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An IoT-Based Water Leakage Detection and Localization System

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

In this research, we present a proposed Internet of Things based model, which we have named *iWaLDeL*, for the detection and localization of water leakages which we simulated for the Ghana Water Company (GWC) pipe network, using YF-S201 Flow Rate Sensors and Static Leak Detection techniques. Through an extensive review of existing methods, the research highlights the limitations of traditional detection approaches and emphasizes the potential of modern technologies. The *iWaLDeL* system harnesses the power of IoT devices, deploying an array of strategically placed sensors capable of detecting leakages and pressure variations. These sensors form a distributed network which communicates with a central hub, ensuring comprehensive coverage of the monitored area. Crucially, the research delves into the innovative aspect of leak localization. By combining data from multiple sensors and pipes, the system can estimate the precise location of a leakage following a mathematical model we developed. This localization capability significantly reduces the time required for maintenance teams to address leakage issues, minimizing water loss and further damages. To validate its effectiveness, the system was

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prototyped and tested, which demonstrated a successful leak detection and localization, showcasing its adaptability in both residential and commercial settings. The system's seamless integration with existing smart infrastructure enhances its feasibility for real-world implementation.

Keywords: IoT; leakage detection; leakage location; flow rate sensors; arduino cloud.

1. INTRODUCTION

Internet of Things (IoT) consists of three main fundamental components; the *Thing*, the *Gateway* and the *Cloud*. Internet of Things applications are very useful for MicroElectro-Mechanical Systems (MEMS) [1]. It is a network of embedded systems connected with sensors and software for the purpose of exchanging data over Internet. This ecosystem of sensors, micro-controllers and cloud services interact together to take input from the environment and process them in order to help electronic appliance act smart. According to Yahia et al. [2], IoT is the connection of devices, software, sensors, actuators, and physical objects that are embedded in networks, cars, home appliances, and other products that help these things to communicate and share data. Wireless technology has been regarded as the main technology that facilitates the fast spread and adoption of IoT technology across the globe, coupled with the existence of embedded devices and low power Microcontrollers which can work remotely for years without maintenance. According to Chan et al. [3], technologies and IoT have the capability of transforming every sector of a country's economy including agriculture, water quality control, health, manufacturing industry, education, weather fore-cast, asset monitoring as well as the energy sector. This innovative sector is of greater benefits not only to companies but individuals as well, since it can assist them to automate their homes and offices and control them remotely. The IoT based water leakage intelligent detection system was modelled to detect water leakages in pipe networks and to locate the exact leaked pipes in the network. Flow sensors were installed in the system to compute the flow rate of water passing through the pipes. The sensor values are compared with threshold flow rate values to determine whether there is a leakage or otherwise, with the help of micro controllers, Gateway, cloud and software. The Quality Water Control Officers can interact with the system remotely to identify faulty pipes and their locations with the help of the IoT remote mobile application.

Quality control management has been one of the key problems for GWC. The company's main responsibility is to produce and distribute quality treated water for both domestic and industrial use. Despite its readiness to provide its customers with quality and affordable service, water losses through pipe leakage hinder the company from meeting its targeted goals. The commonest path for water losses is pipe leakage, which can be estimated to be contributing to about seventy per cent of water loss in water transmission systems. This value is expected to become higher in less controlled networks [4]. Comparatively, gas pipeline networks suffer from similar fates. Leakages in gas pipelines can be more dangerous and more expensive than water leaks [5].

The GWC has three major categories of pipelines; main lines, distribution lines and service lines. The main lines are two with an analogue meter attached and stationed at the treatment plant. This meter reads within the threshold when there is no leak but falls below thresholds to indicate that there is a leak/burst. Both the distribution and service pipelines are manually monitored for leaks resulting in reasonable amount of water losses since the volume of water loss is directly proportional to the duration of leakage detection, location and repair time. Even though GWC has some available measures for water leakage detections, it is yet to utilize the full benefits associated with Internet of Things (IoT) devices in the area of quality water management. With the IoT intelligent leakage detection system, GWC will be able to detect and identify the exact location of leakage for prompt response.

Leakage and loss of water is bound to occur either on daily basis or occasionally on both residential and commercial water distribution systems. The volume of water loss mostly depends on certain factors including the characteristics of pipe network, company operational plan and availability of experts and technicians needed to manage the project. Total water loss is simply the difference between the water produced and water consumed. It can also be defined as the summation of physical losses and apparent losses. Mathematically, $(Tl) = Wp - Wc$ where T_l is Total Water loss, Wp is water produced, and Wc is Water consumed, or $(Tl) = Pl + Al$, where Tl is Total water loss, Pl is Physical losses, and Al is Apparent losses. Water leakage during its transportation through pipes is very common and has the tendency of increasing production cost resulting in a loss of about 32 billion cubic meters each year [6].

In GWC, leakages from main pipes can be detected with the help of the pipe analogue meter mounted and monitored at the water treatment centre. Leakages on the distribution and service pipes are detected and reported through the regular surveys undertaken by monitoring teams. According to Nyarko-Dokyi et al. [7], when a leakage occurs on the pipe network, there are two major ways through which the management gets notified. One is by active search mostly by the leakage technicians, and the other is through reports from the public. If the diameter of the leaking pipe is within permissible limits to be handled by the technician, he or she proceeds with repairs. Otherwise, a backup team is immediately informed after pipe isolation is done. The technician ensures that, the leakage is fixed within the shortest possible time to limit water loss. Leakage detection includes installation of meters, variation of traditional step-test, sounding survey and the use of leak localizers. Meters are usually either installed at the treatment plant to control the main pipe line, or on the service pipes to monitor water consumption. Leak localizing also known as noise logging is one of the popular techniques that has been recently used as an alternative to Step-test. When properly installed, the loggers listen for and record the constant source of noise produced by a leak, usually over a 2-hour interval period.

2. RELATED WORKS

Many researchers have advanced several IoT techniques at different industrial and domestic scale; techniques as varied as IoT systems for monitoring and predicting water consumptions, managing supplies, detecting leakages etc. While these techniques have proven to be effective for different reasons, they still have inherent gaps that need further research attention.

2.1 Monitoring and Forecasting Water Consumption and Detecting Leakage Using an IoT System

The IoT water monitoring and forecast system is used for monitoring water leakages and usage in poly tank water distribution system. It is recommended for people living in the urban centers. With the help of Support Vector Machine algorithms, the system is able to determine water requirements in a society by calculating the supply and demand relationship. It is also able to detect leakage and leakage rate, allowing immediate action to be taken to correct the cause of leakage, and ultimately saving treated water [8]. Some of the advantages of this system include;

i. It saves water and reduces its loss.
ii. It saves a lot of users' efforts when checking the level in the water tanks.
iii. It allows an equal distribution of water for all.
iv. The system is good for people living in the urban area.

The weaknesses of Monitoring and Forecasting system included the following;

i. The system cannot be used in monitoring underground pipe leakage. It can only be used in monitoring rooftop tanks
ii. No Mobile Application for convenient remote monitoring of leakage.
iii. Ultrasonic sensors have limited sensing distance and cannot be used in detecting leakage location in underground pipelines.

2.2 An IoT-Based Framework for Smart Water Supply Systems Management

Some researchers [9] employ IoT based framework for Smart Water Supply Systems Management to tackle water supply management issues. This is particularly done to manage the rising demand for quality water as a result of global population growth and climate change. This system is one of the first to use IoT Complex Event Processing and Declarative Process in managing water projects. However, the approach combines many systems such as, Declarative Process, Internet of Things and Complex Event Processing to collect and to analyze data, which is not only costly but requires technical people to program, install, deploy and maintain.

Even though the system is effective in managing quality water project, it relies heavily on water pressure from the pipes for leakage detection. Exact locations of leaked pipes are not also easily identifiable with this system, hence creating a research gap that needs to be addressed.

2.3 Smart Water LoRa IoT System

The Smart Water Long Range (LoRa) IoT system permits administrators to monitor water network continuously. Applied through both wired and remote identifiers across the system, it works with information investigation, upholds client enquiry, and permits opportune admittance to water quality data. The ultrasound water meter also finds water leaks and makes water usage more efficient. The leakage alert system, alongside the leakage location equipment, utilizes AI to take care of water leakage issues [10]. Though this system is good because of the application of AI, It is very costly to implement because it uses a lot of IoT technologies for just a purpose that can be achieved using relatively low-cost flow rate sensors.

2.4 Leak Localization Techniques

Leak location is the identification of leak position when identified from any leak detection techniques. Some of the location techniques include ground microphone, sounding stick and leak noise correlator. All these methods are used in similar manner for locating leakages in pipes. Apart from these, other sophisticated location technologies include in-pipe acoustic technology and ground Rada [11].

2.5 Categories of leak detection models

The literature and the applied works reviewed in leak detection have been grouped into two main categories. These categories are static leak detection and dynamic or mobile leak detection. Each of these categories is capable of identifying, locating, and pinpointing leaks on its own. That notwithstanding, both can be combined to perform the same function [12]. The two categories of leak detection systems are;

I. **Dynamic leak detection systems:** These are systems that rely on moving leak detection devices to suspected leakage area to perform an investigation. They rely initially on suspicion of an existing leak or regular surveys undertaken by the monitoring team around cities to identify leaks as soon as possible. Even though these systems can confirm the existence of leaks and localize them, it is unable to report real time leakage, which consequently increases leak detection and response time resulting in high loss of water.

II. **Static leak detection systems:** These systems depend on sensors and data collectors that are placed within the water network and on valves. They transmit data periodically to the network administrators. The data can be used to identify, localize, and pinpoint leaks based on the values of flow rates transmitted from different sensors [13]. The researchers used static leak detection approach and strategically placed sensors on the pipes and labelled them for easy localization of leakage.

2.6 Sensors Used for Water Leakage Detection

Sensors used for water leakage control include Ultrasonic Sensors, Flow Sensors, Hydrophone Sensors, Infrared Thermal Imaging Camera Sensors and Ground Radar Sensors. Ultrasonic sensor for instance can be used to measure water volume by sending Ultra Violet (UV) rays to determine the distance of the water level from the top of the tank using sonar. It is also good for detecting leakages on surface pipes in short distances. The weakness of Ultrasonic sensors is that it cannot be deployed in underground pipe network. Hydrophone sensors use dynamic leak detection technique which cannot provide real time data leakages and location. Infrared thermal imaging camera uses thermal camera for detecting and locating leaked pipes. Even though it is very effective, it is very expensive and relies on other expensive hardware equipment including flying drones to map areas for leakage survey. Ground radar uses radio frequency signals to listen to leaked sound of underground pipes. These sensors also use the dynamic leak detection technique which makes it difficult locating leakages in noisy environments since they listen to the vibration of the ground produced by the leaked water of leakage for further investigations. [14].

2.7 Communication Protocols

The IoT based systems rely on communication devices such as cellular data network, Wi-Fi

Network and hybrid Network for communication and sharing of resources. The Wi-Fi has been regarded as the most frequently used communication network for IoT projects. This is because it is less costly, and can be used for transmitting videos, text and images as well [15]. For these reasons, the *iWaLDeL* was deployed on a Wi-Fi network. Cellular networks such as 3G/4G GSM and Nb-IoT are the second popular communication network. These networks use cellular network for data transmission and have larger coverage. The major problem with GSM and Nb-IoT networks is that, users are required to pay for the services rendered. The LoRa is another useful network that can cover a large area and does not need any service charge to use. Latency and boundary jitter of LoRa is too high for use in real-time application. This coupled with slow data transfer rate and low transmission rates make LoRa network ineffective for the proposed research. ZigBee, and Bluetooth, have widely been used for multiple transducer connections. Bluetooth is used for communication over a short range of 1–100m with better data transmission speed as compared to ZigBee and GPRS. The GPRS and 3G have relatively low data transfer speed but their coverage is up to 10 km. ZipBee and Bluetooth have low coverage issues, while GPRS has issues relating to security vulnerabilities where data can easily be hacked and it its integrity compromised [16]. On that account, we chose a communication protocol based on the end application and availability of required resources to achieve desired results of cost-effectiveness, reliability, and low power consumption.

2.8 Alert Signaling Devices

There are several devices that are used to provide alert signals in IoT systems. Some of them included GSM modules, Buzzer, LED light indicators, Notification, motion sensors and Web cameras. Some researchers [17] identified some strategies of security alert devices that carry out home security tasks utilizing IoT. One of such techniques is the use of web cameras to an extent that, at any point, if there is any movement recognized by the camera, it sounds a caution and sends a mail to the proprietor. This technique for distinguishing interruption is interesting, even though it is fairly costly, because of the cost of the cameras associated with the cycle. In this research, the camera module was not considered, because the flow sensors by themselves transmit data automatically to the cloud server that can be monitored by the administrators via mobile Application.

There is also the SMS based framework which utilizes GSM proposed by Karri and Lim [18]. This allows internet providers to send messages to a house proprietor rather than the customary SMS. Some other researchers [19] prefer to execute a fingerprint-based verification framework to open an entryway. This framework helps clients by just permitting the clients whose finger impression are approved by the proprietor of the house. The framework is combined with a couple of more home insurance highlights like gas spillage and fire mishaps. A few specialists contend that, just depending on a fingerprint sensor isn't protective enough, as it is somewhat simple to lift somebody's fingerprints and reproduce them, which is the reason it is constantly encouraged to involve unique finger impression scanners with two factor verification frameworks, where an extra layer of safety is provided by means of a PIN, password, voice acknowledgment etc.

3. THE PROPOSED iWaLDeL SYSTEM

The Static Leak Detection approach was used in this research; the sensors were connected directly to the pipe network for the leakage and location detection. This approach is more convenient and less time consuming. We achieved the development of an intelligent model for detecting water leakage and leakage location in water pipes network, via the YF-S201 Flow Rate Sensors which we connected directly to the pipes to transmit signals to a microcontroller. The programed microcontroller is able to compute the leak-locations, and then transmit the leaked data to a user for prompt actions.

3.1 Flow Rate Sensor Pulse Sampling and Counting

The YF-S201 flow rate sensor includes a plastic body, a rotor and a Hall Effect Sensor. Flow sensors come in different diameters, pulse rates and flow rates (L/m). The sensors used for this research have 20mm diameter, 1.75MPa water pressure and 1-30L/m flow rate, and operating on 3.5-24VDC voltage. They have three wires (Vcc, GND and Pulse wires) which can be easily interfaced between any microcontroller or Arduino board. It requires only +5V (Vcc) to give pulse output. The sensor needs to be tightly fitted between water pipes.

3.2 Sampling and Counting Procedure

i. Connect the microcontroller to power source
ii. Connect VCC, GND and Pulse pins to Arduino 5v, GND and pin 4 respectively as shown in Fig. 2.
iii. Upload the pulse counting code to the microcontroller with different delays (update time)
iv. Take a gallon of water and pour it through the inlet of the sensor
v. When water passes through the rotor, it rolls and its speed changes with different rates of flow. The Hall Effect Sensor outputs the corresponding pulse signals.
vi. Record the signals using the Serial plotter or Serial monitor. These pulse values can then be used to compute flow rate.

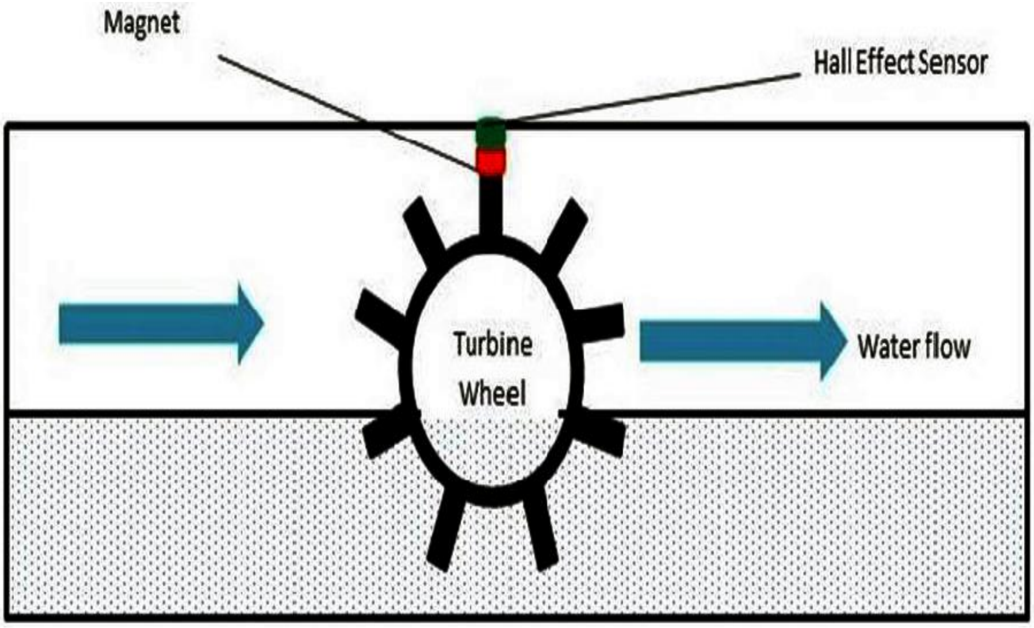

Fig. 1. Pulse sampling and counting

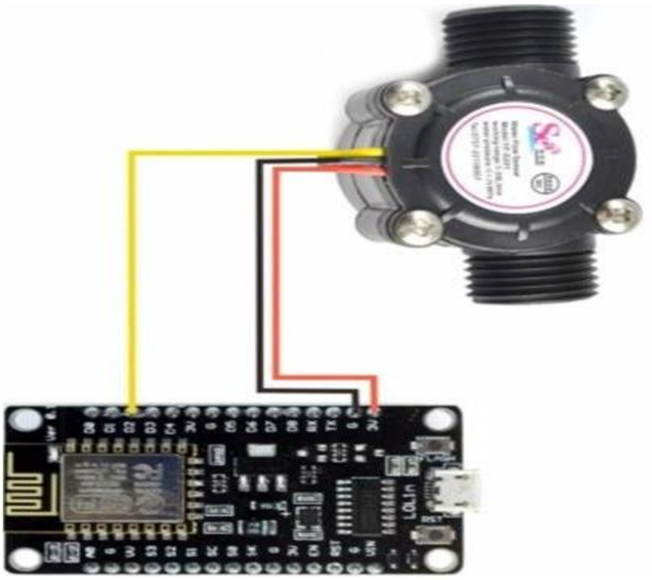

Fig. 2. Flow sensor connected to microcontroller

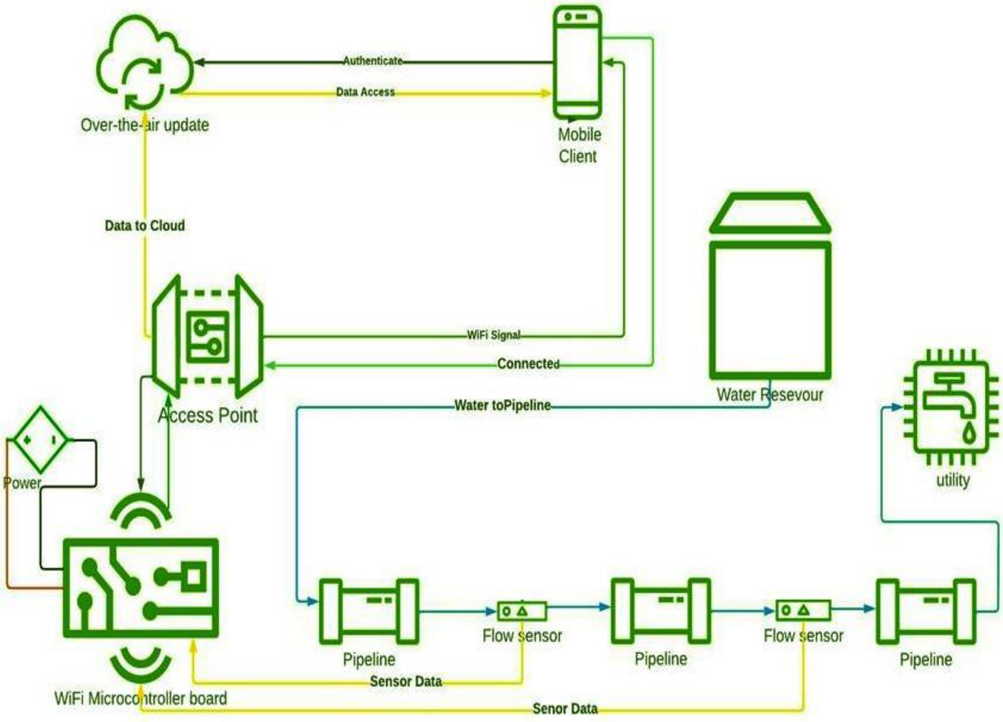

Fig. 3. Water leakage detection and localization architecture

3.3 Water Leakage Detection and Localization Architecture

The following architecture of the *iWaLDeL* system illustrates its components which work together to detect, notify, and mitigate water leakage incidents. The pipes in the system were numbered from pipe 1 ($P1$) to pipe n (Pn) with sensors installed at every 100m interval. The labeling of the pipes made it possible to calculate the location of a leaked pipe from the origin with the help of sensor numbers and readings.

3.4 Description of the Components

3.4.1 Water reservoir

Water reservoir is a large storage facility where water is stored for further distribution. Since the sensors are mainly attached for distribution and service pipes, leakage from the reservoir and main pipes do not form part of the study, since the main pipes have their monitoring meters installed at the main station to check leakages. The reservoir was used to only supply water to the distribution and service pipes where the flow sensors are installed for the actual monitoring of leakages.

Fig. 4. Water reservoir

3.4.2 Pipeline

The minimum diameter of water service pipes was ¾ inch (19.1mm), whiles the main pipes were 16inch. The 19.1mm PVC pipes were fitted into the sensor’s inlet and outlets.

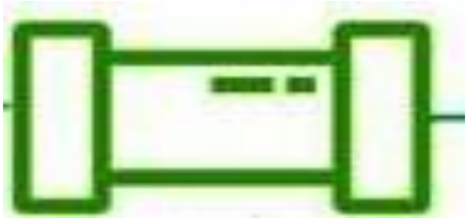

Fig. 5. PVC pipe

3.4 3 Flow Sensor

Water leakage detection systems use sensors that can be strategically placed at equal interval to detect water leaks within the pipe network. Theses sensors can equally be used in home water networks and can monitor areas such as basements, bathrooms, kitchens, or near water supply lines. These sensors can be moisture sensors, leak detection cables, or water flow meters. Turbine flow sensors were used in this research; a turbine flow meter has a rotor with blades that spin as fluid flows through the meter. The rate of rotation is proportional to the flow rate or velocity of the flow of water. The sensors therefore detect the rotation and generate real-time pulses as water is flowing through the pipes. The pulses generated by the sensors are transmitted to the ESP32 microcontroller where they are recorded as flow rates at five minutes intervals. The data collection mechanism is able to indicate an increase or decrease in the flow rate, which is not necessarily indicative of leakage in a pipe.

Fig. 6. Flow sensor

3.4.4 ESP32 microcontroller

This ESP32 microcontroller is an 8bm wireless microcontroller, which communicates with the Arduino cloud using IEEE 802.11 Long Range protocol. The microcontroller wirelessly transmits the real-time data generated to the cloud for storage. The ESP32 which is a popular microcontroller module is widely used for various IoT applications or projects, due to its powerful capabilities, low cost, and excellent community support. The ESP32 builds upon the success of the ESP8266, which provides enhanced features and performance.

Fig. 7. ESP32 microcontroller

3.4.5 Communication devices and cloud storage

Various IoT devices can communicate with each other and with the users over the internet to enable remote control and automation. An access point was used to provide a wireless internet connectivity to the microcontroller and to mobile devices. This communication medium enabled the ESP32 microcontroller to send data to the cloud. The cloud storage provided a convenient platform for storage and easy access to the senor data which are used by our model to compute a leakage as well as the location of the leakage.

3.4.6 The water leakage detection and localization computation

The model which is implemented and loaded on the ESP32, reads in the flow rate values and compares them; if the successive sensors record the same reading, it means there is no leakage. On the other hand, if successive sensors record different readings with the same pressure, it means there is a leakage on the pipe preceding the sensor that read the lower value.

From the Fig. 8, if pipe two ($P2$) gets broken, then Sensor three (S3) will read a low value, and if pipe four ($P4$) is broken, then Sensor three (S5) will read low in that order.

Fig. 8. Block diagram of water leakage localization

3.4.7 Water leakage localization computation

Let d=constant distance between sensors ………………………………………………… (1)
Sn= Leaked detected sensor number. ………………………………………………….. (2)
Pn=Leaked pipe number. ………………………………………………………………. (3)
L_1 =Leakage location. ……………………………………………………………….. (4)
L_1= Pn× d, where Pn=Sn – 1 ………………………………………………………… (5)
L_1= Sn – 1× d ……………………………………………………………………….. (6)

Table 1. Excerpts of real-time data stored on the cloud storage

Date/Time	Sensor	Value
6/15/2023 11:20	Sensor1	10.0 L/m
6/15/2023 11:20	Sensor2	10.0 L/m
6/15/2023 11:25	Sensor1	09.2 L/m
6/15/2023 11:25	Sensor2	09.2 L/m
6/15/2023 11:30	Sensor1	07.1 L/m
6/15/2023 11:30	Sensor2	07.1 L/m
6/15/2023 11:35	Sensor1	05.0 L/m
6/15/2023 11:35	Sensor2	05.0 L/m
6/15/2023 11:45	Sensor1	10.0 L/m
6/15/2023 11:45	Sensor2	8.7 L/m
6/15/2023 11:50	Sensor1	09.0 L/m
6/15/2023 11:50	Sensor2	06.2 L/m
6/15/2023 11:55	Sensor1	04.4 L/m
6/15/2023 11:55	Sensor2	01.3 L/m

Algorithm 1. Water Leakage Detection

```
1.  Begin
2.  Define Microcontroller for SY200 flow sensor (Data, GND, VCC)
3.  Read volume $v$, time $t$.
4.  Q←v/t
5.  Read Flow rage QSn
6.  if (QSn mod QS(n − 1) = 0 )
7.  a←0
8.  Display "No Leakage detected"
9.  Display QSn
10. Repeat steps 6 to 8.
11. Else
12. b←1
13. Display "Leakage detected"
14. Display $QS_n$
```

4. SIMULATED RESULTS AND DISCUSSION

The figure depicts the flow rates at water speeds (pressure) through the pipe. At X, the interruption of the turbine magnet and the Hall Effect sensor (frequency) were very rapid due to high pressure of water through the pipelines, causing the signals (throw and crest) to be concentrated. At Y, the flow rate signals were moderately distributed because the water pressure supplied was neither low nor very high. This caused the turbines to oscillate normally. The Z signals were scattered because the rate of flow was very slow, taking the turbines long time to make a single oscillation. Generally, it was observed that the rate of flow was inversely proportional to pressure and the time taken.

4.1 Error Reading of the Sensor from Arduino Serial Plotter

When the sensors were initially connected to the microcontroller board and the code was uploaded for the first time, it gave a false reading of 6 liters/minute even when there was no water running through the pipe and for some time, it became stable and started to give accurate readings. Many sensors exhibit similar characteristics of false reading in the beginning when they start collecting data from the environment. But a few munities later, the sensors become adaptive and start giving accurate reading (see Fig. 10).

4.2 Stable Recordings of the Sensors

After two minutes of false reading, the sensors began recording true readings as can be seen in Fig. 11. It can be observed from the figure that the sensors were giving a parallel 0,0 liters/minute readings when there was no water running through the tab. In order to minimize the error reading for our real-time setup, the system was rigorously calibrated by flowing water through it several times for the pulse reading to stabilize before the simulation was conducted.

4.3 Serial Plotter Recordings from a Sixteen litter gallon of water of Non-leaked Pipe

A Sixteen liters gallon was filled with water and then connected to unbroken pipes as well as to the sensors and the microcontroller. As illustrated in the Fig. 12, the flow rate started from 10 L/m and gradually decreased to about 6 L/m within 1 minute time frame. This decrease was as a result of the decrease in pressure, resulting from the reduction of water volume in the container. This confirms that, the flow rate is directly proportional to pressure of the water. That is, the greater the pressure, the higher the flow rate, and vice versa. Apart from the mobile application, the serial plotter for monitoring leakages and reduction in water pressure within the pipe network can also be used.

4.4 Leaked Pipe Results

The test was repeated with broken pipes; it was observed that, the readings peaked at 6 L/m and started sloping down as the pressure reduces. The reading could not peak at 10L/m as in the case of the unbroken pipe results in Fig. 13. This is because, some of the water run out through the broken pipe before reaching the sensor, hence reducing the pressure.

4.5 Machine State Model of Water Leakage and Location Detection

The machine state model for water leakage and location detection comprises of comparison state, leakage location state, leakage detection state, cloud, Application and Gateway states. It also consists of start and end activities. The comparison state is a composite state that houses the sensor reading states. If all the sensors read normal, the system remains in its idle state but on the event that any of the sensors read below the threshold, a report will be sent to the leakage detection state, signaling that there is a leakage. The Gateway state ensures there is a connection between the microcontroller and the mobile phone, for effective monitoring of leakages. The location state on the other hand indicates the exact sensor that is leaking.

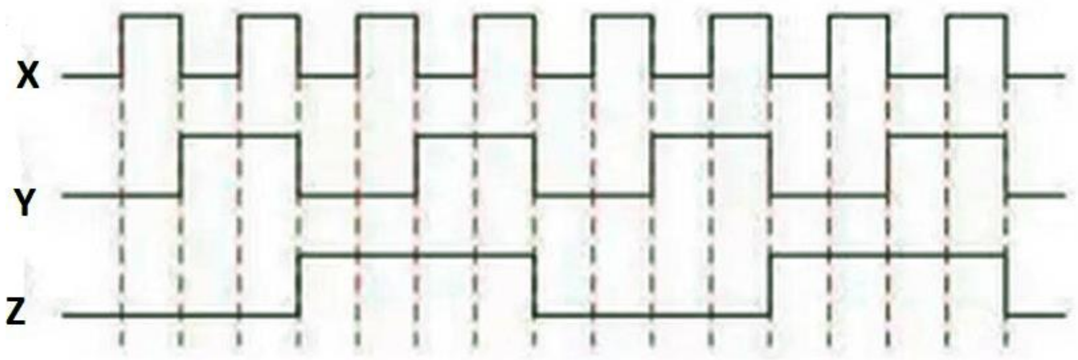

Fig. 9. Flow rate sampling

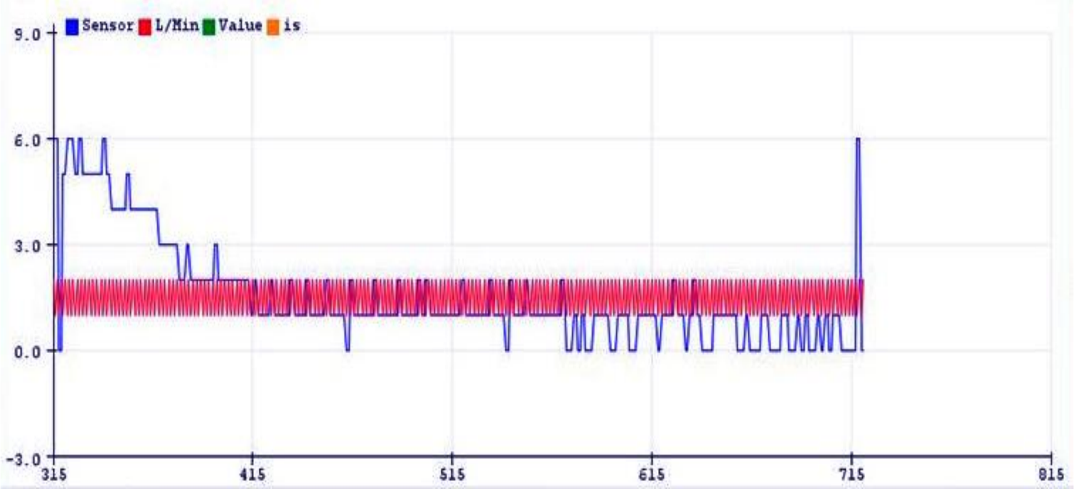

Fig. 10. Initial error readings of flow sensor

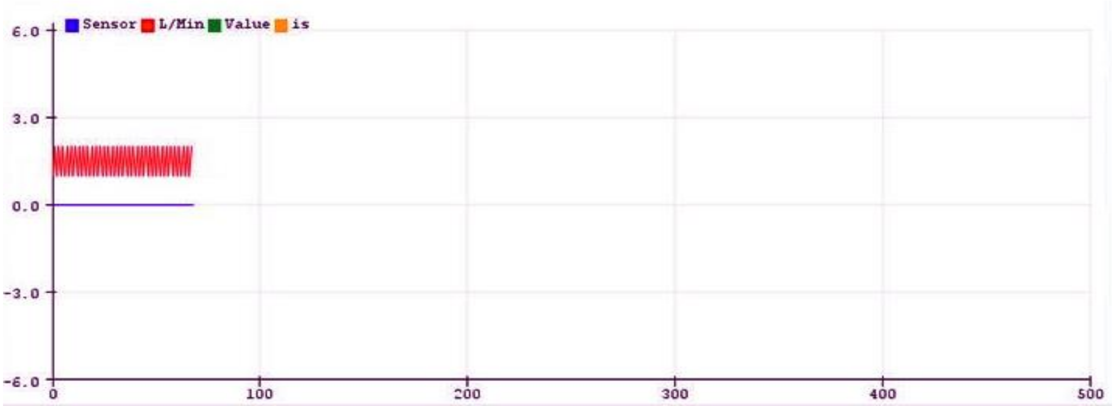

Fig. 11. Stable sensor reading

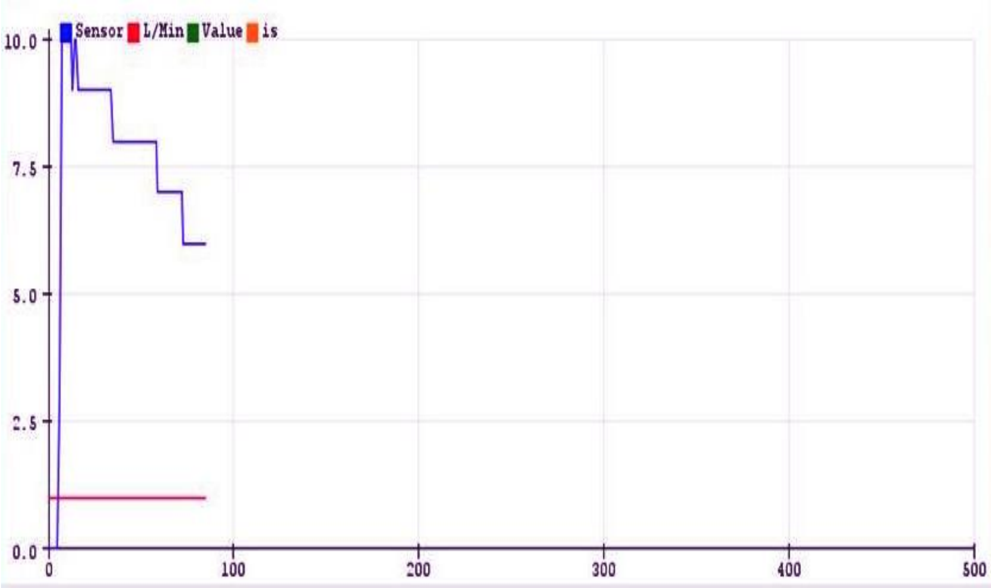

Fig. 12. Leakage-free Serial Monitor Reading

Fig. 13 Serial plotter recording leaked pipe results

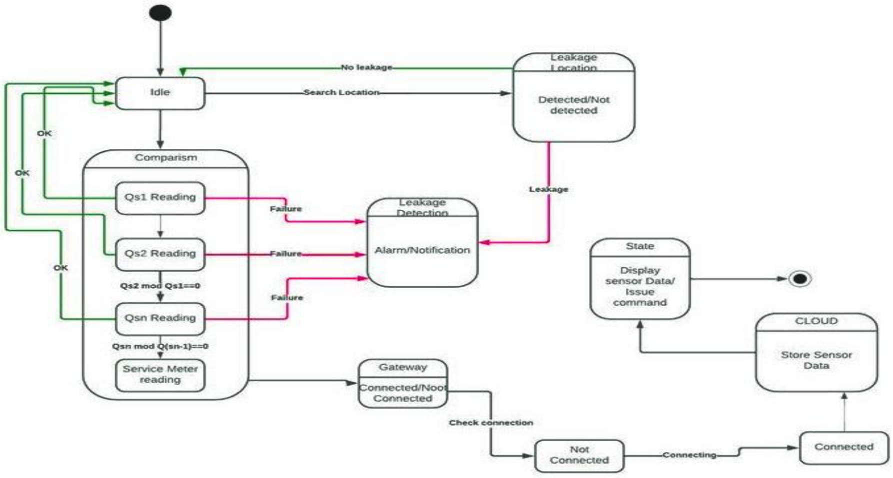

Fig. 14. A machine state model for leakage detection

Fig. 15. IoT dashboard

4.6 Dashboard of the IoT System

The dashboard contained gauge and chart widgets for sensors. These widgets are used to record the flow readings of the sensors. The red and green LEDs are used as indicator lights to show whether there is leakage or not. When the green LED is ON, it means there is no leakage but the blinking of the red LED indicates leakage in the pipe network. It also allows the administrators to share their dashboard to other users. Apart from that, the dashboard has a download feature that helps the administrators to download daily data recorded by the sensors.

The red LED is used to signal leakage detection whiles the green LED indicates normal flow. The buzzer was also connected to the controller with the help of the bread-board to trigger alarm in case of leakage detection.

5. CONCLUSION

This research presents a comprehensive water leakage detection system that harnesses the potential of smart technology. By combining advanced sensors and real-time communication technologies, the system offers a proactive approach to leak detection and localization.

This innovation holds great promise in mitigating the consequences of water leakages, promoting sustainable resource management and fostering the growth of smart environments. After evaluating the IoT sensors deployed on the pipe network for detecting water leakages and locations, it was proven to show accurate data with fast response time. This system does not only rely on mobile application interface for monitoring data, data could also be monitored using Serial monitor.

The Mathematical model and algorithm we developed ensured the detection and localization of leakages. Leak locations were easily computed without using any leakage investigation device. The model also made leakage location in noisy environment possible, as compared to systems that relay on the vibrations of the leak water from underground.

6. RECOMMENDATION

It is recommended that the results of the study which included leakage detection and localization should be adopted by both residential and commercial water distribution companies in order to help reduce the time required for the maintenance team to address leakage issues, minimize water loss and damage of pipes.

Furthermore, the following are some recommendations for future work that can be done to improve this study; Incorporate machine learning algorithm to study soil temperatures in different environments and its impact on leakage detection; Integrate advance IoT sensors that could detect the causes of pipe burst and recommend for appropriate remediation. This will complement the *iWaLDeL* leakage detection system to be more robust to meet the contemporary challenges facing the water industry.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Phua WK, Rabeek SM, Han B, Njihof E, Huang TT, Chai KTC, Lim ST. Ain-based mems (micro-electro-mechanical system) hydrophone sensors for iot water leakage detection system. Water. 2020;12(11): 2966.
2. Yahia M, Gawai R, Ali T, Mortula MM, Albasha L, Landolsi T. Non- destructive water leak detection using multitemporal infrared thermography. IEEE Access, 2021;9:72556–72567.
3. Chan TK, Chin CS, Zhong X. Review of current technologies and proposed intelligent methodologies for water distributed network leakage detection. IEEE Access, 2018;6:78846–78867.
4. El-Zahab S, Zayed T. Leak detection in water distribution networks: an introductory overview. Smart Water. 2019;4 (1):1–23.
5. Inaudi D, Belli R, Walder R. Detection and localization of micro-leakages using distributed fiber optic sensing. In International pipeline conference. 2008; 48579:599–605.
6. Kielmann K, Cataldo F, Seeley J. Introduction to qualitative research methodology: A training manual. United Kingdom: Department for International Development (DfID). 2012;1-4.
7. Nyarko-Dokyi K, Nyoagbe M, Akosah-Kusi, M. (n.d.). The ghana water company transformation journey.

8. Gautam J, Chakrabarti A, Agarwal S, Singh A, Gupta S, Singh J. Monitoring and forecasting water consumption and detecting leakage using an iot system. Water Supply, 2020;20 (3):1103–1113.
9. Gon¸calves R, JM Soares J, MF Lima R. IoT-based framework for smart water supply systems management. Future Internet. 2020;12(7):114
10. Wang Jx, Liu Y, Lei ZB, Wu, KH, Zhao XY, Feng C. Smart water lora iot system. In Proceedings of the 2018 international conference on communication engineering and technology. 2018;48–51.
11. Phua WK, Rabeek SM, Han B, Njihof E, Huang TT, Chai KTC, Lim ST. Ain-based mems (micro-electro-mechanical system) hydrophone sensors for iot water leakage detection system. Water. 2020;12(11): 2966
12. Atef A, Zayed T, Hawari A, Khader M, Moselhi O. Multitier method using infrared photography and gpr to detect and locate water leaks. Automation in Construction. 2016;61:162-170. Available:https://www.sciencedirect.com/science/article/pii/S0926580515002113 DOI:https://doi.org/10.1016/j.autcon.2015.10.006
13. Bazilian M, Brandt A, Billman L, Heath G, Logan J, Mann M, Benson S. Ensuring benefits from north american shale gas development: Towards a research agenda. Journal of Unconventional Oil and Gas Resources. 2014;7:71–74.
14. Gautam, J., Chakrabarti, A., Agarwal, S., Singh A, Gupta S, Singh J. Monitoring and forecasting water consumption and detecting leakage using an iot system. Water Supply. 2020;20(3):1103–1113.
15. Islam MR, Azam S, Shanmugam B, Mathur D. A review on current technologies and future direction of water leakage detection in water distribution network. IEEE Access; 2022.
16. Ali H, Choi JH. A review of underground pipeline leakage and sinkhole monitoring methods based on wireless sensor networking. Sustainability. 2019;11:(15): 4007.
17. Govinda K, Kumar G. T secure data storage in cloud environment using fingerprint. Asian Journal of Computer Science and Information Technology. 2012;2(5):99–103.
18. Karri V, Lim JD. Method and device to communicate via sms after a security intrusion. In 1st International Conference on Sensing Technology, Palmerston North, New Zealand. 2005;21–23.
19. Anitha A. Home security system using internet of things. In Iop Conference Series: Materials Science and Engineering. 2017;263:042026.

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