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College of Science and Technology

AFRICAN CENTER OF EXCELLENCE IN INTERNET OF THINGS

Research Thesis Title: IoT based solution for Early Leak detect in Water Pipeline

A dissertation submitted in partial fulfilment of the requirements for the award of masters of science degree in internet of things: Embedded Computing System

Submitted by:

Name: NYIRAMUGISHA Denyse (Ref. No: 215028931)

November, 2023

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Supervised by:

-Name of Main supervisor: Dr. Emmanuel Masabo

-Name of co – supervisor: Dr. Gaurav Bajpai

November, 2023

Declaration

I NYIRAMUGISHA Denyse, Master ‘student from African Center of Excellence in internet of things, at University of Rwanda. I declare that this research thesis is my own original work and it has never been presented before anywhere in the world.

Denyse NYIRAMUGISHA
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Signed:
Date:09/11/2023

Bonafide certificate

This is to certify that this submitted Research Thesis work report is a record of the original work done by NYIRAMUGISHA Denyse (**Ref. Nu: 215028931**), MSc. IoT-ECS Student at the University of Rwanda / College of Science and Technology / African Center of Excellence in Internet of Things, the Academic year 2020/2021.

This work has been submitted under the supervision of Dr. Emmanuel Masabo and Dr. Gaurav Bajpai

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ABSTRACT

Many organisms on this earth need water to survive and the importance of resources is increasing continuously; the transport of water through pipelines becomes extremely important, but there are high losses of water due to water leak pipeline. The problem is not the size of the leak, but the time it takes to detect it. Few of us think about the impact of water damage to our properties until it's too late and the damage is done. This can cause many consequences including financial loss, environmental damage like floods, lack of water at home that leads to chronic diseases.

The amount of water loss is typically between 20% to 30% of production, and it cost 28.8 Million annually with leakage being the main component in Rwanda. This work focuses on the issue of water distribution, more specifically, on the issue of "water leaks" in residential areas. The leak detection systems are highly important to identify possible leakages in real-time to avoid financial losses or any other inconvenience such as both time and energy consumption. In this research, the IoT based system was introduced with the aim of early leak detection in water pipeline as a solution for water loss due to undetected leak in the pipeline, the researcher used IoT system as a tool consists of web-enabled smart devices that use embedded systems, such as processors, sensors and communication hardware, to collect, send and act on data they acquire from their environments. The IoT devices shared the sensed data they collected by connecting to a MQTT where data is sent to the cloud to be analyzed through a developed dashboard.

This research developed a real-time IoT system installed in the hydraulic facilities of a residence, to detect water leaks. The system consists of a pressure sensor and flow rate sensor installed by a water reservoir of interest, a water sensor to collect the data and evaluate whether it is a water leakor not, by sending an email alert message, and an electrical actuator to shut off the main water supply to avoid water losses until the relevant authorities will intervene then water will flow as usual. The result of using the developed system is improving the efficiency of operation, reducing delay time and cost of maintenance pipelines after leakage detection.

Keywords: Internet of Things, Dashboards, Sensors, leakage detection, real-time.

LIST OF ACRONYMS

ACEIoT: African Center of Excellence

WASAC: Water and Sanitation Corporation

NRW: Non-Revenue Water

IoT: Internet of Things.

CEO: chief executive officer

USD: United States Dollar

SMS: short message service

LDI: Leakage Detection Index

LoRa: Long Range

Wi-Fi: Wireless Fidelity

UR: University of Rwanda

GPR: Ground-penetrating radar

MQTT: Message Queuing Telemetry Transport.

CSD: cross-spectral density

LCD: liquid-crystal display

LED: Light Emitting Diode

GPS: Global Positioning System

RURA: Rwanda Utilities Regulatory Agency

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Chapter 1. INTRODUCTION

1.1 Background and motivation

Nowadays, technology takes a major role in our lives that leads us to work for better solutions to solve daily problems, mainly to improve and autonomously ease repetitive tasks with less effort. This evolution in technology reached new potentials with the increase of devices being used every day, allowing for the concept of the Internet of Things (IoT) to arise and be part of the proliferation of smart technologies and cities [1]. The evolution of the internet is called IoT [2] and it connects devices that are capable to sense the environment and control it through communication protocols the data are sent to the cloud where they can be saved virtually as well as being analyzed [3].

Today, smart water networks, smart homes, and intelligent transportation are infrastructure systems that make our world more connected. Based on several types of sensors the totality of the physical infrastructure is firmly combined with information and communication technologies. The main concept is the internet of things. The main motivation of IoT is to make objects in the community to be connected through the internet so that they can automatically share information without human interaction. There are many technologies such as LoRa for long-distance, ZigBee, and Bluetooth for a short distance, sensors for understanding field data, actuators react accordingto sensor value help things to communicate together via distributed sensor networks.
Water might be the source of all life where water pipelines are one of the most vital structures to transfer fresh water for consumption over long distances. However, the major problem of the water transportation pipeline is a leak which can cause water resources loss, possible human injuries, and environmental pollution problems [4].

Americans and Canadians are the world's largest users of water. Water utilities in both countries face growing challenges in their attempts to meet the demand for drinking water [5]. An estimated 26.50 billion liters (˜15%–25%) of all treated freshwater is lost through leakage from the distribution pipeline infrastructure in the United States [6]. In many developing countries significant amounts of drinking water are lost in the water supply system. Several studies have been conducted to determine water losses, studied water losses in five water utilities in Bosnia- Herzegovina, and found leakage of between 25% and 60% of system input volume [7]. The research shows; In Pilot, Serbia, leakages make up 80% of non-revenue water. Recent research in Delhi suggested up to 25% of the supply of water is lost due to leaks [8]. In Bangladesh, up to 50% of Dhaka's water is lost due to substandard connections and leaking pipes [9]. In Sub-Sahara Africa, the NRW is 64% based on Non-Revenue Water [NRW] rates by country done by Liemberger and Wyatt, 2019.

In Rwanda; The water and sanitation corporation is the entity set up to manage water and sanitation services [10], it has a mandate of water distribution to people through a pipeline. In Kigali, residents experience dry taps for months, with technicians from the Water and Sanitation Corporation [11], that is in charge of supply in urban centers, routinely blocking the flow in severallocations where the utility detects broken pipes as a way for repairing, this is very hard to identify the location of any leakage in water pipeline during water distribution network.

WASAC CEO mentioned that the water distributed is safe for drinking but gets contaminated along the way due to broken pipes [11]. The amount of water loss is typically between 20% to30% of production, and it cost 28.8 Million annually with leakage being the main component [12].

Most water pipes are integrated into the underground and detection of water pipe leakage is difficult [13], its leakage can be identified by water utilities through manual checking or being called by their customers once the water comes out of the soil, this increases the water shortage specifically in urban areas; a flooded basement, mold growth, damaged floors, and ceilings, are all expensive problems that can result from leaks.

Leakage comprises the physical losses from pipes, joints, fittings, and overflows from service reservoirs. These losses can be severe and may go undetected for months or even years. In this case, these pipelines must be carefully and real-time monitored. Water pipe leakage can be caused by different factors such as natural disasters, human activities, engineering activities, and breakdown of pipelines caused by corrosion. Internet of Things is helping to connect devices with environments where those devices can exchange information easily anywhere through the internet without human interaction. The developed system is about using the Internet of Things as a technology that is a process to connect microcontroller and sensors by collecting data from fields where pressure and flow rate sensors are used in the conducted experiments, those data are stored through developed dashboards where they can be analyzed for meaningful insight. This technologyis less effort, real-time monitoring and it avoids financial losses.

1.2 Problem Statement

Water pipe leakage is a common and significant problem around the world. It is estimated that around 20% of clean water produced in most countries is leaked from their distribution networks [14]. In Rwanda, Through the report conducted by RURA in March 2020 showed that 44.4 percent of water supplied within all branches was water losses due mainly to illegal connections, leakages [15]. The amount of water loss is typically between 20% to 30% of production, and it cost 28.8 Million annually with leakage being the main component, WASAC CEO said.

To reduce NRW; the water utilities found that 38% of water losses are counted as non-revenue water. The main causes of NRW are water pipe leakage. The problem is not the size of the leak, but the time it takes to detect it. Due to the high rate of water losses (38%), water utilities will spend around 31 million USD by reducing NRW from the current 38% to at least 25% in five yearssince 2016 [16]**.**

This work focuses on the issue of water distribution, more specifically, on the issue of "water leaks" in residential areas. To tackle this issue, a real-time IoT system was developed and installedin the hydraulic facilities of a residence, to detect water leaks. The system consists of a pressure sensor and flow rate sensor installed by a water reservoir of interest, water sensor to collect the data and evaluate whether it is a water leak or not, once any leak is detected the system sends an automatic email as an alert message to the user of the system for quick notification, and an electrical actuator to shut off the main water supply to avoid water losses until the relevant authorities will intervene then water will flow as usual. This system will improve the efficiency of operation, reducing delay time and cost of maintenance pipelines after leakage detection.

1.3 The study objectives

The objective of this research project is to design a real-time IoT based system for early leak detection in water pipeline and develop a prototype that helps the user of the system to get an email notification once the leakage is detected and also an electrical shut off valve is used for avoiding any financial loss before the pipe is being repaired, data visualization is done through developed dashboard.

1.3.1 General Objectives : To develop an IoT system with low-cost and easy-to-use for leak detection by helping water utilities to improve their effectiveness in locating leaks and taking interventions.

1.3.2 Specific Objectives

- To collect data using sensors regarding pressure, flow rate, and the presence of water.
- To analyze and develop a dashboard that will help to visualize and manage the data on the cloud.
- To test the leakage detection system and validating findings.

1.4 Hypotheses

This research is about to detect a water leak in the pipeline, once the water flow and pressure become low once in the tank is any amount of water then the system will notify the user of this system that there is leak detection as well as an electrical shutoff valve to turn off the water supplyonce the pipe is not repaired this will lead to avoid technical and financial loss.

1.5 Scope of the project

This research focuses on the issue of water distribution networks, more specifically, on the issue of "water leaks" in residential areas. Anyone who has had a water heater, dishwasher, or burst pipe disaster in their home knows how important early detection can be. Even those slow leaks that only cause mold damage requires expenses to repair.

1.6 Significance of the Research

This research has an impact on the community by saving energy lost by water utilities to cross the urban and rural areas searching the root of water pipe leakage, as well as the water losses, will never happen due to the developed system can shut off the valve automatically once the leakage is occurring and the notification is sent to the relevant authorities for the quick response.

1.7 Organization of the Research

This research is structured in chapters where:

Chapter 1 is all about the introduction, background, and motivation of the research, research objectives by showing general objectives and specific objectives, the scope of the research is shown accompany with significance and organization of the research to introduce the aim of research to the reader.

Chapter 2: is about the literature review, it shows the work done by other researchers and gaps identification that leads to the contribution of this research.

Chapter 3 shows the research methodology by indicating the methodology used to achieve the hypothesis and objectives of the research which leads to an implementation plan.

Chapter 4 shows system design and implementation where the simulation used will be shown through screenshots and demonstration.

Chapter 5 is about interpreting the findings

Chapter 6 shows recommendations and a conclusion where the summary of achievement is shown through conclusion and suggestions will be allocated as recommendations.

1.8 Conclusion

By reading chapter one of this research, the reader is aware of research background that talks about how water leak is a problem as well as how it affects the community in the different domain including financial means, it shows also the research questions and why this research is important.

The significance of the study is included to indicate the impact of this research technically and financially. The organization of this research is showing how it is structured based on the chapters where chapter one is based on introduction and background of the research that leads to the motivation of developing water leak detection system, chapter two is about related work and its summary regarding to the work done for detecting water leaks in water pipeline, this chapter leads to show the gaps that are in the work done before, chapter three indicated the research methodology to develop the research, chapter four showed all about the system design and analysis, chapter five is all about results and analysis and chapter six is all about conclusion and recommendations.

Chapter 2. LITERATURE REVIEW

2.1. Introduction

Reading the literature and writing a literature review can be an informative, interesting, and thought-provoking endeavor. It is an opportunity for students to learn an issue of importance to them, to gain a thorough understanding of the research that has been conducted about their capstone focus, and learn what gaps exist in the literature in their area of focus [17].

2.2. Summary of related works and gaps in the existing research.

The Internet of Things technology is used to detect leakage in a building's hydronic pipes with the support of sensors [18] but this system has mechanical control. Ground-penetrating radar (GPR) used to identify water leaks in the pipeline due to it circulates near the pipe but the research ends up with no definite conclusion due to many reasons such as the clay soil with high natural moisture, radar signals were highly affected, and also the soft soil was not conducive [19].

Method of correlation is another way for recovering water pipe leakage but it is time plus energy-consuming; it acquires much calculation with more comparison about the result obtain, again it is not a real-time response [20]. Leak detection in water distribution network was done by Samer EI-Zahab, he found that the theory behind was broad to sense the leak detection field research [21].

By using vibration sensors to identify leakage in the water pipeline, this research found that leaks can be identified only when two different types of pipes are connected by using time different [22]. Satisfactory results have been gained for both leak detection and friction factor system calibration for the Test Network based on the genetic algorithm technique. These results highlight the usefulness the potential of this technique for application on larger networks. A new crossover operator has been introduced to take advantage of the continuous nature of the variables being represented in the genetic algorithm string. Leak detection was made by developing both the inverse transient technique and the genetic algorithm technique that uses transient data to calibrate and detect leaks in a network but one of the big issues in developing these models is the health of the pipes especially if they are old, it is quite hard to obtain reliable estimates of roughness height for each pipe in the system using steady-state calibration techniques [23].

The IoT-based solution was proposed by using different sensor nodes including soil moisture on water pipeline distribution network [24], cluster head nodes to collect all data from sensor nodes then those data reached the control center through a gateway to be analyzed remotely. By conducting three experiments there were found different results within different times by detectingleakage in water pipeline but the system is high power consumption, short-range coverage and itis time-consuming were the first experiment took 7min 42sec, the second experiment took 13 min then the third experiment took 52min 13sec [24]. Another system is proposed; its purpose is a statistical analysis to determine whether or not if there was any direct correlation between the Leakage Detection Index (LDI) values and soil backfill. Only LDI values of the healthy state [6] were used in the statistical analysis due to the system was expected to be in a more consistent stateacross the scenarios for the healthy state as opposed to the possibility of potential inconsistency in system conditions in leaky states resulting from slight variations in the leakage flows.

The obtained results by comparing the Leakage Detection Index to determine the presence of leakage with cross-spectral density (CSD) for pipeline acceleration; suggest that the burial of the pipeline and the compaction of soil backfill had small changes over the LDI values, but there does not seem to be a clear trend of LDI variation with pipeline burial [6]. The leakage detection technique investigated in the research uses flow-induced vibration to identify leakages, and it can be further developed and used for continuous monitoring of PVC pipelines soon.

Ryan Hanson proposed a new system for water leakage detection, but this project is more proof of theory due to time and budget constraints as well as it shows that the proposed system will be high power consumption [25].

Ali.M Sadeghhioon [26] proposed another system that can use smart wireless sensors network for leak detection in water pipeline by measuring the variation of pressure, as well as temperature in water distribution network which is not showing the reallocation of leak due to temperature, can vary for different factors not only for the leakage.

2.3 differences and similarities between the existing related works and the researcher's contribution

The Internet of Things as technology to address the issue of water leaks but some gaps are identified through reading the related work, conducted by other researchers such as time- consuming to identify water leakage in the water pipeline, high energy loss by doing comparison about measured parameters, reallocation of leak due to temperature that can vary for different factors not only for the leakage as well as financial losses. This research aimed to fill those gapsby providing an IoT-based solution for early leak detection which can identify the location of a water pipe leakage in real-time. This system is an automatic shut-off of the valve before pipe repairing in parallel with releasing water to pass within as usual once pipes are repaired. This system can help to increase the economy due to it saves water from any loss together with no watershortage will occur. This system is a real-time system by sending a notification to the system usersby sending an email when the leakage has occurred.

Similarities	**Gaps in existing research**	**Contribution of this research**
Used technology (Internet of Things, IoT)		
Sensors deployment		
	1.mechanical control	1. automatic control
	2.high energy power consumption	2. low energy power consumption
	3.high cost for the existing system	3. cost-effective
	4.time consuming	4.real-time system

Table 2.1 similarities, gaps in existing research and contribution of the researcher

Chapter 3. RESEARCH METHODOLOGY

3.1 Introduction

This chapter provides an outline of the research methodology used to answer the research questions- the research approach, a description of the primary data collection process for the interviews, secondary research, data analysis techniques used, and limitations of the adopted research method.

3.2 Research Approach

Research approaches are plans and the procedures for research that span the steps from broad assumptions to detailed methods of data collection, analysis, and interpretation [27]. The selection of a research approach is also based on the nature of the research problem or issue being addressed, the researchers' personal experiences, and the audiences for the study. Two types of approaches are available- deductive and inductive. Induction is defined as moving from the specific to the general, while deduction begins with the general and ends with the specific; arguments based on experience or observation are best expressed inductively, while arguments based on laws, rules, or other widely accepted principles are best expressed deductively [28]. This research addressed the audience's experiences of water leakage in the water distribution network in Rwanda by using a deductive research approach as it aims to tests the theory by taking action from decision making based on IoT developed system functionality that helped a researcher to work from theory to hypotheses to add to or contradict the theory through sensors to sense the environment by collecting data from the field and data are pushed to cloud through gateway and cloud based serveris serving for data analytics and visualization for meangiful insights .

3.3. Data collection methods

3.3.1. Observation

The observation research method is used in this research for evaluating the situation regarding water leakage situation that occurs every day, how relevant authorities currently solve this problem, the energy that is spent by technicians by searching the leakage in the water pipeline, how plumbers got information if there is any water leak in the system, how undetected water leakage affects technically and financially. The findings showed that currently, the technicians are still spending lots of energy as well as time by searching the water leakage in the water distribution network and once they found it they worked on it but the water is leaked until the water pipe is repaired this cause financial loss reason why this research developed an IoT based system which helped relevant authorities to easily find the location of water leak accompanied with electrical shut off valve for water supply by saving water from any loss before water pipes repairing, an email notification is sent to the user of the system.

3.3.2 interview

An interview is one of the methods that are used in research, it helps the researchers to conduct a formal conversation between interviewer and respondent wherein the two participates in the question-answer session. In interviews, since the interviewer is present with the subject, there is an opportunity to collect nonverbal data as well and to clarify the meaning of questions if the subjects do not understand [29]. This research method was applied by conducting this research by starting to identify key persons for the interview and what are the main questions to ask those interviewees. At first, the interview was conducted at the household level where the homeowners requested to participate in the interview because they are ones who face the challenge of water leakage in water pipeline such as dry tap, financial loss, any flood can occur or water can get contaminated once the pipe is not repaired quickly, the targeted interviewers were 40 and the responses showed that 90% are the ones who didn't know when the leakage has occurred and 10%responded that they can identify if there is any leak when they don't have water in their water tap, they experienced to call to their neighbours by asking why there is no water and they can respond that there is a water leakage somewhere.

Secondly, the water utilities in Rwanda was targeted through this interview as the ones who are responsible for water distribution among the community, the main questions were regarding how they identify any water leakage through water pipeline, how it is affecting their clients, and what time it takes to find it, what are the current systems that are used to tackle water leakage in the water pipeline. The findings showed that there is a big challenge to identify the water leakage in water distribution network due to it takes time to cross the country by searching where the leakhas occurred or they can be called by their clients through a telephone call, their clients sometimes experience dry tape especially in urban areas where the leakages are high due to engineering activities, this causes a technical and financial loss because they don't have a way to find those leakages easily.

3.3.3. Online Research

This method refers to the review of existing information, and in the quantitative context may involve the manipulation of statistical data [30]. the secondary data collection methods were applied during this research to gain background knowledge and understanding of the water leakagesituation all over the world as well in Rwanda also. The findings were that an estimated 26.50 billion liters (˜15%–25%) of all treated freshwater is lost through leakage from the distribution pipeline infrastructure in the United States [6]. In many developing countries significant amounts of drinking water are lost in the water supply system. Several studies have been conducted to determine water losses, studied water losses in five water utilities in Bosnia-Herzegovina, and found leakage of between 25% and 60% of system input volume [7]. The research shows; In Pilot,Serbia, leakages make up 80% of non-revenue water.

In Rwanda through new times, water utility representatives mentioned that the water distributed is safe for drinking but gets contaminated along the way due to broken pipes [11]. The amount of water loss is typically between 20% to 30% of production, and it cost 28.8 Million annually with leakage being the main component [12]. Through the report conducted by RURA in March 2020 showed that 44.4 percent of water supplied within all branches was water losses due mainly to illegal connections and leakages [15].

3.4. Data analysis

There are two methods available for data analysis like Quantitative and Qualitative. They all aimed at identifying educational problems using different approaches [31]. The qualitative research approach creates a wider understanding of behavior. Hence, the qualitative research approach provides abundant data about real-life people and situations. Christensen and Johnson (2012, p32-36) found that qualitative researchers view the social world as being dynamic and not static. The non-use of numbers by qualitative researchers makes it difficult and impossible to simplify findings and observations. Quantitative research is used to test hypotheses, look at cause and effect.The advantage of quantitative research is the use of statistical data as a tool for saving time and resources. the use of scientific methods for data collection and analysis makes generalization possible with quantitative methods.

During this research, qualitative and quantitative research was applied during data collection and analysis where interviews were conducted over the homeowner as the beneficiaries of water at residential places as well as the ones who faced the challenges for identifying any water leak are 90 % which leads to financial loss and lack of water in the pipe at the household level. Through internet research, the statistical analysis was done by looking at the percentage of water loss dueto water leakage around the world, developed countries as well as in Rwanda also, the analysis showed that above 44.4 % of water loss due to the main cause is water leakage in the water distribution network. By ending data collection and analysis, the researcher found that there is no way to easily identify water leakage in a water distribution network and many challenges are associated with it such as lack of water in water tap, technical and financial loss, a lot of energy is spent to cross the country by looking if there is any leak accompanied with time-consuming. By referring to those findings, this research developed an automatic water leak detection system that can identify the location of any leak in the system and sends a notification email to the user of the system once the leaks occurred followed by an automatic shut-off valve before pipe repairing.

Experimental research was conducted during this research; it is a study that strictly adheres to a scientific research design. It includes a hypothesis, a variable that can be manipulated by the researcher, and variables that can be measured, calculated, and compared [32]. During the experiments, two variables were examined such as water flow and pressure of water by confirming their relationship as well as their dependency or independence as they are shown below.

Water flow: The amount of water passing through a pipe at any given time is described as water flow [33]. The flow of water can be affected by the width of a supply pipe. If any appliances or houses were to receive their water from a supply pipe with a small width, the flow rate would be lower than if the pipe were a wider width. Here is the way to find out the flow rate of water. The easiest way to get a fairly accurate measure of your water flow rate is to time yourself filling up a bucket [34]. So for example, if you fill up a 10 liters bucket in 1.5 minutes, then your flow rate will be:10/1.5 = 6.66 Liters per minute.

The pressure is the measure of the force applied to an area. The common units for pressure are pounds per square inch (PSI), Pascal's (Newton per square meter), [35]. There are also some traditional measures such as inches of water or inches of mercury which are defined as the pressure exerted by a column of water (or mercury) of 1-inch height.

Water pressure: is the measure of force to get water through the mains and into your pipe work [36].

Water pressure also is the amount of force per unit area that water exerts, say, on the container it's in or on a submerged object. where the density of water is 1000 Kg per cubic meter, and g is the gravitational constant at the Earth's surface.

3.4.1. Similarities & Differences Between Water Pressure and Water Flow

It must be stated that water pressure and water flow are not the same things. An easy way to describe it would be, water flow is how much water flows down a faucet, and water pressure is how hard the water falls down the faucet.

Both water pressure and water flow are related to friction. Friction will slow down water as it moves through a pipe, depending on the pipe's texture and diameter. If the water pressure is sufficient, the smoother the pipe, the less friction there is and the faster the water slides through.If there is efficient water flow, the friction in smaller pipes may be subdued so the flow stays high.

Generally, the larger a pipe is, the higher the water flow. The water pressure level always must be taken into consideration, however. Even the biggest, smoothest pipes will not have effective water flow if the water pressure is low, because there is not enough strength to defeat the force of friction.

To change water flow, the opening of a pipe must be adjusted. To adjust pressure, the diameter or texture of the pipe must be altered using a different regulator/pump or regulator/pump setting. The water pressure can also be adapted by changing the amount of water that is raised above the water that is coming through the waterline.

3.5. Used materials.

3.5.1 hardware parts.

Arduino Uno: The Arduino Uno is a microcontroller board based on the ATmega328 (datasheet). It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header, and a reset button [37]. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with an AC-to-DC adapter or battery to get started.

Figure 3.1 Arduino Uno front and backside

Microcontroller	ATmega328P-8bit AVR family microcontroller
Operating Voltage	5V
Recommended Input Voltage	7-12V
Input Voltage Limits	6-20V
Analog Inputs Pins	6(A0-A5)
Digital Input Pins	14(out of 6 which provide PWM output
DC on I/O pins	40 mA
DC on 3.3V pin	50 mA
Flash Memory	32KB (ATmega328) of which 0.5 KB used by the bootloader
SRAM	2KB (ATmega328)
EEPROM	1KB (ATmega328)
Frequency (clock speed)	16MHz

Table 3.2 Arduino Uno Technical specification

ESP8266

A cost-effective and highly integrated Wi-Fi MCU for IoT applications. There are many modules available in the market and it is quite easy to get lost with all the choices available [38].In this research Figure, 3.3.4 shows the esp8266 module used for developing a water leak detection system by sending data to the cloud. This module is the most famous one, as it is really small and only costs $5. The ESP8266 Wi-Fi Module is a self-contained SOC with an integrated TCP/IP protocol stack that can give any microcontroller access to a Wi-Fi network. The ESP8266 is capable of either hosting an application or offloading all Wi-Fi networking functions from another application processor. In this research esp8266 is playing a role in networking by allowing embedded devices to be connected to routers and transmit data, it allows also data processing where processing basic inputs from analog and digital sensors for far more complex calculations with an RTOS or Non-OS SDK.

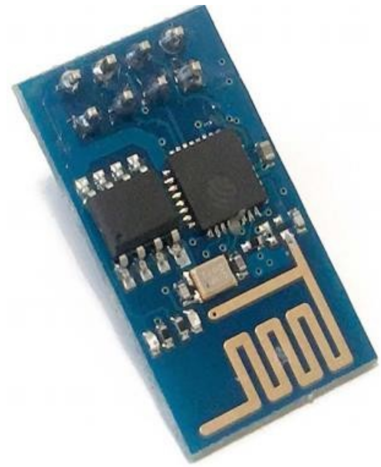

Figure 3.2 ESP8266 module

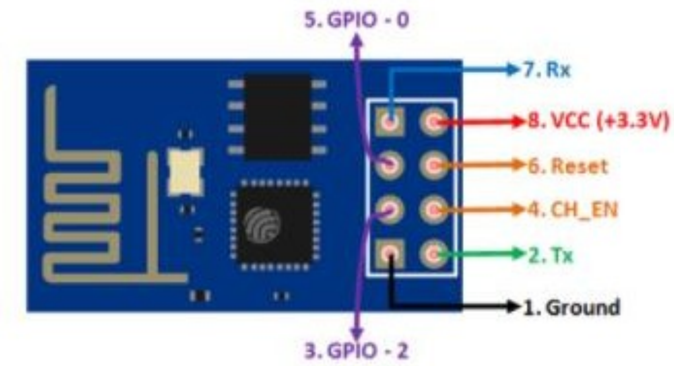

Figure 3.3 ESP8266 pinout

Pin Number	Pin Name	Usage	Alternate purpose
1	Ground	Connected to the ground of the circuit	-
2	TX	Connected to Rx pin of programmer/uC to upload program	Can act as a general-purpose input/output pin when not used as TX
3	GPIO-2	General-purpose input/output pin	-
4	CH_EN	Chip Enable – Active high	-
5	GPIO - 0	General-purpose input/output pin	Takes module into serial programming when held low during start-up
6	Reset	Resets the module	-
7	RX	General-purpose input/output pin	Can act as a general-purpose input/output pin when not used as RX
8	Vcc	Connect to +3.3V only	

Table 3.3 Table shows ESP 8266 pin specifications

Pressure sensor:

the pressure is one of the most important physical quantities in our environment. The pressure is a significant parameter in such varied disciplines as thermodynamics, aerodynamics, acoustics, fluid mechanics, soil mechanics, and biophysics [39]. As an example of important industrial applications of pressure measurement, we may consider power engineering. The pressure is an expression of force exerted on a surface per unit area. A pressure sensor is an instrument consistingof a pressure-sensitive element to determine the actual pressure applied to the sensor (using different working principles) and some components to convert this information into an output signal.

Figure 3.4 pressure sensor

Specification	**Value**
Pressure range	0-0,4 bars
Offset	+25mV
Sensitivity	60mV/V/bar
Linearity	+_0.5%
Impedance	4kr
Break Pressure	3.5 bars

Table 3.4 This table shows pressure specification and value

Water level sensor: Level sensors are used to detect the level of substances that can flow. Such substances include liquids, slurries, granular material, and powders. Level measurements can be done inside containers or it can be the level of a river or lake. Such measurements can be used to determine the number of materials within a closed container or the flow of water in open channels.

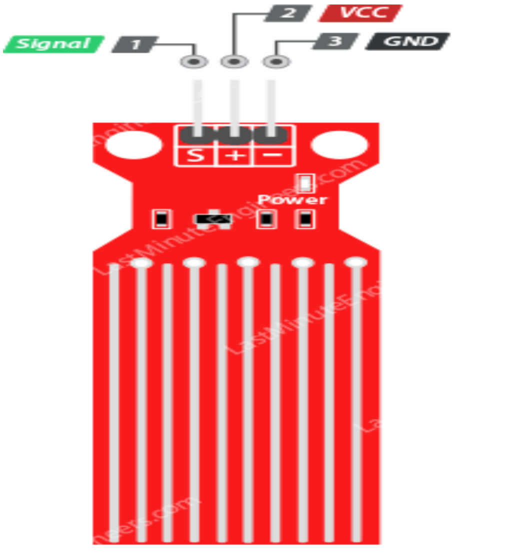

Figure 3.5 water level sensor pinout

Water flow sensor: The water flow sensor consists of a plastic valve body, a water rotor, and a hall-effect sensor. When the water flows through the rotor, the rotor rolls, and the speed changes with a different rate of flow. The hall-effect sensor outputs the corresponding pulse signal.

Figure 3.6 water flow sensor

Water pump: DC-12V Pneumatic Diaphragm Water Pump Motor R365 is the perfect choice for any project that requires water to be moved from one place to another. The pump is supplied with 1M of silicon hose that you can cut to your requirements, the hose provides a good seal.

Figure 3.7 DC water pump 12V

Actuator Control: An automatic water shut-off valve detects water either by monitoring flows in the pipe or by detecting water on the floor. When the flow is irregular or moisture is detected, the valve will shut off the water supply to the home. This can prevent a significant amount of damage that water leaks cause.

Figure 3.8 actuator control

Breadboard: A breadboard is a solderless device for a temporary prototype with electronics and test circuit designs. Most electronic components in electronic circuits can be interconnected by inserting their leads or terminals into the holes and then making connections through wires where appropriate.

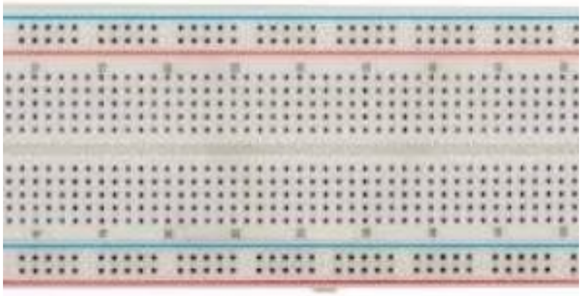

Figure 3.9 Breadboard

Jumper wires: A jump wire (also known as jumper, jumper wire, jumper cable, DuPont wire, or cable) is an electrical wire, or group of them in a cable, with a connector or pin at each end (or sometimes without them – simply "tinned"), which is normally used to interconnect the components of a breadboard or other prototype or test circuit, internally or with other equipment or components, without soldering.

Individual jump wires are fitted by inserting their "end connectors" into the slots provided in a breadboard, the header connector of a circuit board, or a piece of test equipment.

Figure 3.10 Jumper wires

Relay

A power relay module is an electrical switch that is operated by an electromagnet. The electromagnet is activated by a separate low-power signal from a microcontroller. When activated, the electromagnet pulls to either open or close an electrical circuit.

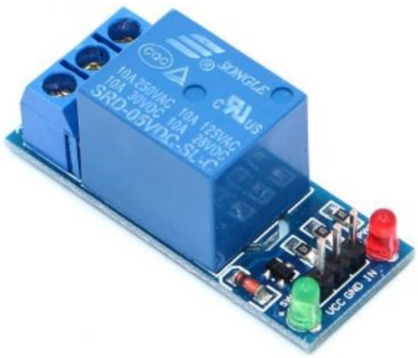

Figure 3.11 Relay

Coil voltage	12V
Power supply	12V
Maximum switching current	10A
Maximum switching voltage	250VAC/30VDC
Logic	5V

Table 3.5 Relay specification

LED

LED stands for Light Emitting Diode. It is a two-lead semiconductor light source. It is a PN- junction diode that emits light when activated. It is a very important electronic device because itis used in a lot of electrical and electronic devices nowadays.

Figure 3.12 Full form of LED

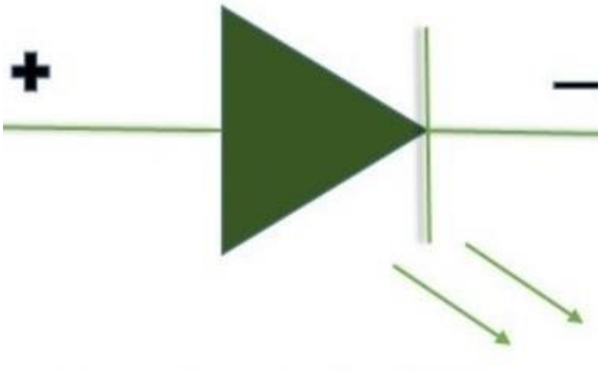

Figure 3.13 Circuit symbol of LED

LCD: Stands for "Liquid Crystal Display." LCD is a flat panel display technology commonly used in TVs and computer monitors [40]. It is also used in screens for mobile devices, such as laptops, tablets, and smartphones, it is also used in most IoT applications for data display.

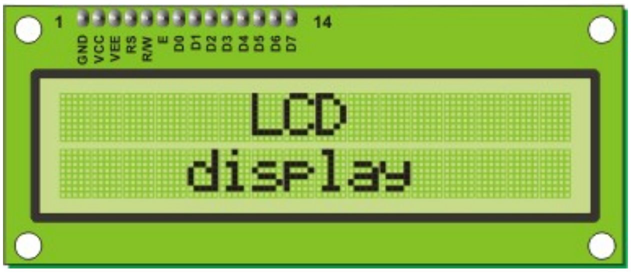

Figure 3.14 LCD Display

GPS: A satellite navigation device, colloquially called a GPS receiver, or simply a GPS, is a device that is capable of receiving information from GNSS satellites and then calculating the device's geographical position. Using suitable software, the device may display the position on a map, and it may offer routing directions. It is high energy consumption; it is not used directly in wireless sensor network localization but deployed for any assistance [41]. The use of location- based technologies has reached unprecedented levels. Location-enabled devices, giving us access to a wide variety of LBSs, permeate our households and can be found in almost every mall, office,and vehicle. During this research development, a GPS module is used to allocate the location of water leakage in the water pipeline.

Figure 3.15 GPS Module

Chapter 4. SYSTEM DESIGN AND ANALYSIS

4.1 Introduction

This chapter aims to show the detailed analysis of the proposed system and provides all the steps involved in designing a water leakage detection system including system models, proposed simulation models, and simulation scenarios. The working principle of the system and how the user will interact with the system will be shown in this chapter.

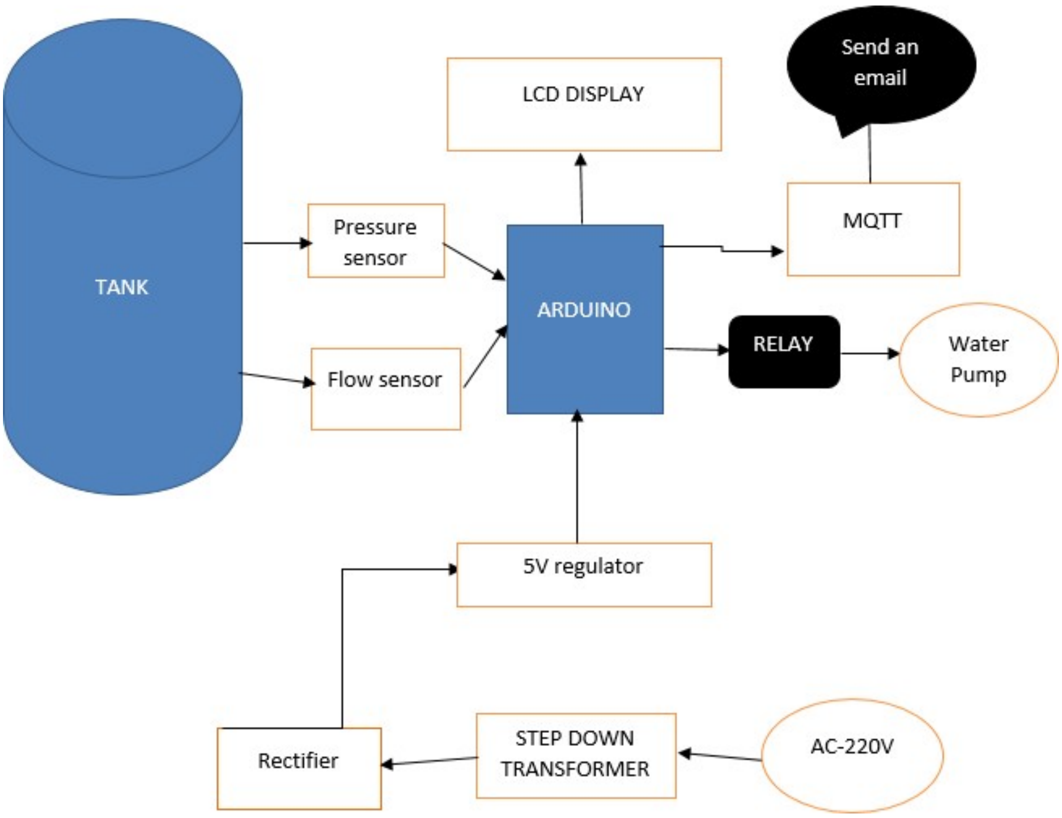

Figure 4.1 block diagram for water leakage detection system

In above Figure 4.1 is explaining which system design of the water leak detection system and its functionalities. The system contains a water tank, which is connected to Arduino as a microcontroller to control the values of sensors from the fields such as pressure and flow rate sensor values, Arduino is powered by a 5V regulator, and the collected data are sent to clouds through MQTT as communication channel where the decision will be made if there is any leak detected or not, if yes then an email notification is sent automatically to the system users and electrical actuator shut off water pump once the leak is detected before any water pipe repair.

Number	Material Name	Used for
1	Arduino	Arduino Uno is used as a boards that reads input and turn it into an output's.
2	MQTT	MQTT is used to send commands to control outputs, read and publish data from sensor nodes.
4	Transformer	A transformer is used to step up or step down voltages.
5	Rectifier	A rectifier is a device that used in this research toconvert an oscillating two-directional alternating current (AC) into a single-directional direct current (DC).
7	Water pump	A water pump is any device for moving water.

Table 4.1 used materials in figure 4.1 block diagram

4.2 Flow chart diagram of the system

The flow chart diagram is used to show a picture of the separate steps of a process of activities from the starting point up to the endpoint during water leakage system development.

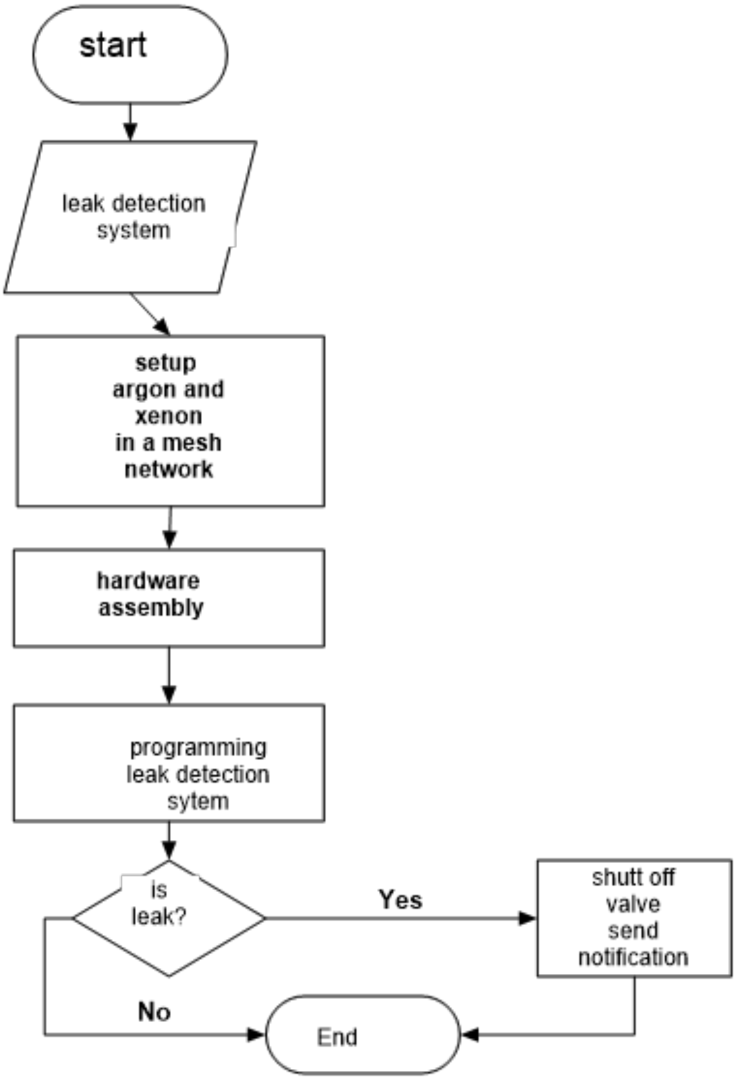

Figure 4.2 Flow chart diagram

4.3 Experiments design

This research was conducted by working on different experiments at three points as Point A, Point B, and Point C. The first experiment was done by considering the water tank in the house as point A and put on a water pipe to measure pressure and flow rate on the source.

By knowing this, the research proceeds by measuring pressure and flow rate after releasing water from the tank, then another measurement was taken at a different point such as at point B and C as the destination of water in usage refers to the pressure and flow rate; if a tap is ON at point B and C then the Sum of pressure and flow rate of those two points should be the same as values at point A. Otherwise, the leakage will be detected in between by showing the location of the leakagewith the time it is happening and the user of the system will be notified via email and the LED willbe turned off to indicate an automatic shut-off valve.

This system is used for saving water losses once the technicians are not around, after repairing the water pipe then water can flow in normal condition and the LED will be turned ON.

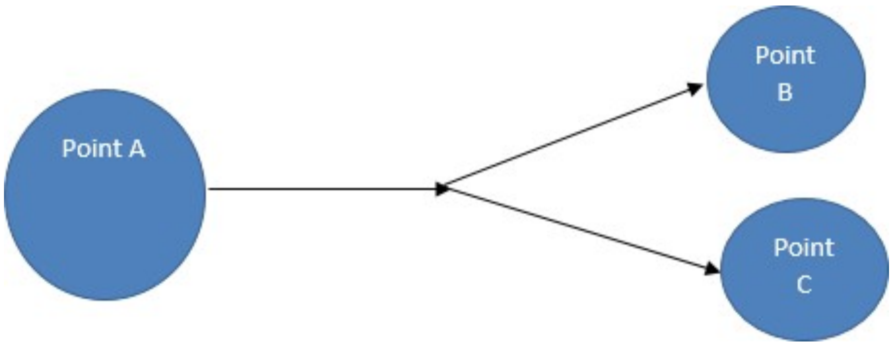

Figure 4.3 three-point that are used during experiments

Through this research, the researcher uses a tank that will contain water to be distributed in different taps in resident such as in the kitchen or bathroom, from this tank the water pressure and flow rate are measured at the source to know about pressure and flow before water distribution in the system; those measurements are done by using water pressure sensors and flow sensors then after the same measurements are taken at Point B and C when water is released from point A whenthe sum of those measurements are the same as from the source there is no water leak detection,the system remains closed and the device is in sleeping mode to save energy and power; otherwise,the water leak is detected then the system alerts the relevant users via sending email to accompany with automatic shut off valve indicated by turning OFF the LED.

4.4 simulation model

In this research, proteus is used as a simulator to connect the microcontroller with water sensors and the values of sensors are displayed on LCD.

Proteus Simulation: The Proteus Design Suite combines ease of use with a powerful feature set to enable the rapid design, test, and layout of professionally printed circuit boards.

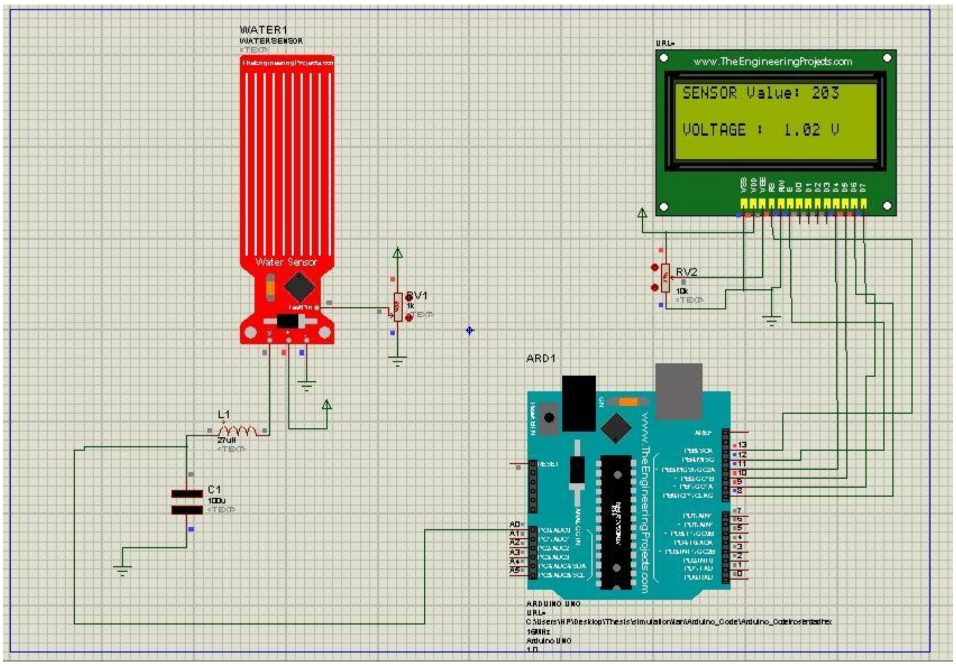

Figure 4.4 proteus simulation where sensors are connected to Arduino board displaying data on LCD

PCB Design Software: Proteus PCB Design combines Schematic capture and PCB Layout modules to provide a powerful, integrated, and easy-to-use suite of tools for professional PCB design.

The Proteus schematic: capture module lies at the heart of the system and combines a powerful design environment with full support for design re-use and assembly.

Another way to develop this system, a prototype was implemented where a water sensor is used to detect the presence of water in any residence where the leakage is found.

Chapter 5. RESULTS AND ANALYSIS

Water leakage detection system in water pipeline was conducted and completed based on analyzing two parameters such as pressure and flow rate in water distribution network where pressure and flow of water are measured, and the results are shown through below attachments. Proteus 8 professionals were used for system testing and the results are analyzed through the dashboard as it is shown in figure 5.1 to help the users and operators (remotely) monitor and controlspecific assets and processes, and depending on safety requirements, access and control an environment from anywhere and the communication to this dashboard was done through MQTTas it is shown on Figure 5.2.

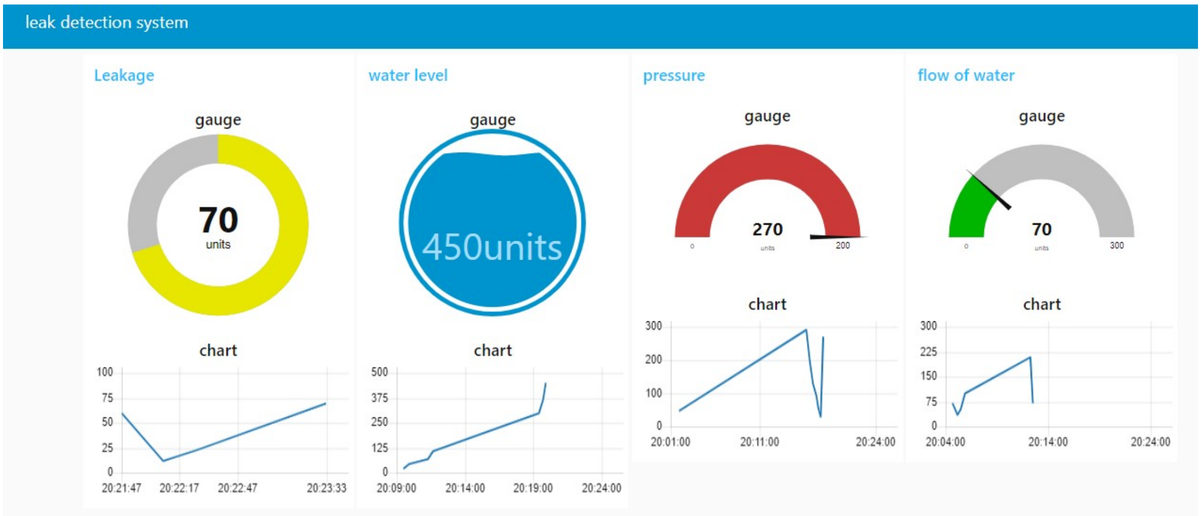

Figure 5.1 dashboard for data visualization from a proteus simulation model

The developed dashboard contains the leakage system, water level in the tank; the measurements are based on the level that is in the tank followed by pressure and flow values and observe how it changes accordingly.

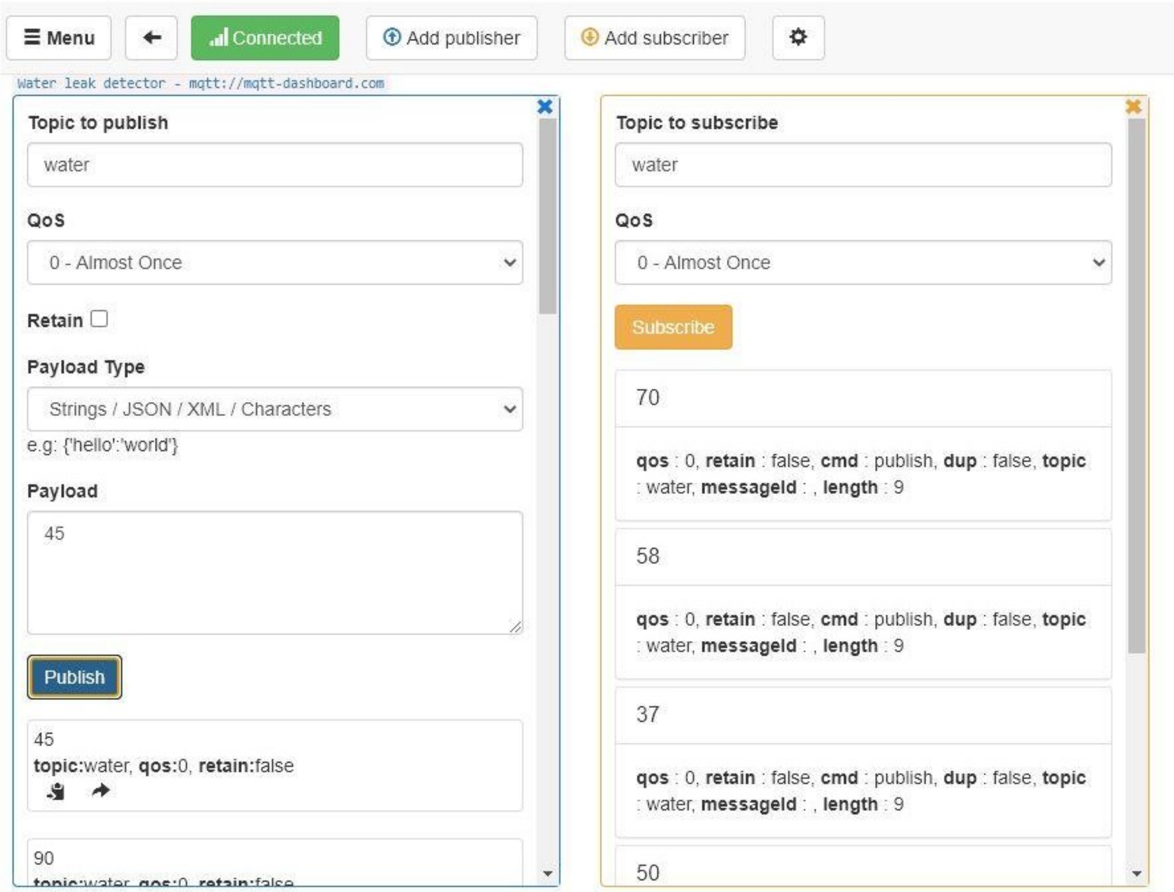

Figure 5.2 MQTT for communication with dashboard

MQTT (MQ Telemetry Transport) is a lightweight messaging protocol [42] that provides resource-constrained network clients with a simple way to distribute telemetry information. The protocol, which uses a publish/subscribe communication pattern, is used for machine-to- machine communication and plays an important role in the internet of things.

MQTT is one of the most commonly used protocols concerning IoT. MQTT enables resource-constrained IoT devices to send, or publish, information about a given topic to a server that functions as an MQTT message broker.

The first concept is the publish and subscribe system. In a publish and subscribe system, a device can publish a message on a topic, or it can be subscribed to a particular topic to receive messages [43].

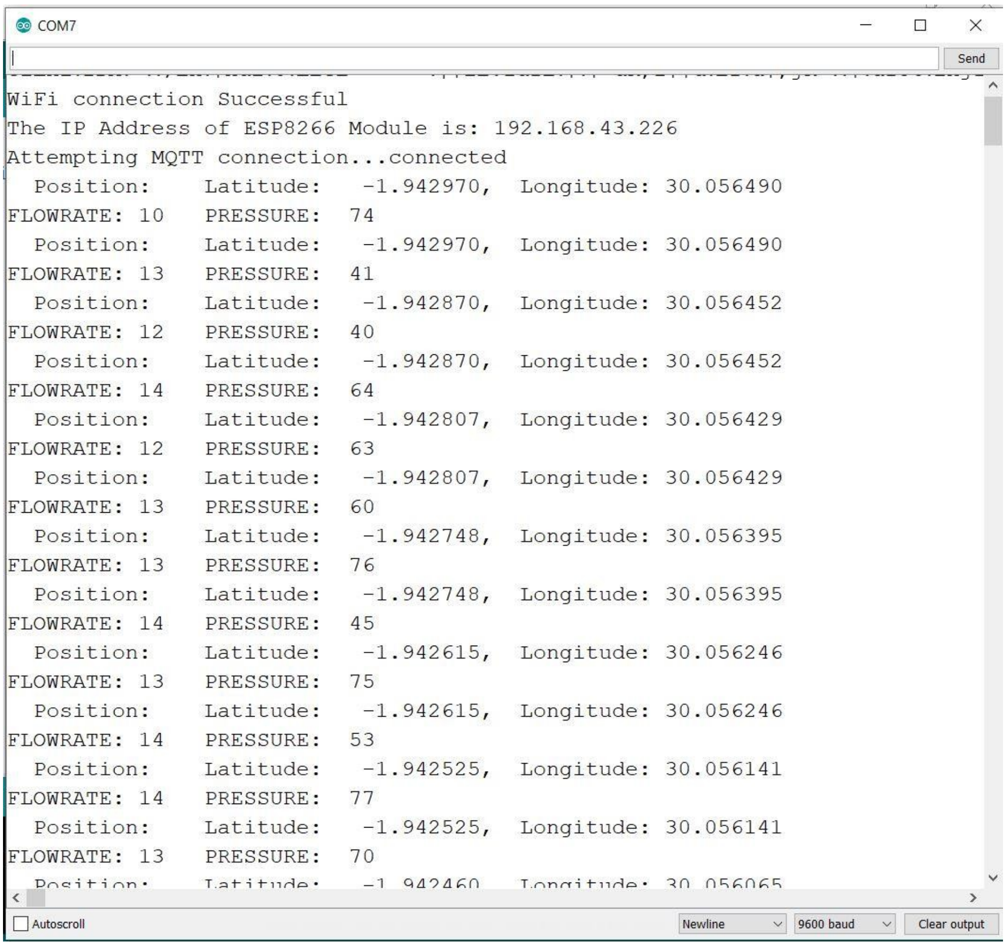

Figure 5.3 locating flow and pressure values in water leak detection system

After knowing and locating sensors values, the data are sent to dashboards for data visualization and meaningful insights.

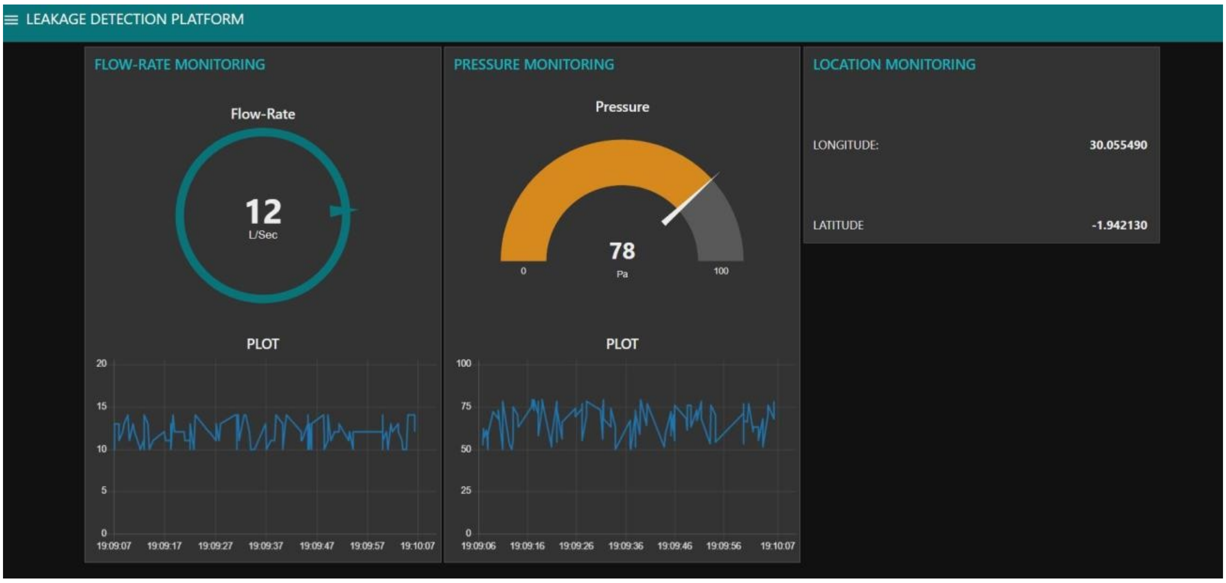

Figure 5.4 dashboard for data visualization from pressure and flow sensors

Water pressure is measured in psi, or pounds per square inch, and represents the force at which water enters your home from the water main. Normal psi for a home pipe system is between 30 and 80 psi. It is not recommended to have psi below 80psi.

In this system, once the pressure is above 80psi then the system will mention the leakage as it is shown in Figure 5.5 as the screenshots taken from the serial monitor of a computer and the user of the system is alerted via email as it is shown on Figure 5.6.

The average household needs 100 to 120 gallons per person per day and a flow rate of about 6 to 12 gallons per minute.

In this system, once the flow is below the normal range of 6 to 12 GPM then the leakage is detected and the user is communicated via email.

By connecting GPS module with water sensor to Arduino board then the data are coming out and are displayed through the serial monitor, once the water leakage is detected the system is automatically indicating where the leakage is found and what time that leakage happens in the system otherwise the device is remaining in sleep mode to save energy for low power consumption.

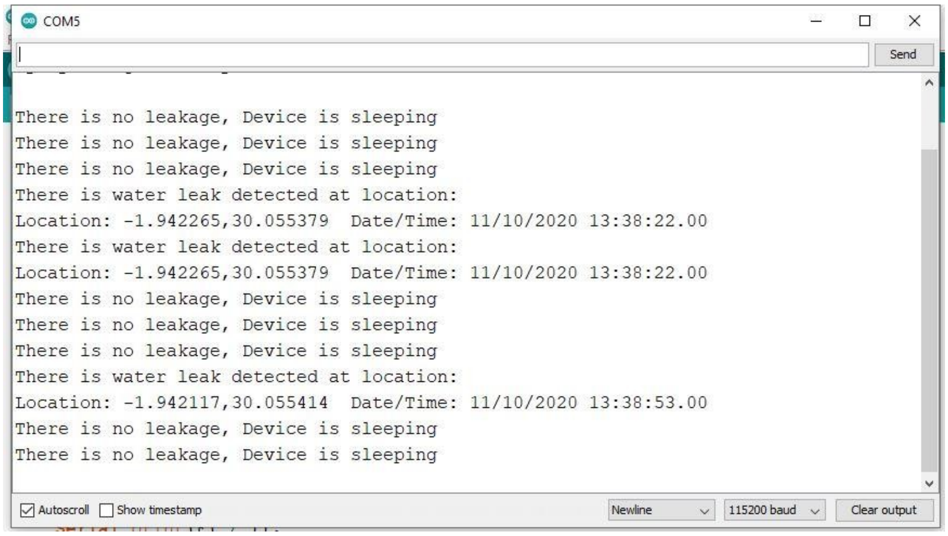

Figure 5. 5 indications of water leak in the system

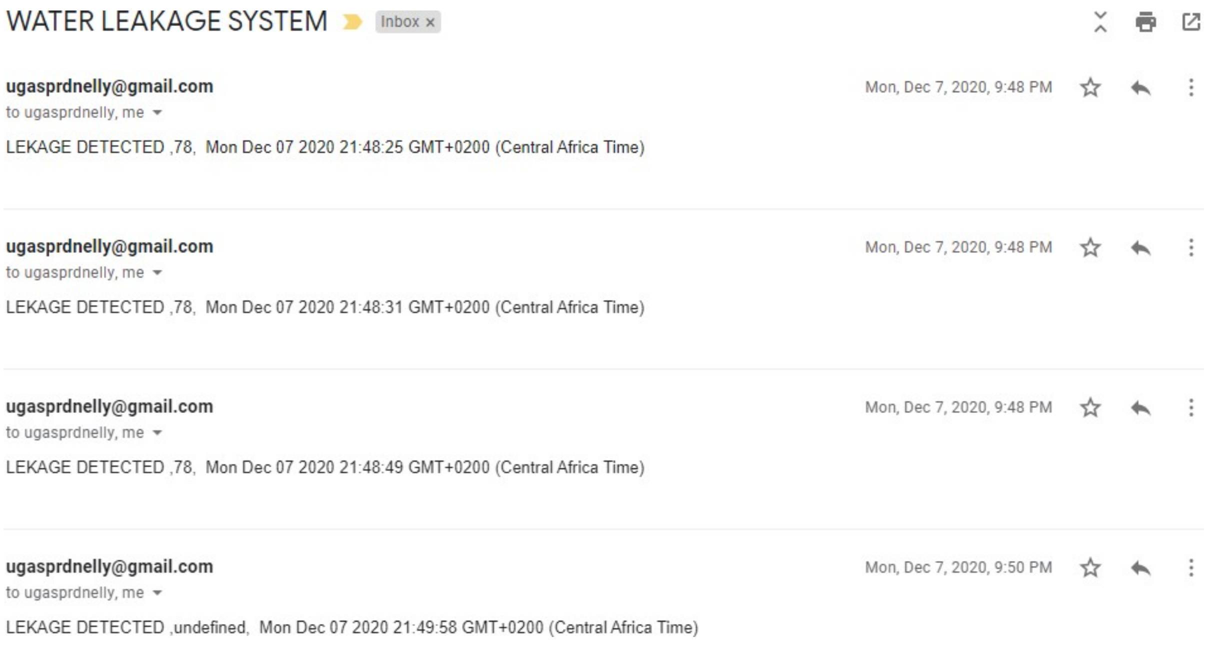

Figure 5. 6 Email notification

Chapter 6: CONCLUSION AND RECOMMENDATION

6.1. Conclusion

The proposed systems are tested on the model of Water Leak Detect which is shown in Figure 4.1. This system feature is expected to draw much attention in the next decades. Water is one of the most important basic needs for all living beings. But, unfortunately, a huge amount of water is being wasted by uncontrolled use and uncontrolled leakage. The problem is not the size of the leak, but the time it takes to detect it.

This work focus on the implementation of water leak detection system IoT based. By using proteus as a simulator to simulate the work done during water leakage detection system development and testing, the result was shown in Figure 5.1 where the water sensor is connected with Arduino Uno; the sensed values are displayed through LCD.

Physical devices are used in this research such as Arduino Uno, water sensor, pressure sensor, and GPS module to develop a prototype for water leakage detection system in a residential house, this work is done by installing a water sensor with Arduino Uno and the values are visualized on Dashboard as it is shown on Figure 5.5, when the leakage is detected the system is shut off valve automatically by turning LED OFF and the user of the system is notified through email as it is shown on figure 5.6, once the leakage is not detected then the device is in sleeping mode to save energy. By transporting data from Arduino to dashboards; MQTT was used as a communication protocol to publish and subscribe to a topic as is shown in Figure 5.2.

In this research, another test was done at 3 points as is shown in Figure 3.2 where the pressure and flow rate of water are measured on the source and the destination then after the system compares those sensed values after looking at it the decision was made based on that assets, if pressure is below 80psi then the water leakage is detected and the user of the system is notified via provided email and the location is also indicated including latitude and longitude as it is shown on Figure 5.3 and Figure 5.4. This system is helping to save time and energy as well as to know the exact location of water leakage when it happens and it is a real-time system.

6.2 Recommendation

In nowadays where technology is at the heart of everything, it is recommended to use the Internet of Things as a tool consists of web-enabled smart devices that use embedded systems, such as processors, sensors, and communication hardware, to collect, send and act on data they acquire from their environments. The IoT devices shared the sensed data they collected by connecting toa gateway where data can be sent to the cloud to be analyzed virtually or locally.

Future work may focus on the research about Improvements of the water leak detection system by taking long coverage in the water distribution network or using machine learning to train a model that can predict the leakage before happening by using artificial intelligence (AI), this research will contribute to many people as well as institutions especially for water utilities to save Technically and Financially.

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