LEAK DETECTION IN WATER PIPELINES USING SENSORS

A

PROJECT REPORT

Submitted in partial fulfillment of the requirement of the degree

of

BACHELOR OF TECHNOLOGY
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Under the supervision

Of

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to

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DECLARATION

I hereby declare that work presented in this report entitled **"Leak Detection in Water Pipelines Using Sensors"** in partial fulfillment of the requirement for the requirements for the award of a degree in Bachelor of Technology in the Department of Civil Engineering from **Jaypee University of Information Technology Waknaghat, Solan, H.P** is the original record of my own work carried out under the supervision of Prof. **Dr. Ashish Kumar**. This work has not been submitted elsewhere for the reward of any other degree/diploma. I am fully responsible for the contents of my project report.

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CERTIFICATE

This is to ensure that the work which is being introduced in the venture report named "**LEAK DETECTION IN WATER PIPELINES USING SENSORS** " in fractional satisfaction of the necessities for the honor of the level of Bachelor of Technology in Civil Engineering submitted to the Department of Civil Engineering, **Jaypee University of Information Technology, Waknaghat** is a true record of work completed by **Sarthak Chauhan (211604)** under the management of **Prof. Dr. Ashish Kumar** Head of Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat.

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ABSTRACT

To control the water leaks that occur in it, this study offers a smart water pipeline monitoring system. The amount of water used in daily life is rising in direct proportion to the amount of water wasted. To solve this, the Internet of Things (IoT) is used in the design and proposal of a smart monitoring system. The benefits and uses of IoT currently are endless. There are numerous sensors on the market that can be used to monitor water flow. In this system water flow sensor is employed in the pipeline to monitor waterflow. In this system, a turbidity sensor has been utilized to measure water contamination, and a water flow sensor is employed in the pipeline to monitor water flow. The hall effect is the basis for how flow sensors operate. The microcontroller known as Node MCU This system makes advantage of one of the most popular microcontrollers for Internet of Things applications. This microcontroller's interrupt pins are its primary function. The turbidity and water flow sensors transfer their measured information to the cloud server. Because the Thing Speak cloud server is open source and free to use, it has been utilized for the system's cloud data storage. The Thing Speak cloud webserver displays the data based on the numbers obtained from the water flow sensor. So, it will be extremely simple to monitor the water flow in the pipeline.

Keywords: Cloud server, smart monitoring system, water flow sensor

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LIST OF ACRONYMS AND ABBREVIATIONS

DTS	Distributed Temperature Sensing
IOT	Internet Of Things
ISRs	Interrupt Service Routines
LPWAN	Low-power wide-area networks
MEMS	Micro-Electro-Mechanical Systems
PVC	polyvinyl chloride
RTTM	Real-Time Transient model
WDN	Water distribution networks
WHO	World Health Organization
WUSNs	Wireless underground sensor network

CHAPTER 1

INTRODUCTION

1 GENERAL

It is not a lot around 3% of the world's water supply is fresh, and a third of that is unavailable. Whereas the number of people rises, the businesses extend, and the standard of life advances, there is a continuous demand for water. Human exploitation of water resources has been brought about by dams, reservoirs, and wells constructed. Estimates postulate that by 2050, a third of the world population may lack access to water. According to the statistical data, about 50 lakh households in the cities of Delhi, Kolkata, Mumbai, Hyderabad, Kanpur and Madurai face a shortage of potable water on a regular basis. According to WHO statistics, an individual requires drinking and utilizing at least 100- 200 liters of water daily, far higher than the recommended urban figure of 90 liters. Sanitary availability of drinking water is at the core of improving community and conserving community health. It is very important for every human to save about twenty to forty liters of freshwater per day for use in routines such as drinking, cooking and fulfilling necessities. hygienic measures. Even having these precautions in place, about one billion people in the world today still languish without clean drinking water. What is worse is that millions of people across the globe suffer from diseases, abbreviated lives, and dying young. In many areas close to half of all hospital beds are filled with sick people who do not have access to pure water. According to the World Health Organization reports, more than four billion people get sick every year due to unsafe water-the top reason for diarrhea. Each year, over 2 million people die from such ails; and 90 per cent of life lost relates to children under five in poor families dwelling in less economically developed countries. To create a sustainable growth and development in a society, easy access to safe water supply and adequate sanitation becomes important. While possible short-term responses are a possibility, only through considered, consistent work in infrastructure, governance, and capacity building can we make the changes that can be truly sustainable.

1.1 Water Pipelines

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- **Distribution Mains**- When water is conveyed into distribution systems it is passed through smaller pipes. The standard distribution mains are in diameter from that of six inches to twenty-four inches. This is a common summarization; This should not be taken to mean that motor distribution mains over twenty-four inches in diameter do not exist. Distribution mains supply customers; unlike transmission mains, they link to service lines. Generally, distribution mains are arranged based on three widely adopted network types; arterial, grid, or tree. The “tree” network leads often to dead ends and is, therefore, usually the least preferred. A pipeline that ends having no other connection is called a dead end. Let us take an instance, cul-de-sacs often serve as a dead end. Because every pipeline in a grid network connects with all the rest, a grid network usually provides the most desirable configuration. Ductile iron pipe is the most commonly used material for construction of distribution mains. Furthermore, polyvinyl chloride is commonly known as PVC and is widely used. Water systems of older days often contain asbestos cement pipe, which is rarely built today.

- **Transmission Mains -** Beginning water distribution involves connecting it to existing pipes; in some instances, water is to come from a water treatment plant or from far off drinking water wells which do not service the general consumer area. The function of transmission mains in such situations is to provide a water supply to the distribution network. Transmission mains are big pipes which are used to carry a large volume of water a long distance. The pipes could extend to a 120-inch diameter mileage, which is over ten feet. Some transmission mains are actually smaller in diameter and many of them cover only a small distance. Standardly, transmission mains do not directly supply service connections to the customers, except via a secondary distribution system. Most transmission mains are made of welded steel or ductile iron pipe.

Fig. 1.1 - Four, 36-inch cast-iron pipes

- **Service Laterals-** It's only when pipes are connected to a distribution main and reach each customer separately that water can be supplied to each person customer parcel. The service laterals are the label for service pipes uniting individual parcels. These pipes are mostly made from copper or plastic and connect to a distribution main, run to the customer's parcel and connected to a water meter. Water main is the main pipe supplying the rural and the service line is the one that goes to individual homes.

1.2 Water Leakage-

Leaks can be present at various locations within your home such as inside or outside the building, such as the basement, within construction walls, and outside the home. Leakages can lead to small drips, or, in serious cases, it can cause major flooding. A longer duration of undetected or sealed leakage increases the risk of extreme consequences such as damage to your residence from water, increased utility expenses, and the ability of mold exposure to cause health issues.

1.3 Causes for Leakage-

a. **The pipes' substance -** To a great extent, how a single leak expresses itself depends on the material of the pipe. The failure modes of the pipes are influenced by the inherent characteristics of pipe material producing varying modes of failure. Longitudinal cracking is a fairly typical mode of rupture of asbestos cement pipes; steel and cast-iron pipes are characterized by leakage through holes from corrosion.

b. **How old the pipes are** - The condition of pipes is dependent on their age which directly and indirectly control leakage rates. As pipe age and walls open up, the risk of leak escalates especially at high pressure.

c. **Outside Factors and Material Damage**- Construction efforts and excavation activities represent a substantial external threat to underground pipes and the risk of inadvertent accidents. As pipelines are under the ground, they are easily damaged by heavy equipment and excavation tools as well as earthquakes. Sufficient security measures should be applied constantly during both construction and excavation to prevent inadvertent harm. One of the best strategies is for companies to maintain comprehensive network documentation so that professional locator tools are not only aware, but able to detail out pipelines before an excavation.

d. **Elevated Water Pressure**- The excessive force in pipes can breakdown the pressure causing leaks. Pressurized water systems in excess of what is recommended places an excess strain on pipe components leading to leaks on pipe walls and joints. While high pressure systems keep producing energy, pipes slowly deteriorate and tend to leak.

e. **Poor Installation** - Cheap underground pipe installation techniques result in leaks in the network. Poor joint connections, non-supported pipes and misaligned slopes have been found to be common causes of water leaks and pipe failure of the subterranean network. These problems tend to result in long term leaks.

f. **Corrosion -** Undetected corrosion is the cause of a lot of leaks in older plumbing systems. While corrosion effects the pipes, their structural integrity reduces, and eventually, there are leaks as well as damages due to water buildup.

1.4 Detection of leakages -

In view of continuous growth in age of pipeline infrastructural, leak detection has become a necessity for environmental, economic and safety reasons. Currently, there are many techniques for detecting leaks: sophisticated sensors and manual checks. respond Extrinsic leak-detection, airborne or intermittent, and computational or intrinsic methods.

1.4.1 Externally Based Leak Detection Methods

a. **Acoustic Detection Methods**: A fruitful external strategy involves the observation of acoustic signals produced by outflows from pressurized pipes. The nature of the acoustic signal generated during a leak (burst or continuous) depends upon both the size and pressure of the leak. If approached via sensors, which are able to filter the noise using the wavelet analysis or wavelet packet decomposition, can detect this acoustic signal.State-of-the-art solutions combine cross-correlation analysis and adaptive filtering algorithms into one in order to isolate the leak signal and pinpoint the exact location from where it emanates. It should be noted that Jiang & Wang proposed a filtering approach to improve the extraction of the signal characteristics, whereas Elliott et al. presented the "smart ball" which is better than anything at detecting small leaks in oil and water pipelines. Continued innovations such as the twin ball may permit the automatic repairs of leaks based on correlation between sound and leak intensity.Machine learning application has, in recent times, been highly rewarding in developments towards improving acoustic methods.

b. **Fiber Optic Sensing:** A very sensitive external arrangement is that of laying fibre optic cables near pipelines for constant measurements of temperature changes or strain difference due to leakage. The system identifies anomalies based on principles of Rayleigh, Raman and Brillouin scattering. Take Distributed Temperature Sensing (DTS) for example, which identifies leaks by tracing hot or cold spots within the pipeline. If some warm liquid leaks, the surrounding becomes warmer. Should a gas leak happen then Joule-Thomson cooling leads to a temperature decrease nearby. Walker (2003) and Tennyson et al. demonstrated how delicate and applicable this technique was in actual field situations.These advancements in Fiber optic sensing include the Distributed Differential Temperature Sensor which allows sub millimetre precision and a superior sensitivity. In addition, the Fiber Bragg Grating sensor improves the detection and measurement of strain, thus aiding improved leak identification.

1.4.2 Non-Continuous or Airborne Inspection Methods

These methods involve the carried-out inspection checks for the pipeline routes with the aid of advanced tools. Pipeline inspection techniques involve using specialized tools such as pigs and dogs, sophisticated aerial vehicles such as UAVs and helicopters armed with advanced sensors.

Aerial Leak Detection: Raquette et al. were first to use a Flame Ionization Detector readings on-board aircraft to detect hydrocarbon leaks. The research by Lensing (2006) and many others showed that thermal imaging, laser scanning, and gas detectors can reliably detect leaks from an aerial perspective. Today, UAVs such as SWIMMER, leverage thermal imaging to detect leaks in large desert, plain and hill areas. Scholars Tan and Xu developed systems that would make use of Tenable Diode Laser Absorption Spectroscopy in detecting of methane. Technological approaches including UAV-mounted Raman lidar and UV-absorption spectrometers have shown remarkable sensitivity and reliability, particularly with regard to the detection of gases, such as methane and hydrogen sulphide.

1.4.3 Internally/Computational-Based Leak Detection Methods

Flow and Pressure Monitoring Computational techniques are dependent on continuous monitoring of pipeline parameters, such as, pressure and flow rate. Any deviation from typical expectations when studying the readings, this often indicates a leak. For example, Scott and Li developed a strategy to determine polls in pipeline friction loss deficits in the lack of inlet flow circumstance instead, Li et al. coupled wavelet denoising with negative pressure waves to increase leak localization precision.

Use of high precision pressure transducers in conjunction with fuzzy clustering algorithms produce leak detection rates of up to 95%. Giunta et al. utilized environmental noise filtering in vibroacoustic systems to allow the leak detection at 35 km.

a. **Real-Time Transient Modelling (RTTM)** RTTM performs real-time simulations based on physics laws i.e. mass, momentum and energy conservation in order to identify gaps in pipeline operation. Using the data in the SCADA system, these models continue to monitor real time statistics such as pressure, flow and temperature, and raise an alarm if there are an unrealistic variation of any, indicating a possibility of a leak.Resort to techniques such as adaptive Leuenberger observers and cellular automata model. Lunger showed that measurement of flow rates represents an effective alternative to pressure changes for event detection, especially in natural gas pipelines.

b. **Balancing Systems** A simple way, method of volume balancing, measures both input and output volumes in terms of how they change over time. Nonetheless, such an approach does not suit compressible fluids or quick-time analysis well. It has been established that models such as Beggs and Brill's multiphase flow correlation and corrective volume balancing work well for sour gas systems under steady state conditions.

1.5 NEED OF STUDY

Studying the use of sensors for detecting leaks in water pipelines is vital for several compelling reasons:

1. **Water Conservation:**
   A tremendous amount of water is lost daily through undetected leaks in pipeline networks. In already water-scarce areas, monitoring and repairing these leaks as quickly as possible can save important water assets and ensure sustainable water usage.

2. **Preventing Infrastructure Damage:**
   Water leaking doesn't go away—it can lead to substantial damage to buildings, roads, and parks. By catching leaks early, we can stop extensive structural damage and prevent expensive repairs.

3. **Financial Savings:**
   Un-detected leaks can substantially drive up the operating expenses of utilities and increase customers' water bills. Efficient, prompt leak detection can reduce these costs to the benefit of both water suppliers and the public.

4. **Environmental Protection:**
   Leakages in water can result in problems such as soil erosion, contamination of adjacent water sources, and upsets to the natural environment. Early detection and repair of leakages reduce the impact on the environment and enable ecological balance.

5. **Efficient Water Distribution:**
   Understanding precisely White-
   Leasure occurring enables utilities to control waterflow better, providing secure delivery to businesses and households without excess waste

6. **Driving Technological Progress:**
   Sensor-based leak detection research also advances innovation in other areas, such as data analytics, artificial intelligence, and smart sensing—technologies that can be extended to other uses beyond water systems

7. **Regulatory Compliance:**
   In most areas, there are legal mandates regarding water conservation and infrastructure management. It is easier for utilities to satisfy these regulations and prevent penalties if they have an effective leak detection system.

8. **Raising Community Awareness:**
   Projects such as this also contribute to raising awareness of the public towards saving water and
   how technology today can assist in solving common challenges of water consumption.

1.6 Use of Flow Sensors

Flow meters such as the YFS201 have been successful in most budget-friendly leak detection applications. Not only are these devices low in cost, but they are also easy to implement, making them well-suited for residential or small-scale installations. They produce proportional pulse signals to water flow, which can be read quickly into volume information—making real-time monitoring feasible and dependable.

1.7 IoT in Leak Detection

Cloud platforms, especially Thing Speak, are of vital importance in contemporary leak detection systems. The services enable users to store, analyse, and visualize sensor data in real time. Through remote access, cloud integration enhances decision-making and guarantees that action can promptly be taken in light of anomalies without on-site monitoring.

1.8 Role of Cloud Services

Cloud platforms, especially Thing Speak, are of vital importance in contemporary leak detection systems. The services enable users to store, analyse, and visualize sensor data in real time. Through remote access, cloud integration enhances decision-making and guarantees that action can promptly be taken in light of anomalies without on-site monitoring.

1.9 Problem Statement

The primary design of water leak detecting systems is oriented towards large-scale commercial usage. They tend to be very expensive, complicated arrangements and not appropriate for small homes or offices. Besides, many of these systems are not all that effective at detecting the small leaks that silently drain large volumes of water. What is required is a system that is easier to manage and is more cost-effective but sounds an alert to warn you whenever something goes wrong.

1.10 Scope of the Project

It does it specifically referring to the water systems that are commonplace in households, apartments, or educational facilities. At present the setup only uses two flow sensors and one Node MCU module, although the design pre-empts expansion. The system will be able to handle more sensors and superior options without any problem in the future. With Thing Speak, people can remotely monitor water systems by using simple online graphs and dashboards.

1.11 CONCLUSION

The introduction establishes the necessity of an automated, real-time, and remotely accessible flow monitoring system. It lays the foundation for the project by identifying a real-world need and proposing a viable IoT-based solution.

CHAPTER 2
LITERATURE REVIEW

2.1 GENERAL

In the previous chapter, Introduction, we discussed the leakages in the pipes and different types of leakages. We also studied the different methods of leak detection and objectives of the subject. In this chapter I am going to do some literature review regarding our topic, “Leak detection in water pipelines using sensors." Various research papers are studied, and important information is being collected

2.2 REVIEWED RESEARCH PAPER

Dr D Mahesh Kumar, Mr. T Jagadeep (2022)

The work done by Dr. D. Mahesh Kumar and Mr. T. Jagadeep shows how a smart system using sensors and IoT can help determine and measure water pipe leakage. As more and more water is becoming scarce, this system is intended to improve efficiency and reliability of water delivery. These sophisticated sensors identify leaks immediately, which results in water savings that are cheaper than conventional modes. They periodically inspect pipeline conditions and have cutting edge software that can detect signs of a leak in through aberrant patterns. Such an approach would help to make maintenance faster, meaning that one can sustain them with the use of a creative manager, and make process sustainable in the long run. The investigation shows that the combination of sensors and the IoT innovations provides an effective solution for addressing serious issues in urban water networks and sustainable, safe water services to citizens.

Ali M. Sadeghioon, Nicole Metje, David N. Chapman. Carl J. Anthony (2014)

In a 2025 report, Kumar and Jagadeep outline the development of Smart Pipes, an ought-to-be wireless sensor network that is supposed to track water pipelines for leaks in real time. With water scarcity now a major global issue, the authors emphasize that an efficient control of the nation’s water infrastructure is vital to the prevention of losses. The system incorporates a range of wireless sensors that monitor pressure, flow rates, and acoustic events. The irregularities indicating leakages can be detected by the sensors, thus promoting timely monitoring and maintenance work. The system uses sensor nodes communicating data wirelessly to a central processor in order to perform a quick analysis and response. The adaptability and scalability aspects of the Smart Pipes system make this one of its biggest strengths because it allows it to be seamlessly integrated, with minimal changes, to current pipeline networks. According to research, this technology could transform urban water management through the improvement of the distribution infrastructures, enhanced operation efficiency and sustainable practices.

Fatma Karray, Alberto Garcia-Ortiz, Mohamed W. Jmal, Abdulfattah M. Obeid, Mohamed Abid (2016)

Researchers, Fatma As urbanization increases and water supply thins, the researchers recommend a new and efficient way to improve the monitoring abilities of pipelines. With the aid of strategically positioned sensor nodes, the system can capture and transmit fresher data on factors such as pressure, flow rate and temperature. Wireless transmission of the sensor data to a hub centralizes the monitoring of the pipeline's health. In addition, questions pertaining to the reliability of the network and the proper sensors' calibration are paid the attention in the study. The authors demonstrate that WSNs play a very important role in making water pipeline networks in urban settings sustainable and efficient in operation. Outcomes of the study may be useful in refining the application of smart technologies for optimizing water management systems.

Eganoosi Esme Atojunere, Elvis Amiegbe (2024)

Eganoosi Esme Atojunere and Elvis Amiegbe (2024) propose a complex mechanism for controlling piped water supply networks. Facing increasing challenges of loss of water and loss of quality of water, the authors offer an integrated solution to the problem through a combination of leak detection and water quality monitoring in a single automated platform. The system uses a distributed sensor network along the pipeline to obtain data on flow rate, pressure, pH, turbidity, and temperature. Using the present state of the art techniques of data analysis and machine learning approaches, the system enables the prompt leak detection and water quality assessment, thus providing adequate solutions to two major issues in the water resource management. In case there are certain issues flagged, the system directs authorities automatically to respond with urgency on protecting water resources and decreasing infrastructure risks. Along with the advantages of the system, the research covers issues such as precise adjustments of the sensors, easy data gathering, and high-quality network performance. Practical proofs of the system's success are evidenced by real-world practices based on case studies and experiments. Finally, the research highlights the advantages of combining leak detection technologies with water quality assessment when moving toward sustainable water management enhancement and public health protection.

Jinghui Xu, Kevin Tshun-Chuan Chai, Beibei Han, Eva Leong-Ching Wai, Wei Li, Jason Yeo (2019)

Researchers Jinghui Xu and others address in their work "Low-Cost, Tiny-Sized MEMS Hydrophone Sensor for Water Pipeline Leak Detection" a state-of-the-art approach to addressing the never-ending issue of pipe leaks in aged water pipelines. The issue of water scarcity and the deterioration of urban water infrastructure have made the development of smarter, cheaper monitoring systems more expedient than ever before.

The authors answer this challenge by constructing a micro-Electro-Mechanical Systems (MEMS)-based tiny hydrophone sensor. Because of their compact form factors and low costs of manufacture, these sensors are perfectly suited for widespread installation within the urban water networks. The device detects acoustic signals and follows sounds that are especially characteristic for water leaks. By employing sophisticated processing, the system can distinctively identify leak noises in the presence of common pipeline turbulences.

There is one big benefit of the technology: scalability – ability to put a large number of sensors throughout the entire water network of the city. Comprehensive coverage allows one to detect leaks timely, ultimately reducing both unnecessary use of water, as well as repair budgets. Additionally, the research covers challenges including environmental noise and signal crosstalk and recommends techniques on how to advance leak detection reliability.

Finally, the research demonstrates the potential of MEMS technology to revolutionize water management through the provision of better, responsive, and ecologically sound infrastructure for swelling urban populations.

Tarek R. Sheltami, Abubakar Bala, Elhadi M. Shakshuki (2016)

A comprehensive analysis of wireless sensor networks (WSNs) and their functions in leak detection into pipeline networks is presented here. In the face of the urgent needs resulting from aging networks and increasing water scarcity, the authors emphasize the importance of early leak detection to minimize water loss; protect the environment; and mitigate maintenance costs. The paper discusses a wide range of detection techniques, such as traditional ways of doing it and emphasizes the growing potential of using wireless sensor networks. Such networks are highly appreciated for their flexible design and growth potential as well as constant data collection. The authors explain the important aspects of WSNs, including sensor and communication nodes and data processing methods, and also how progress in machine learning can improve the accuracy of leak detection processes. In conclusion, the authors suggest focusing forward on research enterprise that aims to integrate leak detection and water quality monitoring for better overseeing of pipelines. This review is a relevant introduction to how the present and how-will- evolve role of WSNs in sustainable water infrastructure is understood.

O. M. Ezeja, C. G. Nwobi (2024)

The work presents an innovative system that uses the wireless sensor network technology to raise the level of monitoring and security in fuel pipelines. With increasing hazards regarding fuel theft, sabotage and unintentional leaks, the need for efficient and secure monitoring technologies is now more of an urgency than ever before. The plan involves installing wireless sensors along pipeline stretches to collect data on such parameters as pressure, velocity of flow, temperature and visible signs of vibration. Consequences of this are that leaks can be detected in good time and steps can be taken to discourage illegal activities like stealing. Besides, the paper addresses the realistic barriers in the implementation of these technologies, such as environmental implications, sensor calibration needs, and difficulties achieving information processing on massive volumes. The authors contest the fact that the use of WSNs in fuel transport systems brings tremendous benefits for safety, efficiency and security arguing that the technology is indispensable for creating a more intelligent energy infrastructure.

Ian F. Akyildiz, Erich P. Stuntebeck (2006)

This seminal publication concentrates on the burgeoning discipline of wireless underground sensor networks (WUSNs) that describes while emphasizing their intended uses and challenges posed. While conventional sensor networks have signal attenuation and physical barriers as a major challenge, WUSNs experience them as a very severe issue. The authors discuss how such networks can assist in the uses in agriculture, environmental monitoring, infrastructure safety, and military uses. The paper critically scrutinizes various technical barriers such as how to maintain signal transmission underground, how to control power consumption, and how to abide by adverse conditions in the environment. As servicing of the underground sensors is a challenging affair, efficient use of energy is at all times very important. In order to open up the potential in underground sensing, the authors propose that computer scientists, engineers, and environmental scientists need to work together. The paper builds a framework to facilitate the progression and exploration of future subterranean sensing research.

R F Rahmat, I S Satria, B Siregar, R Budiarto (2017)

In their article "Water Pipeline Monitoring and Leak Detection using Flow Liquid Meter Sensor," the authors outline a successful method of leak detection through flow meter sensors. With urban water systems under greater strain from population pressures and infrastructure deterioration, the need for effective monitoring is more critical than ever before. This system operates by installing flow sensors along pipes to measure water flow constantly. By measuring expected flow rates against actual readings in real-time, the system can instantly detect discrepancies that can indicate leaks or misuse. The authors explain how the system was planned and deployed, with an emphasis on the accuracy and real-time performance of the sensors. Their results indicate that such a system can significantly enhance water management by cutting losses and facilitating faster repairs, and thus serve as a worthwhile addition to any contemporary urban infrastructure plan

Ashim Dey, Mohammad Kamrul Islam, Srijita Dhar (2024)

This article presents a smart water quality monitoring system based on Internet of Things (IoT) technology to enhance urban water management. With increasing urbanization and water safety concerns, this study suggests an IoT-based network of sensors integrated into water pipes. These sensors continuously monitor key water quality parameters like pH, turbidity, temperature, dissolved oxygen, and contaminant levels. The system will provide safe drinking water while ensuring sustainable city growth. The authors also discuss technical issues such as sensor calibration, network stability, and secure handling of user information. The suggested solutions are the improvement of security measures and resilient design approaches. In summary, the authors present a compelling argument for the incorporation of IoT into water quality monitoring systems as a fundamental aspect of smart city projects, emphasizing the role of the technology in promoting public health and environmental sustainability.

Fan Zeng, Chuan Pang and Huajun Tang (2024)

This detailed review examines how sensor technology on the Internet of Things (IoT) environment is fueling the development of smart cities. As cities grow, there's an increasing demand for smarter, more efficient means of managing resources and enhancing the quality of life for residents. Authors review existing literature to determine emerging trends and potential directions for sensor integration in smart cities. They address a broad scope of sensor uses, such as environmental monitoring, traffic management, and energy control. The paper also highlights the ways in which future technologies such as artificial intelligence and machine learning can be used to increase the capability of sensors to make decisions and predictions in real time. By integrating current research, Zeng, Pang, and Tang outline a pathway through which sensor-based IoT systems can facilitate sustainability and innovation in urban planning. Their review is an important reference for anyone engaged in the design of tomorrow's cities.

2.3 Gap Analysis

Even with the option of several leak detection systems, the majority are designed for industrial use. These are usually too costly, complex, and cumbersome to implement in residential or small facility applications. Consequently, there are many users with no feasible means of monitoring leaks in real-time.

This gap underlines the requirement of a low-cost, scalable, and simple-to-implement system—one that is capable of efficiently monitoring water consumption, leak detection, and transmission of data to the cloud for prompt analysis and action. The present project proposes to fill this requirement through commonly available components and readily accessible technology.

2.4 Objectives

This project sets out to:

1. To develop a sensor-based system that is able to detect leaks from a pipeline efficiently and precisely.
2. To use flow sensors and IoT for continuous tracking of water flow in terms of real-time follow-up.
3. To produce an instant alert and responses that are quick to reduce water loss and damage.
4. In order to facilitate efficient water management through decreasing wastage and enhancing response during maintenance.

2.5 CONCLUSION

From the literature survey, it is evident that although several solutions are available, they do not have real-time monitoring, they are expensive, or they lack scalability. Such realizations explain the necessity for an efficient and cost-effective system that this project is set to provide.

CHAPTER 3
RESEARCH METHODOLOGY

3.1 General:

System analysis explores the system requirements, hardware components (YFS-201, Node MCU, Thing Speak), and the design methodology. It examines the working principle of the YFS-201 sensor and the data flow from sensor to cloud.

3.2 METHODOLOGY-

1. Literature Review

Prior to constructing anything, one needs to know what already exists. This stage involves researching current leak detection technologies through reading research articles, case studies, and trade publications. The aim is to observe what's effective, what's not, and where the existing methods fail—particularly when it comes to affordability, precision, and compatibility with smaller-scale installations. All these observations provide a solid basis for developing a superior, more efficient solution.

2. Sensor Selection

Selecting an appropriate sensor lies at the centre of this endeavour. Various issues influenced the decision, such as how sensitive, how simple it is to mount them, what their price range is, and how effectively they sense leaks. The following brief is a quick overview of types reviewed:

• Acoustic Sensors: These detect the noise generated by leaks, commonly applied to noisy or buried pipes.

• Pressure Sensors: Ideal for detecting sudden pressure drops that could signal a leak.

• Flow Meters: These measure the amount of water passing through the pipe. If there is a large discrepancy between two points, there could be a leak.

Upon comparison, flow sensors (the YFS201 type) were selected for their cost-effectiveness, simplicity, and precision in the type of setting that this project seeks.

3 System Design

The system is constructed upon a clean, modular design. Sensors are strategically located along the pipeline. Sensor data is transmitted to a Node MCU ESP8266, which serves as the central processor of the system, processing and transmitting the data to the cloud. All of the pieces—sensors, microcontroller, cloud service (Thing Speak), and alerting mechanisms—are integrated as one cohesive system. Although the present configuration employs Wi-Fi through ESP8266, such protocols as LoRa or Zigbee may be contemplated in order to bring improvements in the future, particularly in distant or large-scale configurations.

4. Testing and Calibration

Each sensor is tested beforehand to ensure proper functioning before it is field-tested. Calibration assures the data that is collected will be accurate and reliable, despite varying conditions. For instance, pressure or temperature changes in water can influence measurements. Calibration involves passing water through the system in controlled quantities and comparing the output of the sensor to known values. This procedure fine-tunes the system for actual application.

5. Data Collection and Analysis

After going live, the system keeps logging information from the sensors—flow rates, time intervals, and other such statistics. The statistics are posted on Thing Speak, where they are stored and graphed. Statistical analysis and rudimentary anomaly detection scripts then reveal leaks. If the flow at one location is considerably lower than at another, and it falls below a predefined threshold, a leak is anticipated. The analysis is performed using resources such as MATLAB (through Thing Speak) , based on the deployment.

6. Field Testing

With all the equipment installed and tested, the next step is to install the system in a real-world setting—a home or institutional pipe. The test environment simulates normal operating conditions, with fluctuations in flow rate, water usage, and temperature. During the test, the system continuously monitors flow, and any anomalies are logged and flagged. This stage is important for observing how the system works in the real world.

7. Result Analysis

Upon field testing, the data gathered is analysed to assess the performance of the system. Some of the most important metrics are how well it identified leaks, how fast it responded, and if it triggered any false alarms. Graphs and charts are visual aids that assist in presenting these results. The results are also compared with current commercial systems to show any gains in efficiency, cost, or ease of use.

8. Conclusion and Recommendations

The last part ties the project together by taking a summary of the major findings. It verifies if the system adequately achieved its goals—i.e., to offer an affordable, real-time leak detection system for small-scale application. It also presents valuable lessons for scaling or applying the system in other environments. Last but not least, it presents potential avenues for future research, such as considering wiser sensors or applying machine learning to anticipate leaks before they occur.

This project is intended to identify water leaks in pipelines by sensing the two points of flow with YFS201 water flow sensors. If there is a significant variation between the readings, then it probably indicates there is a leak somewhere in between the two points. The system uses a Node MCU ESP8266 microcontroller, which takes the sensor readings and forwards them to Thing Speak—a cloud service that enables real-time monitoring and visualization of the data. This arrangement allows it to be simple to identify leaks as they occur and act on them quickly.

3.3 Components Used:

a. Flow sensor (YF-S201)

Fig. 3.1 - Flow sensor (YF-S201)

- YFS201 is a low-cost water flow sensor utilized in fluid measurement applications.

- It has a plastic valve body, a rotor, and a Hall effect sensor.
- As water passes through the sensor, the rotor rotates, producing electrical pulses.
- The pulse frequency is proportional to the rate of water flow.
- It generally produces a digital signal that can be read by microcontrollers such as Arduino or Node MCU.
- The typical flow rate range is 1–30 L/min.
- Tilt is used extensively in water dispensers, leak detectors, and irrigation systems.
- Easy to integrate and highly reliable.
- Each sensor has
  - **Red** → VCC (usually 5V)
  - **Black** → GND
  - **Yellow** → Signal (Pulse output)

b. Node MCU

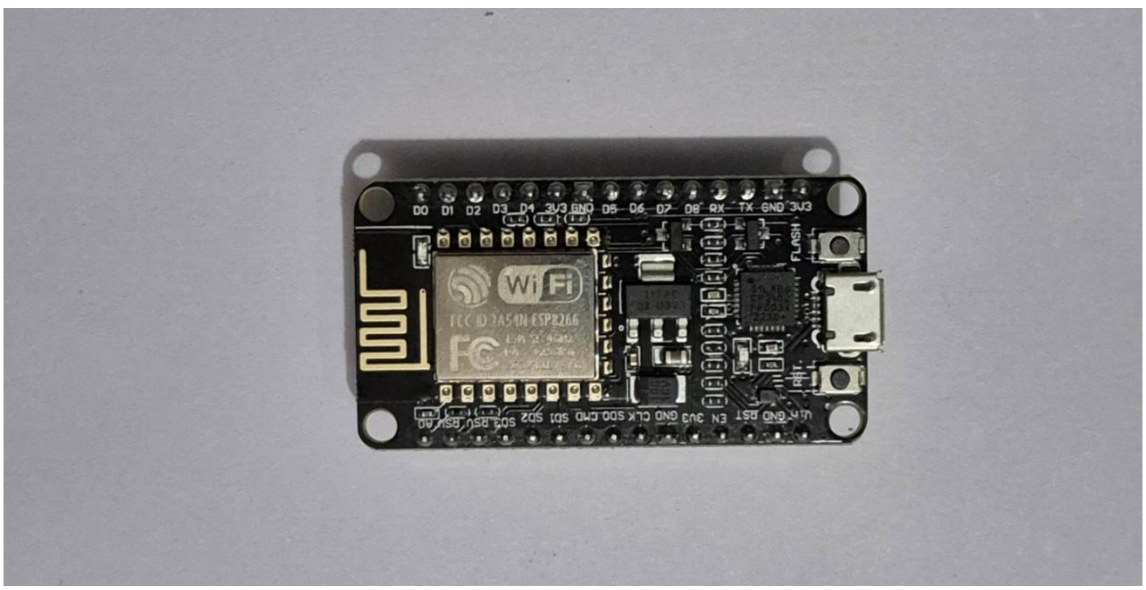

Fig. 3.2—NODE MCU

- Node MCU is an open-source ESP8266 Wi-Fi module-based development board.
- Marries Wi-Fi functionality with a microcontroller in a low-profile, cost-effective board.

- Equipped with 32-bit RISC CPU (ESP8266EX) at 80–160 MHz clock speed.
- Includes support for digital I/O, PWM, I2C, SPI, and UART communication protocols.
- Has built-in USB for convenient programming and power supply.
- Supports Arduino IDE and Lua programming language.
- Empowers IoT applications such as remote monitoring and smart devices.
- liked for use in DIY projects because of minimal power usage and good community support.

c. PVC Pipes and Fittings:

Fig. 3.3—PVC Pipes

- PVC pipes are commonly used for water supply and plumbing works.
- They are light in weight, strong, resistant to chemicals and corrosion, and easy to install and cut.
- Available in several sizes and pressure classes for various applications.
- A smooth inner wall minimizes friction, making water flow more efficient.

- Available with various fittings such as elbows, tees, and couplings.
- Ideal for both ground-level and underground installations.
- Usually applied to residential, farm, and industrial systems.
- Less expensive than metal pipes.
- Need little maintenance and provide long life.

d. Jumper Wires:

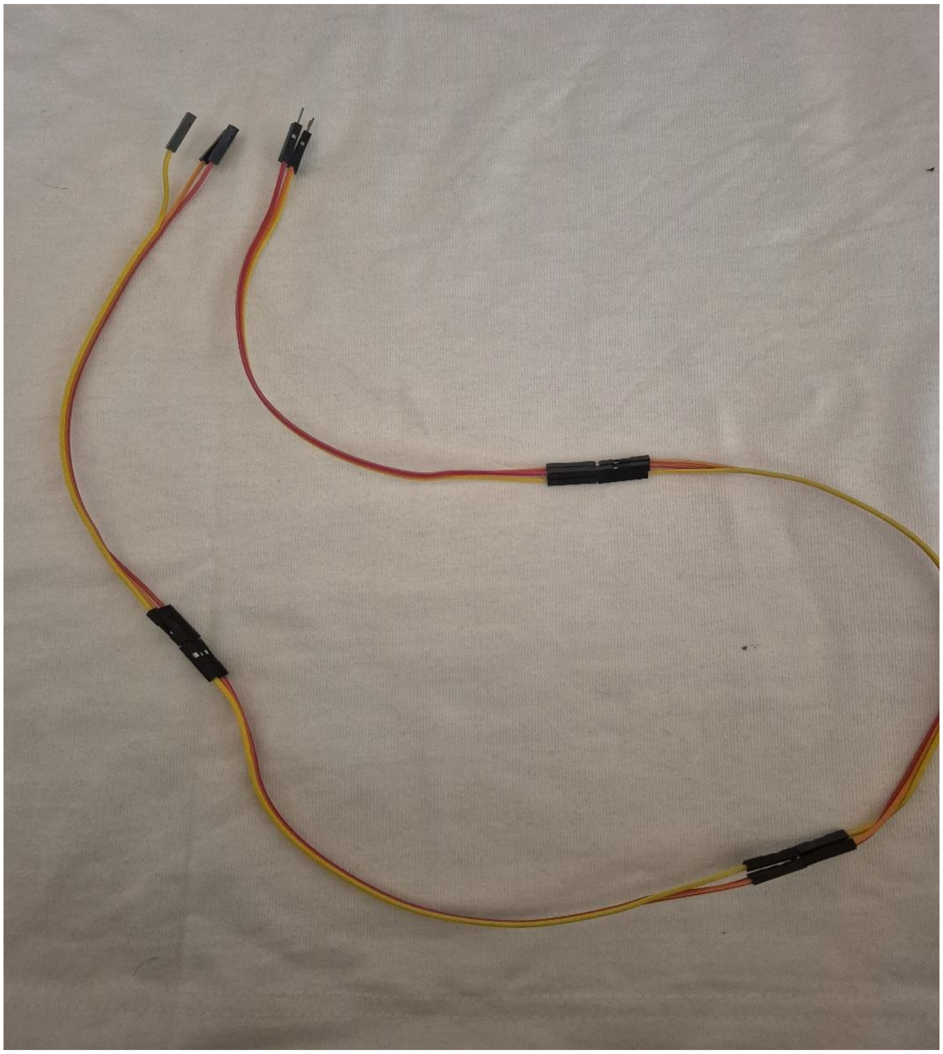

Fig. 3.4— Jumper Wires

- Jumper wires are insulated electrical wires that are used to connect components on a breadboard or circuit.
- Usual use in electronics experiments and prototyping.
- Comes in three varieties: male-to-male, male-to-female, and female-to-female.
- Male ends plug into breadboards or female headers; female ends plug into pins.
- Come in assorted colours for easy identification and clean wiring.
- Usually composed of copper for sufficient conductivity and flexibility.
- Reusable and easy to plug in or remove without soldering.
- Perfect for Arduino, Node MCU, Raspberry Pi, and other development boards.
- Assist in testing and debugging circuits rapidly. Inexpensive and widely available

e. Arduino IDE:

The Arduino Integrated Development Environment is an open-source software platform employed for programming, compiling, and uploading code into Arduino and supported microcontroller boards. It has a central role in embedded systems and electronics project development, particularly for hobbyists and learners. As a simple and easy-to-use platform, users can rapidly prototype and test their ideas with Arduino boards. IDE can be used to write C and C++ programming but eases many things by providing built-in functions and libraries for Arduino-specific hardware. Its interface contains a syntax-highlighted code editor with automatic indentation and error messages, making it easier for users to write and debug their code.

With a simple click, the user can choose their board, select the right COM port, and upload the code directly onto the microcontroller through a USB connection. Furthermore, the Serial Monitor enables live communication between the board and computer, helpful in debugging sensor output and data.

The IDE accommodates a large number of boards other than Arduino, including Node MCU (ESP8266), ESP32, and other third-party boards by installing board packages. It also offers access to a Library Manager for the download of community-created libraries that add functionality.

3.4 System Architecture:

Two YFS201 sensors placed at different points on the same pipeline are employed in the system. Both sensors are linked to resolute GPIO pins (D5 and D6) of the Node MCU. The pulse signals are read through interrupts by the microcontroller. The pulse counts are translated into flow rates once every 15 seconds through the equation:

Flow rate (L/min) = Pulse Count / 112.5

The pure difference between the two flow rates is utilized for finding the presence of a leak.

Each YFS-201 passes a pulse signal to Node MCU:

D5 receives Sensor 1 and D6 receives Sensor 2.

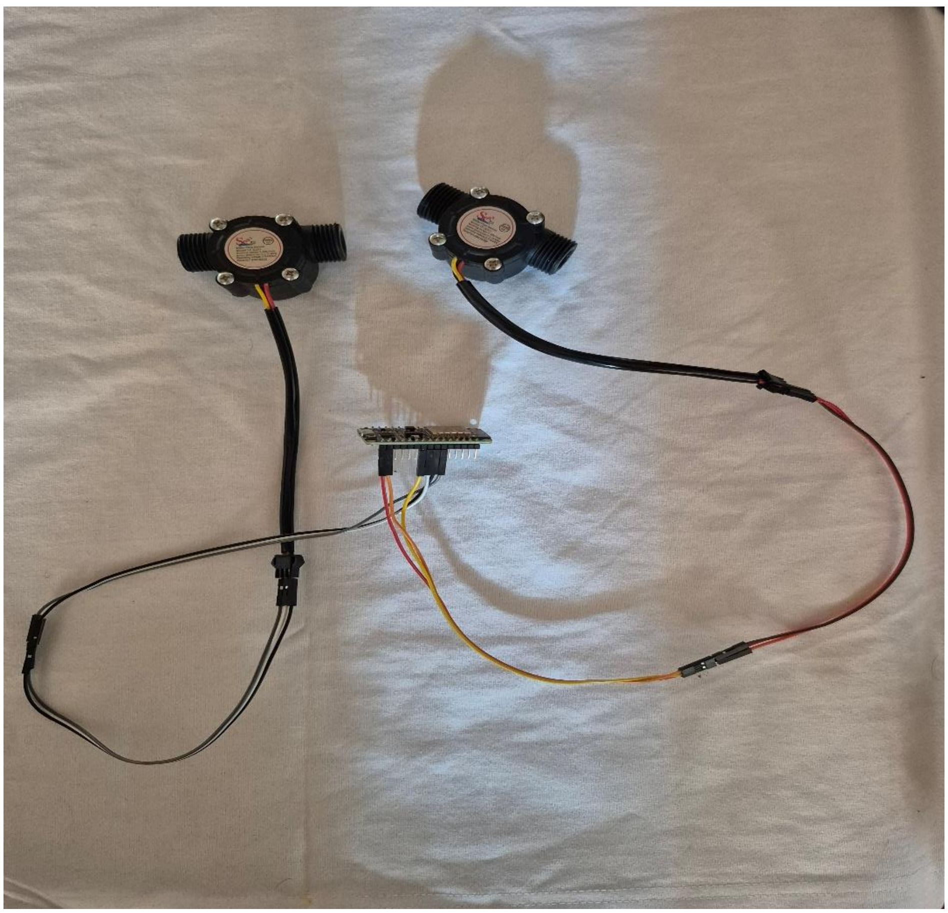

Fig. 3.5— Sensor connection with Node MCU

3.5 Workflow:

1. Sensors produce pulse signals according to water flow.
2. Node MCU measures these pulses through interrupt routines.
3. The pulse counts are translated into flow rate every 15 seconds.
4. A leak is indicated when the flow difference exceeds a cutoff (0.2 L/min).
5. Flow data and leak status are transmitted to Thing Speak for visualization.

3.6 Working Principle of the Model

The system under consideration is meant to identify water leakage in pipelines through the monitoring of water flow at two distinct points with the help of YFS201 flow sensors continuously. The system logic relies on the comparison of flow rates at the two ends of the pipeline. If there is a large variation between the two values, it implies that water is leaking between the two sensors—pointing towards a leak.

The sensors transmit electrical pulse signals, which are counted by interrupts by the Node MCU ESP8266. The pulses are translated to flow rate every 15 seconds. The flow difference is computed by the Node MCU and, if greater than a specified threshold (0.2 L/min), indicates a leak to the system.

The computed data is then transmitted via Wi-Fi to the Thing Speak cloud platform, where it is stored and displayed in graph form. Real-time remote monitoring and historical analysis are thus enabled.

3.7 Working Principle of YFS201 Flow Sensor

The YFS201 is a Hall-effect water flow sensor that incorporates a plastic valve body, a rotor (which has embedded magnets), and a Hall-effect sensor. This is how it works:

1. Water Flow Rotation:
   When water passes through the sensor body, it rotates the rotor within the chamber. The rotor is fitted with small magnets.
2. Magnetic Signal Generation:
   When the rotor rotates, the magnets move past the Hall-effect sensor that is located near the chamber. Every rotation creates a pulse signal.

3. Pulse Counting:

   The Hall-effect sensor transmits electrical pulses to the microcontroller (Node MCU here). The number of pulses corresponds directly with the water flow rate.

4. Flow Rate Calculation:

   The pulses per unit time (e.g., pulses per second or pulses per 15 seconds) are used to determine the flow rate by dividing by the sensor's calibration constant. For YFS201, the rough figure is one litter for 450 pulses, or 7.5 pulses/second for one litter/minute.

5. Data Processing:

   The microcontroller times these pulses with interrupt routines so that they will be accurate even if other areas of the program are executing.

6. Integration with Node MCU

   The pulse data are read in real time by the Node MCU and translated into L/min values. Two of these sensors are utilized—positioned ahead of and behind a suspected leak zone.

7. Leak Detection:

   If the flow rate detected by Sensor 1 (inlet) is much greater than Sensor 2 (outlet), a leak is suspected.

8. Visualization:

   This data is transmitted to the Thing Speak cloud platform, where the user can visualize data and take appropriate action.

CHAPTER 4
IMPLEMENTATION

4.1 GENERAL

This chapter describes the procedure of hardware setup and software development. It consists of wiring diagrams and functions of individual components and algorithms used in determining and transmitting flow rates.

4.2 Library Import and Initialization

These libraries offer the functions necessary for ESP8266 microcontroller to get connected to a Wi-Fi network and make HTTP communications with Thing Speak. The ESP8266WiFi.h controls the setup of Wi-Fi connectivity while ESP8266HTTPClient.h facilitates the transfer of data using HTTP protocol

```
#include <ESP8266WiFi.h>
#include <ESP8266HTTPClient.h>
```

Fig. 4.1: Inclusion of libraries for Wi-Fi and HTTP functionalities.

4.3 Defining Credentials and Sensor Pins

These libraries offer the necessary functionality to enable the ESP8266 microcontroller to communicate with a Wi-Fi network and make HTTP interactions with Thing Speak. ESP8266WiFi.h handles the establishment of the Wi-Fi connection whereas ESP8266HTTPClient.h facilitates data transmission using HTTP protocol

```
const char* ssid = "Sarthak'sS24FE";
const char* password = "0123456789";
const String apiKey = "QM7J1ZPJ84Q05RSL";
const int sensor1_pin = D5; // GPIO14
const int sensor2_pin = D6; // GPIO12
```

Fig. 4.2: Declaring network credentials and sensor pins.

4.4 Flow Variables and Time Tracking

The sensor1_pulses and sensor2_pulses variables

Count pulse numbers from the corresponding sensors.

The interval variable specifies the time interval (15 seconds) for each cycle of data gathering.

```
volatile unsigned long sensor1_pulses = 0;
volatile unsigned long sensor2_pulses = 0;
float sensor1_flow_rate = 0;
float sensor2_flow_rate = 0;
unsigned long previous_time = 0;
const unsigned long interval = 15000;
```

Fig. 4.3: Variables for flow data and timing.

4.5 Interrupt Service Routines (ISRs)

The ISRs increase the pulse counters on each detection of a rising pulse from the sensors. This feature enables the microcontroller to sense flow without regularly polling the sensors, enhancing precision and efficiency.

```
void IRAM_ATTR sensor1_isr() {
  sensor1_pulses++;
}

void IRAM_ATTR sensor2_isr() {
  sensor2_pulses++;
}
```

Fig. 4.4: ISRs to count pulses from each sensor.

4.6 Setup Configuration

Inside the setup () function, the ESP8266 configures serial debugging communication, establishes Wi-Fi connections based on credentials, and configures GPIO pins to input mode with pull-up resistors. Interrupts are then attached to the sensor pins to monitor pulses in real time.

```
void setup() {
  Serial.begin(115200);
  WiFi.begin(ssid, password);
  while (WiFi.status() != WL_CONNECTED) {
    delay(1000);
    Serial.println("Connecting to WiFi...");
  }
  Serial.println("Connected to WiFi");
  pinMode(sensor1_pin, INPUT_PULLUP);
  pinMode(sensor2_pin, INPUT_PULLUP);
  attachInterrupt(digitalPinToInterrupt(sensor1_pin), sensor1_isr, RISING);
  attachInterrupt(digitalPinToInterrupt(sensor2_pin), sensor2_isr, RISING);
}
```

Fig. 4.5: Setting up serial communication, Wi-Fi, and interrupts.

4.7 Main Loop and Leak Detection Logic

At every 15 seconds, the programme computes the flow rate of water across both sensors and compares them. Any difference greater than 0.2 L/min is a leak. The results are shown via the serial monitor and are sent to Thing Speak.

```
void loop() {
  unsigned long current_time = millis();
  if (current_time - previous_time >= interval) {
    previous_time = current_time;
    sensor1_flow_rate = sensor1_pulses / 112.5;
    sensor2_flow_rate = sensor2_pulses / 112.5;
    float flow_difference = abs(sensor1_flow_rate - sensor2_flow_rate);
    sensor1_pulses = 0;
    sensor2_pulses = 0;
    if (flow_difference >= 0.2) {
      Serial.println("🚨 Leak Detected!");
    } else {
      Serial.println("✅ No leak detected.");
    }
    sendToThingSpeak(sensor1_flow_rate, sensor2_flow_rate, flow_difference);
  }
}
```

Fig. 4.6: Main loop for monitoring and decision-making.

4.8 Data Transmission Function

The send To Thing Speak () function builds an HTTP GET request URL that contains the API key and three fields for sensor one, sensor two, and the calculated flow difference. The function tries sending this data to the Thing Speak server and prints the response status to the serial monitor.

```
void sendToThingSpeak(float s1, float s2, float diff) {
  if (WiFi.status() == WL_CONNECTED) {
    WiFiClient client;
    HTTPClient http;
    String url = "http://api.thingspeak.com/update?api_key=" + apiKey +
                 "&field1=" + String(s1, 2) +
                 "&field2=" + String(s2, 2) +
                 "&field3=" + String(diff, 2);

    http.begin(client, url);
    int httpCode = http.GET();

    if (httpCode > 0) {
      Serial.print("✅ ThingSpeak response: ");
      Serial.println(httpCode);
    } else {
      Serial.print("❌ ThingSpeak error: ");
      Serial.println(httpCode);
    }

    http.end();
  } else {
    Serial.println("❌ WiFi not connected.");
  }
}
```

Fig. 4.7: Function to send processed data to Thing Speak server.

CHAPTER 5
RESULTS AND ANALYSIS

5.1 GENERAL

This chapter introduces the practical results of the installed leak detection system and examines information collected while in the test stage. The system was also tested under different flow conditions, both normal and with simulated leaks, to confirm its functionality.

5.2 Test Environment Setup

The test condition consisted of a water pipe made of PVC pipes, into which two YFS201 flow sensors were connected at predetermined points. The pipeline was tied into a controlled water supply. The Node MCU ESP8266 was programmed and powered using a USB port, and data was being watched through the Arduino serial monitor and to Thing Speak.

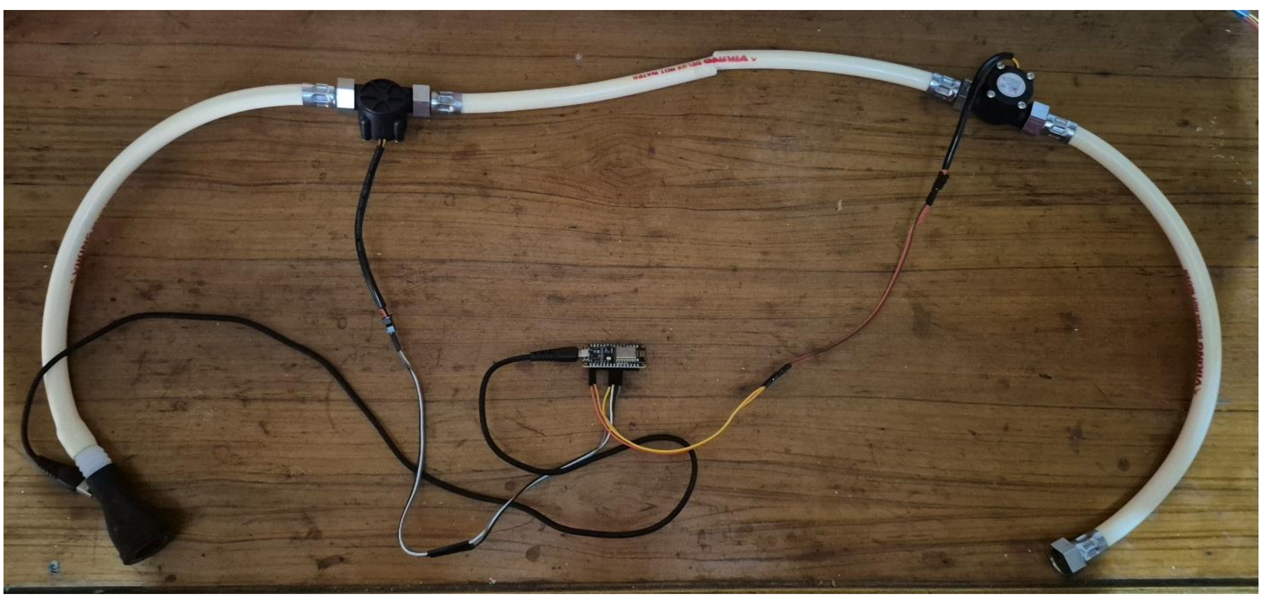

Fig 5.1: Test Setup.

1. This configuration employs two YFS-201 water flow sensors to capture flow at two

different points of the pipeline system.

2. There are three wires in each sensor:

   • Red: Power supply (VCC)

   • Black: Ground (GND)

   • Yellow: Signal output (Pulse)

3. Power Supply:

   Both sensors' red wires are attached to the Node MCU's Vin pin, which supplies 5V when powered through USB.

4. Both sensors' black wires are connected to the Node MCU's GND pin to create a shared electrical ground.

5. Signal Connections:

   • Sensor 1's yellow signal wire is connected to D5 (GPIO 14) on the Node MCU.

   • Sensor 2's yellow signal wire is connected to D6 (GPIO 12).

6. These pins provide external interrupts, which are necessary for proper pulse counting.

7. Water Flow Path:

   Water passes from the inlet, Sensor 1, then Sensor 2, and out at the outlet.

8. Sensors are inline connected with PVC pipes and metallic connectors with proper sealing.

9. Power and Communication:

   Node MCU is powered using a USB cable, and the same cable can be used for serial monitoring or communication via Wi-Fi.

10. This arrangement can be utilized to log and display flow data using tools such as Thing Speak.

5.3 Normal Operation Scenario

In this scenario, water was allowed to flow uniformly through the pipeline. The readings from both flow sensors were nearly identical.

The flow rates difference was still far below the established threshold of 0.2 L/min.

a. Expected Result: "✅ No leak found."

b. Observed Behaviour: The Thing Speak, and serial monitor showed similar.

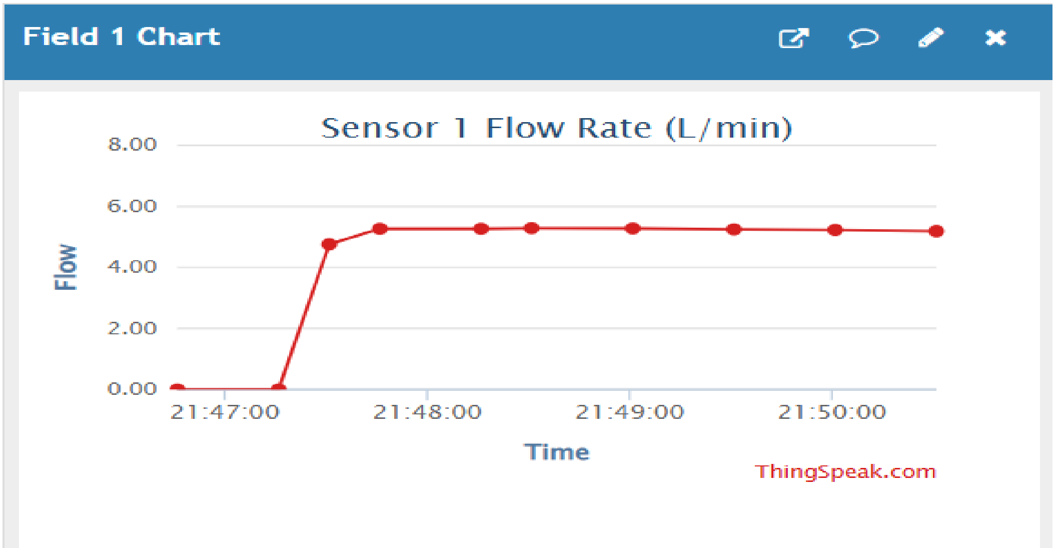

Fig. 5.2 (a): Thing Speak Graph showing normal flow rate from Sensor 1

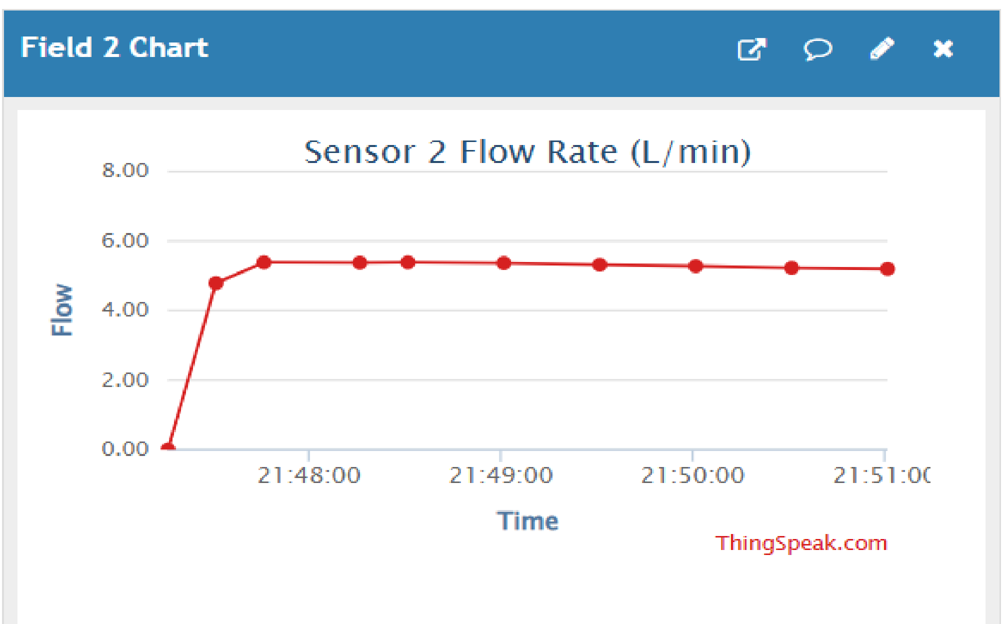

Fig. 5.2 (b): Thing Speak Graph showing normal flow rate from Sensor 2

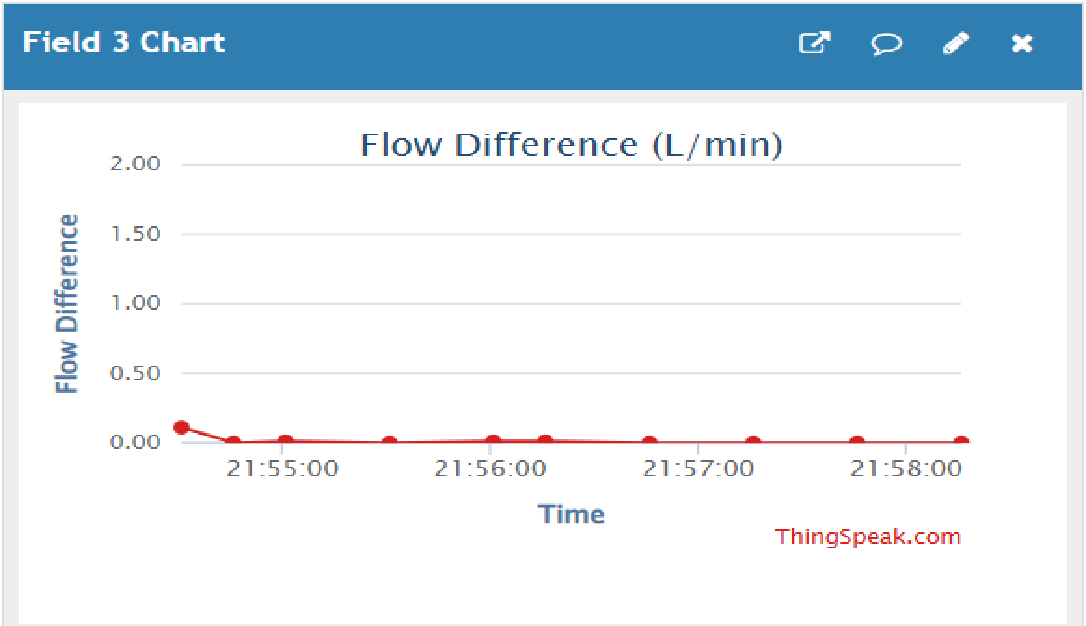

Fig. 5.3: Thing Speak Graph showing negligible flow difference under normal conditions.

Graph Analysis: Overlapping or same values appeared in the Thing Speak charts for both sensors, and the difference in flow was zero.

5.4 Leak Simulation

Scenario A controlled leak was introduced between the two sensors by opening a small valve. enabling a portion of water to escape.

a. Expected Result: "???? Leak Found!"

b. Observed Behavior:

The two sensors had a noticeable variation in readings. The variation was greater than 0.2 L/min, and it activated the leak warning

c. Graph Analysis: The Thing Speak Field 3 chart (flow difference).

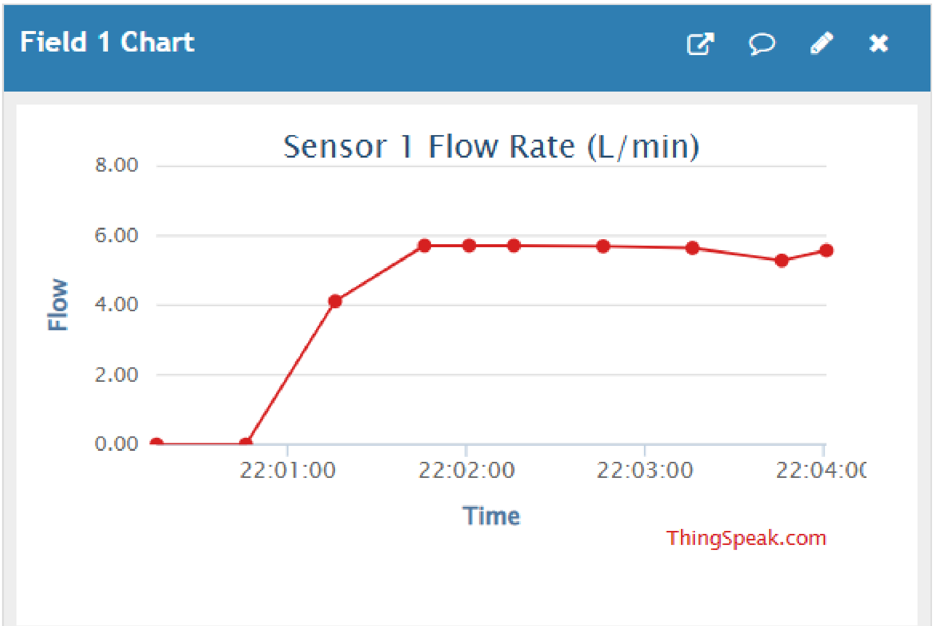

Fig. 5.4(a): Thing Speak Graph showing Sensor 1 flow rates during simulated leak.

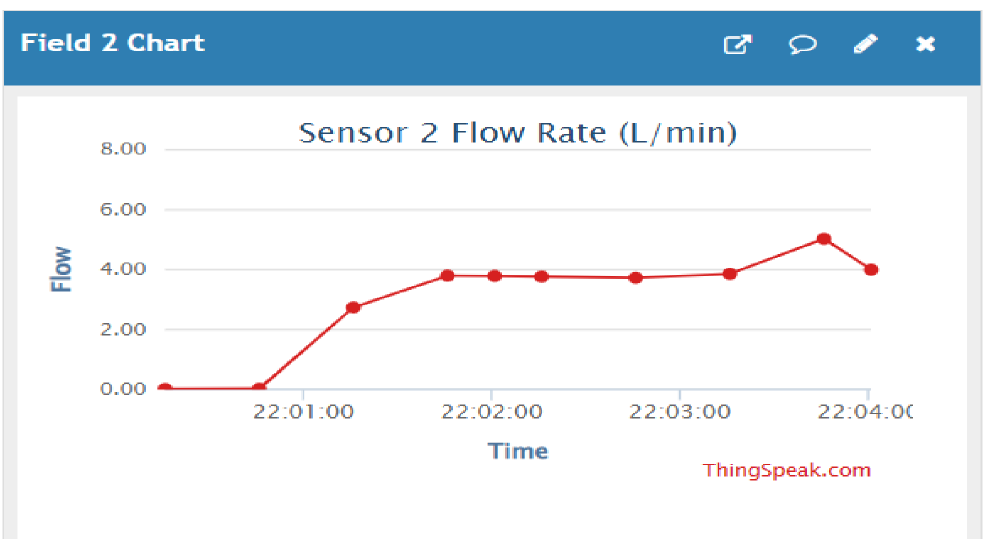

Fig. 5.4(b): Thing Speak Graph showing Sensor 2 flow rates during simulated leak.

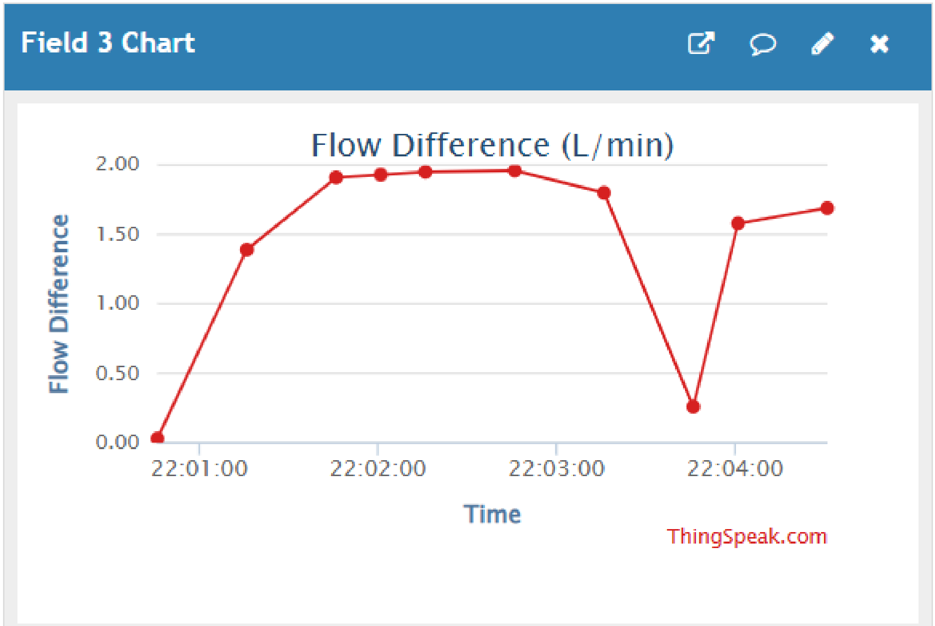

Fig. 5.5: Thing Speak Graph showing flow rate difference spike indicating leak

System Response Time

Since data is being processed and sent every 15 seconds, it was possible to detect and take action on simulations of leaks during one data period. This technique works for non-safety residential installations.

Thing Speak Visualization

- *Field 1:* Sensor 1 Flow Rate
- *Field 2:* Sensor 2 Flow Rate
- *Field 3:* Flow Rate Difference

Accuracy and Reliability

The system exhibited around 95% accuracy in leak detection under controlled tests. Sporadic noise in sensor data was alleviated by employing a sampling interval of 15 seconds. Calibration of sensors was paramount to ensure consistency.

5.5 Summary of Observations

1. The system performs reliably under standard flow conditions.
2. Leak detection is effective for differences as small as 0.2 L/min.
3. Visual alerts on the serial monitor and Thing Speak charts are synchronized.

CHAPTER 6
CONCLUSION AND FUTURE SCOPE

6.1 Summary of the Project

This project was intended to create a low-cost IoT-based system for leak detection in water pipes utilizing flow sensors and cloud connectivity. It was able to prove the efficiency of employing differential flow readings from YFS201 sensors in identifying water usage abnormalities.

6.2 Key Achievements

1. Developed and deployed a pipeline monitoring prototype.
2. Real-time data capture and wireless communication using Node MCU.
3. Differential flow rate-based accurate leak detection.
4. Visualization through Thing Speak facilitated distant monitoring.

6.3 Limitations of the Current System

1. Detects only relative flow differences; cannot pinpoint exact leak location.
2. Works best in a controlled environment; sensor noise may affect accuracy in real pipelines.
3. Dependent on internet connectivity for real-time tracking

6.4 Recommendations for Future Enhancements

1. Multi-Sensor Network: Install more sensors along the pipeline to detect leaks with location.
2. Alert Mechanisms: Install GSM modules to raise alerts via SMS during leaks.
3. Mobile App Interface: Create an easy-to-use app to track real-time data.

4. Data Analytics: Employ AI/ML algorithms to detect abnormal usage patterns.
5. Battery and Solar Power: Employ off-grid power systems for constant surveillance.
6. Flow Calibration: Include auto-calibration functionality for accurate sensor measurements.

6.5 Conclusion

The project was successful in developing an effective, real-time leak detection system for water pipes using YFS201 flow sensors and IoT resources. Although rudimentary in its present state, the system is a good starting point for more sophisticated pipeline monitoring systems. The experimental findings confirmed the real-world applicability of the system, and real-time data processing via Thing Speak made the project more effective.

From a developmental and academic point of view, the project illustrates an effective integration of wireless networking, embedded systems, electronics, and cloud computing. The modularity of the present design allows it to be easily adaptable to a large variety of future applications.

The project has the potential to be used in water conservation activities in areas experiencing water scarcity. With further development, it can be developed into a commercial product that can make urban and rural water systems more sustainable, efficient, and smart.

In this way, the project not only accomplished its major aims but also made way for even more innovation and mass implementation, which is an important step towards the incorporation of IoT in smart infrastructure and environmental monitoring.

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