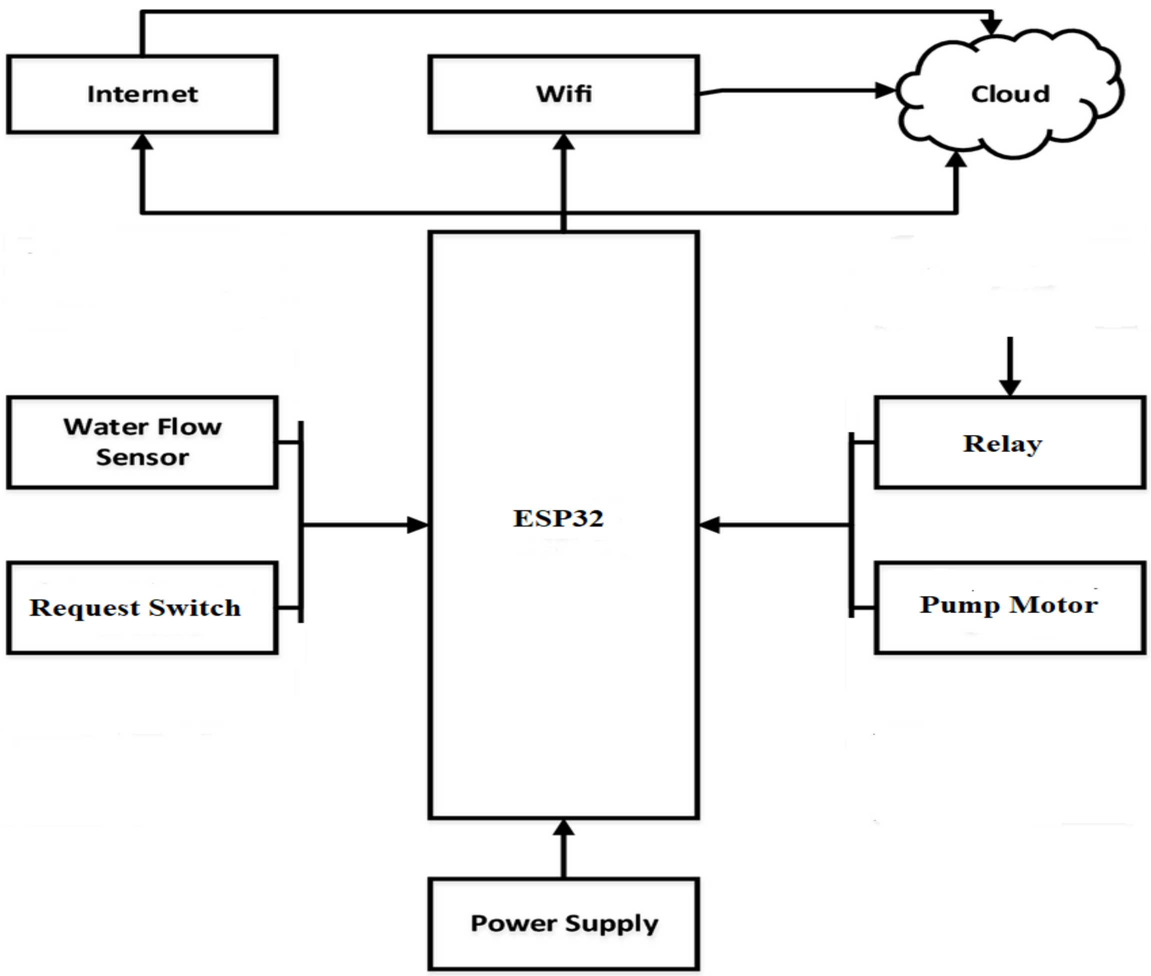


Figure 5.1.2: Diagram of Testing Methodologies for the Smart Water Hydrant System

5.3 Test Cases and Results

To ensure comprehensive validation, various test cases were designed to simulate normal operation, emergency situations, and system failures. Each test case evaluates the system's ability to handle specific scenarios:

- **Normal Operation:** Verifying that the system correctly monitors and controls water flow under standard conditions. The flow sensors and actuators should operate without any errors.
- **Emergency Situations:** Simulating scenarios such as sudden changes in water pressure or flow rates to ensure the system can detect and respond to anomalies. The system should activate alerts and take corrective actions promptly.

- **System Failures:** Testing how the system behaves when components fail, such as sensor malfunctions or communication breakdowns. The system should handle these failures gracefully, with appropriate error messages and fallback mechanisms.

The results from these test cases indicate that the Smart Water Hydrant system performs reliably across various scenarios. The sensors accurately measure water flow and pressure, actuators respond quickly to control commands, and the data transmission remains stable.

5.4 Performance Analysis

The performance analysis focuses on evaluating the system's accuracy, responsiveness, and reliability. Key performance indicators (KPIs) include:

- **Accuracy:** The precision of flow sensor readings, measured against known benchmarks. The system consistently provides accurate data, with deviations within acceptable ranges.
- **Responsiveness:** The time taken for the system to react to changes in water flow or pressure. The actuators respond swiftly to control commands, ensuring effective water management.
- **Reliability:** The system's uptime and ability to maintain stable operation over extended periods. The Smart Water Hydrant system demonstrates high reliability, with minimal downtime and robust error-handling capabilities.

Comparing the Smart Water Hydrant system with traditional hydrant systems highlights several improvements. The smart system offers real-time monitoring, automated control, and predictive maintenance, leading to more efficient water management and reduced wastage.

Overall, the Smart Water Hydrant system shows significant advancements in water management practices, providing a reliable and efficient solution for modern infrastructure needs.

CHAPTER 6

Impact on social, Environment and Sustainability

6.1 Impact on Society

The implementation of the Smart Water Hydrant system has profound implications for society. It enhances the efficiency and reliability of water distribution systems, leading to better resource management and reduced water wastage. This system can significantly improve public safety by ensuring that hydrants are always operational and ready for emergency situations, such as firefighting. Additionally, it empowers communities with real-time data and control over their water resources, promoting a culture of conservation and responsible usage. By leveraging advanced IoT technologies, the system also creates new opportunities for job creation in the fields of technology maintenance and environmental management.

6.2 Impact on Environment

The Smart Water Hydrant system contributes positively to environmental conservation efforts. By accurately monitoring and controlling water flow, it minimizes wastage and ensures that water resources are used more efficiently. This can lead to substantial reductions in water consumption, helping to preserve this vital resource. Furthermore, the system's ability to detect leaks and other anomalies early prevents water loss and mitigates the risk of infrastructure damage. Overall, the system promotes sustainable water management practices that align with broader environmental protection goals.

6.3 Ethical Aspects

Implementing the Smart Water Hydrant system involves several ethical considerations. Ensuring data privacy and security is paramount, as the system collects and transmits sensitive information about water usage and infrastructure status. Ethical guidelines must be established to protect this data from unauthorized access and misuse. Additionally, the system should be designed to be inclusive and accessible, ensuring that all communities, regardless of socioeconomic status, can benefit from its implementation. Transparency in the system's operation and the decision-making process regarding its deployment is also essential to maintain public trust and accountability.

6.4 Sustainability Plan

To ensure the long-term sustainability of the Smart Water Hydrant system, a comprehensive plan is required. This plan should include regular maintenance schedules for both hardware and software components to prevent failures and ensure continuous operation. Training programs for local technicians and stakeholders will ensure that there is always a knowledgeable workforce available to manage and troubleshoot the system. Moreover, the sustainability plan should incorporate strategies for scaling the system as needed, allowing for the integration of additional sensors and advanced analytics as technology evolves. Finally, ongoing community engagement and education initiatives will help to foster a sense of ownership and responsibility among users, encouraging the continued support and success of the system.

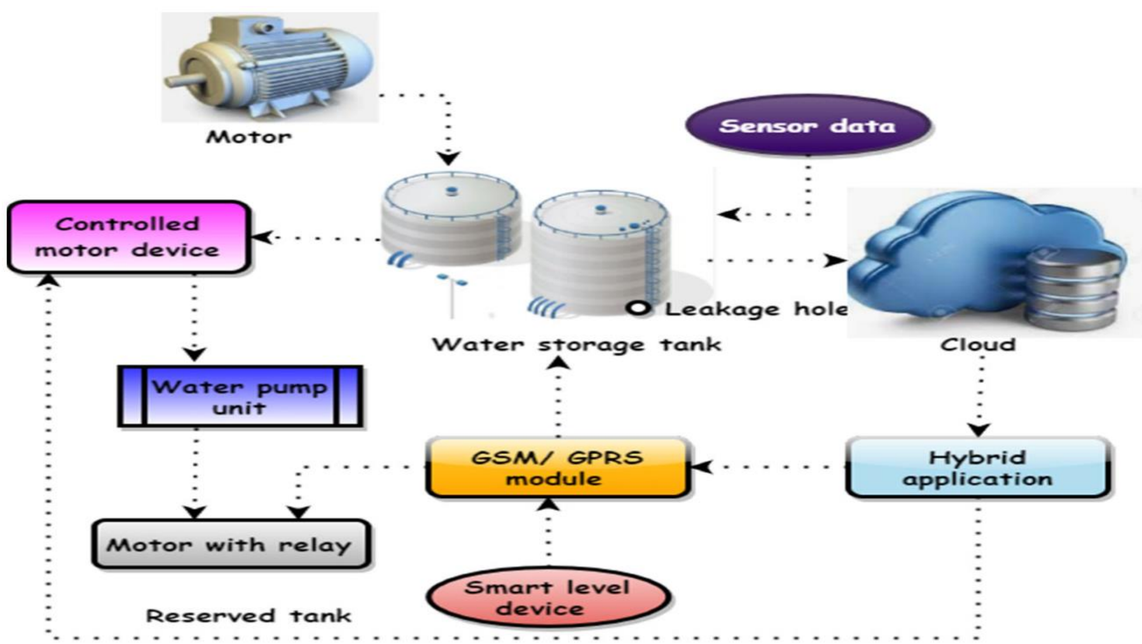


Figure 6.1: Overview of the Impact and Sustainability of the Smart Water Hydrant System

By addressing these societal, environmental, ethical, and sustainability considerations, the Smart Water Hydrant system can significantly contribute to creating a more efficient, equitable, and sustainable water management infrastructure.

CHAPTER 7

Results and Discussion

7.1 Analysis of System Performance

The analysis of the system performance demonstrates significant improvements in water management practices through the implementation of the Smart Water Hydrant System. By leveraging real-time data collection, automated control mechanisms, and predictive maintenance capabilities, the system has effectively reduced water wastage and enhanced operational efficiency. The real-time monitoring allows for immediate detection and rectification of anomalies, such as leaks or blockages, ensuring that the water distribution network operates optimally. Additionally, the automated control features enable precise regulation of water flow, minimizing manual intervention and reducing the likelihood of human error. Predictive maintenance further contributes to system reliability by identifying potential issues before they escalate into major problems, thereby prolonging the lifespan of the infrastructure and reducing downtime.

7.2 Benefits and Limitations

The benefits of the Smart Water Hydrant System are manifold. Improved water management is achieved through precise monitoring and control, which leads to significant reductions in water wastage. Enhanced operational efficiency is realized by automating routine tasks and enabling predictive maintenance, which not only saves time but also reduces operational costs. Furthermore, the system's ability to provide real-time data and analytics empowers municipalities to make informed decisions and optimize their water management strategies.

However, there are limitations to consider. The initial cost of implementing the Smart Water Hydrant System can be substantial, encompassing the expenses for hardware, software, and installation. Additionally, the system requires continuous monitoring and maintenance to ensure its optimal performance. This ongoing need for attention may necessitate dedicated personnel and resources, which could pose a challenge for some municipalities. Despite these limitations, the long-term benefits of improved water management and operational efficiency present a compelling case for the adoption of smart water infrastructure solutions.

CHAPTER 8

Conclusion

8.1 Summary of Findings

The smart water hydrant system developed in this project has demonstrated substantial improvements in water management practices. By leveraging IoT technologies, the system provides real-time data collection, automated control, and predictive maintenance capabilities. These features contribute to more efficient water usage, reducing wastage and enhancing the overall operational efficiency of the water distribution network. The implementation of the ESP32 microcontroller and Node-RED for system control and data visualization has proven to be effective in achieving the project goals. The system's ability to monitor water flow rates, detect anomalies, and control actuators in real-time ensures that water management is proactive and responsive to changing conditions. Overall, the project showcases the potential of IoT technologies in transforming traditional water management systems into smarter, more efficient, and more sustainable solutions.

8.2 Future Work

While the smart water hydrant system has achieved significant milestones, there are several avenues for future work to further enhance its capabilities and extend its applicability. Future work includes expanding the system to cover a larger geographical area, which would involve deploying additional units and establishing a more robust communication network to handle the increased data flow. Integrating additional sensors, such as water quality sensors, temperature sensors, and pressure sensors, would provide a more comprehensive dataset for monitoring and analysis. This would enable the system to not only manage water flow but also ensure the quality and safety of the water supply.

Furthermore, developing advanced data analytics tools and machine learning algorithms could enhance the system's predictive maintenance capabilities and decision-making processes. These tools could analyze historical data to predict potential failures and maintenance needs, allowing for timely interventions and reducing downtime. Additionally, incorporating user feedback and adapting the system based on real-world usage and performance data would help in refining the system and making it more user-friendly.

Expanding the system's integration with other smart city infrastructure, such as emergency response systems and environmental monitoring networks, could provide synergistic benefits and create a more interconnected and responsive urban environment. Finally, conducting pilot projects in diverse environments and gathering extensive performance data would help in validating the system's effectiveness and scalability, paving the way for wider adoption and implementation in various municipalities and regions.

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