Website: www.aceiot.ur.ac.rw
Mail: aceiot@ur.ac.rw


**COLLEGE OF SCIENCE AND TECHNOLOGY**

**AFRICAN CENTER OF EXCELLENCE IN INTERNET OF THINGS**

**P.O. Box: 3900 Kigali, Rwanda.**


# "IoT APPLICATION FOR WATER TANK QUALITY AND LEVEL MONITORING SYSTEM"

**CASE STUDY: KIGALI CITY**

*Submitted in partial fulfillment of the requirements for the award of*

**MASTERS OF SCIENCE DEGREE IN INTERNET OF THINGS- WIRELESS INTELLIGENT SENSOR NETWORKING**

*Submitted by:*


**VALENTINE NYIRASAFARI**

**REF NO: 220015365**


**JAN 10,2022**

UNIVERSITY of RWANDA

ACEIoT

Website: www.aceiot.ur.ac.rw
Mail: aceiot@ur.ac.rw

**COLLEGE OF SCIENCE AND TECHNOLOGY**

**AFRICAN CENTER OF EXCELLENCE IN INTERNET OF THINGS**

**P.O. Box: 3900 Kigali, Rwanda.**

# "IoT APPLICATION FOR WATER TANK QUALITY AND LEVEL MONITORING SYSTEM"

**CASE STUDY: KIGALI CITY**

*Submitted in partial fulfillment of the requirements for the award of*

**MASTERS OF SCIENCE DEGREE IN INTERNET OF THINGS-WIRELESS INTELLIGENT SENSOR NETWORKING**

*Submitted by*:

**VALENTINE NYIRASAFARI (REF NO: 220015365)**

*Supervised by:*

**Dr. Emmanuel NDASHIMYE**

*Co-supervisor*

**Dr. J. Bernard NDAYAMBAJE**

**STUDENT DECLARATION**

I Valentine NYIRASAFARI, declare that this research project entitled "**IoT APPLICATION FOR WATER TANK QUALITY AND LEVEL MONITORING SYSTEM"** is my own research and unique. I agree that, it has never been presented in any other institution or university except some related work used for gaining some ideas about my research. Also, I declare that this research is completed successfully under the supervisors Dr. Emmanuel NDASHIMYE and Dr. J. Bernard NDAYAMBAJE.

Declared by:

**Valentine NYIRASAFARI (Ref. No: 220015365)**

Date: JAN 10,2022

## BONAFIDE CERTIFICATE

This is to certify that the project "**IoT APPLICATION FOR WATER TANK QUALITY AND LEVEL MONITORING SYSTEM**" is a record of original work completed by **Valentine NYIRASAFARI** with **Ref. No: 220015365** in partial fulfillment of the requirement for the award of masters of sciences in Internet of Things in College of Science and Technology, University of Rwanda, Academic year 2018/2019.

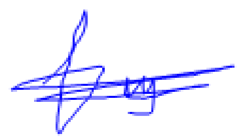
**Dr. Emmanuel NDASHIMYE** and **Dr. J. Bernard NDAYAMBAJE** guided the submission of this project.

Main Supervisor:

**Dr. Emmanuel NDASHIMYE**

Co-Supervisor

**Dr. J. Bernard NDAYAMBAJE**



The Head of Masters and Trainings

Names: **Dr. James RWIGEMA**

## ACKNOWLEDGEMENTS

I am deeply thankful to my supervisors **Dr. Emmanuel NDASHIMYE** and **Dr. J. Bernard NDAYAMBAJE** for their help, encouragement and suggestion which guide to make thesis. I'd want to express my gratitude to the African Center of Excellence in Internet of Things' staff administration for their assistance and sponsorship in completing my project. I'd want to thank all of my coworkers who helped me finish this study by providing encouragement and fresh suggestions.

**ABSTRACT**

Water is life, and all humans require it to survive, some uses of water include drinking, cooking, cleaning, and sanitary purposes. In regions of under development countries, sometimes happen water scarcities caused by climate change or long sunny periods, breaks of water pipelines, mal functioning water treatment plants and increased water demand in different parts. These reasons negatively affect functions which need regular access to water and often lead to fails to deliver on time their outcomes. That is why it is critical to keep water in the tanks and to monitor them. Based on an IoT monitoring system, this research project is deploying a solution (hardware, software, and communications) that aims to keep monitoring water tanks in the region. The system which keeps on communication the statuses of water tanks in terms of water level, water quality by measuring the acidity, basicity, dust in water tank, and make the notification by indicating the locations of the tanks. Sensory parts comprise ultrasonic sensor, Turbidity, TDS (total dissolved solids) and pH. The design prototype use Arduino Uno microcontroller for processing data from sensors and use SIM808 GSM/GPRS/GPS sensor for transmitting those processed data to the cloud-ThingSpeak application to transmit data through API to ThingSpeak that stores and analyses data captured from the water tanks. Based the methodology used, data study, and analysis, the system demonstrates its effectiveness in providing water access to a diverse range of people and functions.

***Keys words:*** *Water Quality, water Level, IoT, pH, and Ultrasonic Sensor*

**LIST OF ACRONYMS**

API: Application Programmable Interface

DC: Direct Current

GSM: Global System for Mobile communication

GPRS: General Packet Radio Service

GPS: Geographical Positioning System

HTTP: Hypertext Transfer Protocol

IFTTT: If This Then That

IoT: Internet of Things

TCP/IP: Transmission Control Protocol/ Internet Protocol

CSV: Comma-Separated Values (JavaScript Object Notation0

GET: Graduate Engineer Trainee,

LCD: Liquid Crystal Display

VDC: Volts Direct Current

VCC: Voltage Common Collector

Wi-Fi: Wireless Fidelity

PH: Potential Hydrogen

TDS: Total Dissolved Solid

MCU: Micro-Controller Unity

WASAC: Water and Sanitation Corporation.

NTU: Nephelometric Turbidity unit.

ppm: parts per million.

LED: Light Emitting Diode

USB: Universal Serial Bus

GND: Ground

TTL: Transistor-transistor Logic

TSS: Total Suspended Solid

WSN: Wireless Sensor Network

AL: Arithmetic Logic

UART: Universal Asynchronous Receiver-Transmitter

SIM: Subscriber Identification Module

# TABLE OF CONTENT

STUDENT DECLARATION ........ ii
BONAFIDE CERTIFICATE ........ iii
ACKNOWLEDGEMENTS ........ iv
ABSTRACT ........ v
LIST OF ACRONYMS ........ vi
TABLE OF CONTENT ........ vii
LIST OF TABLES ........ ix
LIST OF FIGURES ........ x
Chap 1. INTRODUCTION ........ 1
1.1 Background and motivation ........ 1
1.2. PROBLEM STATEMENT ........ 3
1.3. Aims and objectives ........ 3
1.3.1. General objective ........ 3
1.3.2. Specific objectives ........ 3
1.4. Study scope ........ 4
1.5. Significant of the study ........ 4
1.6. Organization of the study ........ 4
1.7. Conclusion ........ 4
Chap 2: LITERATURE REVIEW ........ 1
2.1. Related works ........ 1
2.2. SIM808 GSM/GPRS/GPS ........ 3
2.2.1. SIM808 GSM/GPRS/GPS pinout and features ........ 3
2.2.3. Hardware configurations ........ 5
2.3. Total Dissolved Solid (TDS) ........ 5
2.3.1. How is TDS measured? ........ 5
2.3.2. TDS meter ........ 7
2.4. pH ........ 7
2.5. Ultrasonic sensor ........ 8
2.5.1. Features of ultrasonic sensor ........ 10
2.5.2. Ultrasonic sensor pinout ........ 10
2.6. Turbidity sensor ........ 11

Chapter 3. METHODOLOGY ........ 13
3.1. How the existing system works? ........ 13
3.2. Prototype system design ........ 15
3.3. System design ........ 16
3.3.1. The system technologies ........ 17
3.3.2. Hardware requirement ........ 18
3.3.3. Software requirement ........ 18
3.3.4. Conceptual system Architecture ........ 19
3.3.5. System functionality ........ 21
Chapter 4. IMPLEMENTATION OF THE PROTOTYPE SYSTEM AND ANALYSIS OF THE RESULTS ........ 23
4.1. Design purpose and limitations ........ 23
4.2. Application testing and results ........ 24
4.2.1. Interface ........ 24
4.2.2. ThingSpeak and IFTTT configuration ........ 25
4.2.3. Results obtained through ThingSpeak Platform. ........ 25
CHAPTER 5. CONCLUSION AND RECOMMENDATION ........ 33
5.1. CONCLUSION ........ 33
5.2. RECOMMENDATION ........ 33
5.3. Feature work ........ 34

## LIST OF TABLES

Table 1:Level of TDS per ppm and its rating ..................................................................... 6
Table 2: Pins on ultrasonic sensors are described in detail.......................................................... 10
Table 3:Indicate the level of water whether flesh or not ............................................................. 12
Table 4:Summary of the interviews –people and companies ...................................................... 14
Table 5:Documents revised for waste management in Kigali City ............................................. 15

**LIST OF FIGURES**

Figure 1Municipal water tank (https://www.materialtree.com/bengaluru/500-litres-ganga-kaveri-black-double-layer-water-tank 11/30/2021) ........ 1
Figure 2:SIM808 SM/GPRS/GPS sensor ........ 3
Figure 3:TDS sensor ........ 6
Figure 4:pH scale ........ 7
Figure 5:PH sensor ........ 8
Figure 6:Ultrasonic Sensor principle ........ 9
Figure 7:Ultrasonic sensor pinout ........ 11
Figure 8:Turbidity sensor ........ 11
Figure 9:System design ........ 17
Figure 10:IoT Water tank quality and level measurement system architecture ........ 20
Figure 11:IoT Water tank quality and level measurement system functionality ........ 22
Figure 12:Prototype components and hardware connectivity ........ 23
Figure 13:Polluted water in tank ........ 24
Figure 14:Clean Water in tank ........ 25
Figure 15: IoT Water Quality and Level Measurement setting ........ 25
Figure 16: Ultrasonic sensor for measuring water tank level ........ 26
Figure 17: Measurement of water quality using turbidity sensor ........ 27
Figure 18:Measurement of water quality using TDS sensor ........ 28
Figure 19:Measurement of water quality using pH sensor ........ 29
Figure 20:ThingHTTP for configuring email notification to users ........ 29
Figure 21:Decision making through React web page from ThingSpeaks ........ 31
Figure 22:Email notification for water tank level and tank location ........ 32

## Chap 1. INTRODUCTION

In this chapter different points are described including the background and the motivation, the problem statement that set the general objectives as well the specific objectives, the scope, significance and organization study for this project. The chapter end with the conclusion.

### 1.1 Background and motivation

In all nations, no one doubts the importance of water. Without water, life would be very short. There are different ways that are used to keep water for usage. In poor, dry and underdeveloped countries, water is drawn up from wells by a pump, some people use traditional containers and buckets to draw water mechanically or by hand from the well[1]. Fig.1 shows one of municipal water tank in Kigali city.


*Figure 1Municipal water tank (https://www.materialtree.com/bengaluru/500-litres-ganga-kaveri-black-double-layer-water-tank 11/30/2021)*

This research is being carried out because of the lack of water in homes and offices in developing and underdeveloped countries, where problems continue and have harmful implications. Today, the water is missed in difference region while for other areas water is abundant. Growth of population in cities causes negative impacts in water distribution, water is so needed as compared in rural areas[2]. There is a need of real time measurement of water for any tank in city that helps to ensure that no people have no fresh water.

Internet of Things among up-to-date technologies empowered processes automation in different areas, the devices are made smart as they are enhanced with the abilities of sensing different parameters in their environment, take actions and communicate the data through different communication channels including Wi-Fi, GSM communication technology, Long Range communication technology LoRa, Sigfox, and other Low Power Wide Area Networks communication technologies. Throughout this thesis, IoT will empower a traditional water tank with the sensory system which will make it smart enough to communicate its water level and water purity using GSM/GPS sensor. IoT Water quality uses sensors to ensure water quality by employing pH sensor to monitor hydrogen ions concentrations and display the acidity or alkalinity of water in tank. The Total Dissolved Solid (TDS) is a metric for determining how many of milligrams of soluble solids are dissolved in a water tank. The amounts of soluble solids dissolved in water determines whether the water is clean or not, and the TDS value determines whether the water is clean or not. The TDS value is one of the most often used indicators of water purity. Turbidity is a sensor that measures suspended particle concentrations in a water tank continuously and automatically. That sensor would provide accurate measurements in concentrations ranging from low-turbidity to high-turbidity[3].

After determining the water's cleanliness, an ultrasonic sensor would be utilized to determine the amount of water in tank[4]. It is suggested that both the value indicating the level of water and the value indicating the quality of water be send to the system application so that a message should be send to the company in charge of water refilling indicating location and the tank to be filled.

The project motivation is to provide a solution for water quality monitoring, tank's water level measurement and tank location. Currently Water and Sanitation Corporation (WASAC) manages water and make distribution either rural and urban area. It monitors the water quality and helps all Rwandans to get fresh water.  This system will assist other companies working under the supervision of WASAC in refilling tanks after they have been emptied due to a lack of fresh water. Using an IoT application to increase the delivery of services in getting water provides a solution; nevertheless, this would be useful in Kigali as well as in Rwanda.

## 1.2. PROBLEM STATEMENT

The motivation for pursuing a research thesis focusing on how water is managed in Rwanda, particularly in Kigali city-household.

Kigali's enormous population has resulted in a strain that the city's existing basic facilities are unable to handle [4]. The people do not have enough water; they rely on community tanks for the majority of their needs, and there is no water.

WASAC make a distributed network for water but for people who have water at home, sometime water is scarce and it is difficult to find out other water from different location [5]. In the villages where the water is not yet reached, when it rains, the population often kept rainfall water in the reservoirs or tanks, the population do not have the ability of identifying where this water is fresh or not. Usually, the tanks used are opaque and invisible inside, so it is difficult for the people to know the water status like how much, what water quality is inside tank? This can lead to a very poor management of water. To refill their tanks when it's not raining, company are informed via mobile phone and there is a remarkable delay of service that leads to poor management and monitoring. This cause serious problems to the community or people. A lack of water to be used in household activities can provoke diseases caused by dirt. Also in all people daily life, they drink water and if there no fresh water and also if the population does not know how to identify fresh water or not, that affects negatively the life of people and become diseased chorea or diarrhea. The system that will be designed will be able to detect water quality in order to assist people in keeping the tank clean and monitoring the water tank status in order to keep managing and trucking which is empty to re-fill the water in real time based on its location.

## 1.3. Aims and objectives

The thesis aims to improve tank monitoring by improving service delivery quality based on tank water states. To accomplish this goal, the following general and specific objectives were devised:

### 1.3.1. General objective

The general purpose of this study is to build and implement a smart water tank level system for monitoring water quality and status, as well as locating tanks for real-time re-filling.

### 1.3.2. Specific objectives

The following is a list of the project's specific objectives:

(i) Developing an IoT based water tank monitoring system

(ii) Measuring water tank quality and locate tank.

(iii) Real-time water tank refilling

### 1.4. Study scope

This work focuses on the monitoring of tanks in Kigali city. WASAC is currently attempting to use network pipes to transfer water from one station to another, as well as from station to people's homes, but the problem arises when tanks run dry.

### 1.5. Significant of the study

This work is aiming to improve the management of water in Kigali city, the developed prototype can serve to the implementation of real system that address the problem of water monitoring. The application system is able to detect water tank level, detecting water quality, leakage, location trucking and expected to re-filling the water in the tank once found it is empty. As a result, people's functions that require access to water run smoothly, and the overall work of the authorities in charge of these smart tanks is made easier and more effective. This contributes to the get of flesh water in the context of Rwanda cities, and the work of Water and Sanitation in Kigali will have a huge reputation as the population enjoys the water deployment system.

### 1.6. Organization of the study

After the introduction, chapter two Literature reviews describe the water monitoring in tanks, based on the new technology, review of the existing system as well as the technologies that have been used.

The third chapter draws around methods used for this thesis, system design, prototype model and their parameter. Chapter four discusses on obtained results and makes analysis based on graphs findings. The last chapter concludes the discussion and finals remarks.

### 1.7. Conclusion

Information that relates to water quality, water tank refill and water level monitoring and management within Internet of Things was covered in chapter. For thing-to-thing communication, the Internet of Things, which allows for real-time monitoring, is the greatest option. The study's aims and objectives, as well as the project's scope and significance, were discussed. Motivation to undertake this thesis focusing to water monitoring in Kigali city with consideration of what is needed for stakeholders and beneficiaries. The present stage on water quality in tank helps the owner of the tank to take decision for cleaning the tank and the level of water in tank help the companies' employees to refill water in tank.

In accordance to existing system, there are lacks of policies and there are challenges on tank management.  Focusing on Rwanda, this thesis contributes to the management of water in tank in city of Kigali.

## Chap 2: LITERATURE REVIEW

The chapter two explains the existing literature. It helps in finding gaps and how to overcome from these caps. It shows the existing the technologies and the uses of those technologies based on the existing research.

### 2.1. Related works

There was a lot of interest in Iot water tank Quality and level monitoring in many places. Aanchal M.Pande et al.[6] used Level sensor, a temperature sensor, a pH sensor and aturbidity sensor to measure chemical and physical parameters of water quality, the data was transferred via Wi-Fi and allow the Raspberry Pie to show the data on interface over time.The installation of Wi-Fi in various water tanks has gotten increasingly complicated, making real-time notification more challenging. T. Lambrou et al.[7] recommended a system made of PIC32 MCU board that gets data about water quality based on parameters like pH, turbidity and temperature then transmit these data to Advanced RISC Machine platform that keeps data make their visualization via internet. It makes the notification message through Zigbee transceiver that is high costly system based on their installation and components. S.Pasika et al.[8] measured water quality time to time using sensors like pH for water's pH value, ultrasonic sensors for water level present in tank, DHT-11 for humidity and temperature of surrounding atmosphere and lastly they use turbidity to measure different particles or big thing in water. The use of Wi-Fi become barriers due to its high cost and installation to each water tank. In comparison to the proposed solution of S.Sreekar Siddula et al.[4], who build a system providing real-time information regarding water levels in dams and data sharing to an approved central command center via far-field communication. This research aids in the location of dams utilizing the Internet of Things, which necessitates the installation of new sensors and communication protocols to improve the system.

Further Geetha et al.[9] have developed a system using TICC3200 Launch pad++, Wi-Fi module and database to keep information from sensors.

The android application was designed for system users who have access to acquire information about current data relating to the tank's container, such as the water level and the cleanliness of the water inside the tank.

This system is inefficient. However, by using an Atmega328 as storage and a SIM808 GSM/GPRS/GPS compliant development board with GPS antenna, this system can be improved.

Moreover, in [10], the authors suggest a system that includes system application components for Internet of Things and ICT-based smart water management, monitoring, and control. It covers the peripheral hardware components, which include sensors, actuators, and drives embedded with integrated Wi-Fi, Bluetooth, and ZigBee within IpV6 Address, which ensures the internet protocol's addressing mode.

It also describes the local connectivity that takes data from an embedded system and sends it to the cloud via a web API. The study demonstrates the general concepts for water tank management and control.

V. Radhakrishna et al.[11] discuss the concept of IoT implemented in a water supply system using Wireless Sensor Networks (WSN), Energy Harvesting (EH), and Artificial Intelligence (AI) to measure and monitor water quality in tanks and provide notifications to application users for the purpose of corrective action. In this research thesis, the system is done in a such way that the user receives the notification through email, therefore depending on the received message, the distributers' companies can take decision of bringing water to the tank and refill. On the other hand, the people also take a decision about water usage depending on what kind message content their received.

Furthermore, M. Salah Uddin Chrowdury et al.[12] design an application that allow to remote monitoring the quality of water with IoT. Their concept is around the use of WSN to measure parameters such dissolved oxygen, pH, conductivity, and turbidity. The system application uses an Arduino Mega2560 board, an LCD for data display, and a Wi-Fi module. One the data are sensed; the message will be sent to the application users. That show this system as feasible and good  but it is costly and not easily applicable in our study case due to the existing infrastructures. It is suggested to replace Wi-Fi model with GSM/ GPS module.

For this thesis, IoT Application for water tank quality and level monitoring will helps in good health of people by measuring the parameters like acidity and basicity of water, quantity of dust in water for tank So, the study makes the easy refill of tank, and make time management.

The help in water refill in different tanks and making some measurement concerning the cleanness of water provide a good solution in developing countries that still poses various barriers in the domain of using smart technologies.

## 2.2. SIM808 GSM/GPRS/GPS

When used in conjunction with Arduino, the SIM808 SM/GPRS/GPS compatible development board has a SIM808 module that may be utilized for GSM communication and GPS functions. This module aids in the sending and receiving of SMS as well as the tracking of a position. On the card, the SIM808 module serves as a global system for mobile communication and positioning. The module is utilized as a real-time tracking system that supports large scale users based on GPS to track the emptied water tank. The embedded GPS and microprocessor system is designed to send and receive real-time data across a broad packet radio service and a global mobile communication system[13].

### 2.2.1. SIM808 GSM/GPRS/GPS pinout and features

The power supply for the SIM808 SM/GPRS/GPS module is 5-26V. USB-TTL debugging on a computer is convenient and portable. The GPS and GSM antennas were connected to two sets of SMA Antenna ports.

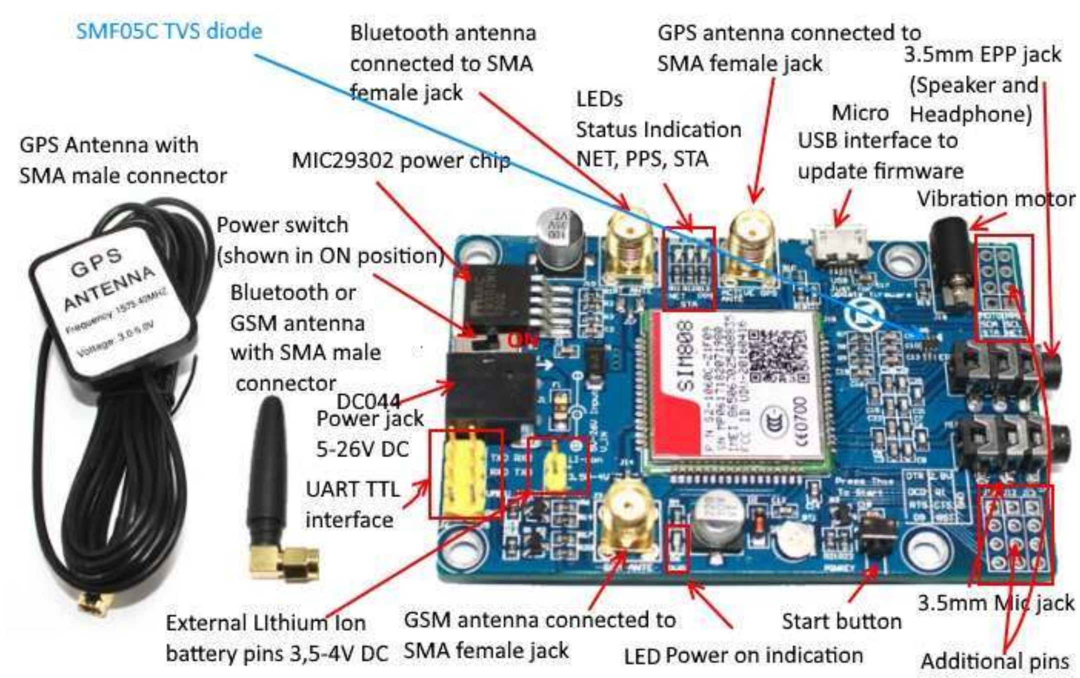



*Figure 2:SIM808 SM/GPRS/GPS sensor*

### 2.2.2. Features of SIM808 GSM

(1) Quad-band 850/900/1800/1900MHz support, compatible with all 2G networks worldwide.

(2) Internal MT3337 GPS receiver with a precision of -165Bm and control via the same serial connection.

(3) Voice calls with an electret microphone are supported by earphone/microphone outputs on a card or an external 32-ohm speaker.

(4) SMS sending and receiving

(5) GPRS data transmission and reception (TCP/IP, HTTP vb).

(6) UART communication with baud rate settings that are automatically adjusted.

(7) Multi-slot GPRS class 12/10

(8) Class B GPRS mobile station

(9) Comply with GSM phase 2/2+ requirements, such as:

    i. Class 4(2 W @ 850/900MHz)
    ii. Class 1(1W@1800/1900MHz).

(10) Provide a low-power mode: 100mA@7V-GSM mode.

(11) Assist with AT command control (3GPP TS 27.007,27.005 and SIMCOM enhanced AT commands)

(12) Supports the GPS satellite navigation system

(13) Power supply status, network status, and operation modes are all supported by LED status indicators.

(14) Working temperature range: -40oC to 85oC

**SIM808 GPS:**

(1) 22 tracking/66 acquisition channel

(2) GPS L1 C/A code

(3) Precision: Tracking: -165bBm,

(4) Cold start: -148 dBm

(5) Finding Location Time (typical: Cold start:32sn, Warm start:5sn)

(6) Accuracy: -2.5m

### 2.2.3. Hardware configurations

(1) 1Connect the USB_TTL to the UART interface USB-TTL SIM808

| | |
|---|---|
| TXD | RXD |
| RXD | TXD |
| GND | GND |

(2) Insert the valid SIM card to the SIMCARD holder.

(3) Connect the GPS antenna and GSM antenna to the board.

(4) Connect the power adapter to the DC044 Interface.

(5) Change the switch.

(6) Press the POWKEY button for 2 seconds, the SIM808 module will work and the other 3 LEDs will light.

## 2.3. Total Dissolved Solid (TDS)

TDS is made up mostly of inorganic salts with a minor bit of organic stuff thrown in for good measure. Calcium, magnesium, potassium, and sodium, which are all cations, and carbonates, nitrates, bicarbonates, chlorides, and sulfates, which are all anions, are all common inorganic salts found in water. Cations have a positive charge, while anions have a negative charge.

Mineral concentrations in water can come from a variety of sources, both natural and man-made. As a result, large concentrations of dissolved solids must be examined in order to determine the mineral concentrations that can have aesthetic, cosmetic, and technical consequences [14].

### 2.3.1. How is TDS measured?

TDS is measured in milligrams per liter (mg/l), sometimes known as parts per million, as a volume of water (ppm). The approved maximum level of TDS for your drinking water is 500 ppm, according to EPA (Environmental Protection Agency) secondary drinking water rules. TDS levels more than 100 ppm are considered dangerous. A filtration system may not be able to filter TDS properly if the level surpasses 2000 ppm. The most straightforward technique to determine total dissolved solids is to test your water with a TDS meter. Figure 3 illustrate TDS meter reading of 100 ppm, for example, suggests that out of one million particles, 100 are dissolved ions and 999,900 are water molecules. This is an example of a low TDS level.

A TDS meter, on the other hand, does not show what forms of TDS are present, which is the most vital information to know about your water quality[14]. As a result, a home water-tank is advised for determining the types of TDS in your water. Your water supplier is also obligated to test and maintain water quality records, which they will supply upon request. The TDS water chart is shown in Table 1 as a measurement to be used when determining the behavior of water in terms of cleanliness.

*Table 1:Level of TDS per ppm and its rating*

| **Level of TDS** per ppm | **Rating** |
|---|---|
| <50-250 | Low |
| 300-500 | Ideal |
| 600-900 | Not great |
| 1000-2000 | Bad |
| >2000 | Unacceptable |

Furthermore, water with a very low concentration of TDS has been shown to have a flat taste, which is disliked by many people. Increased dissolved solids concentrations can also have technical consequences, since high levels of dissolved solids can stain household fixtures, damage pipelines, and give water a metallic flavor.

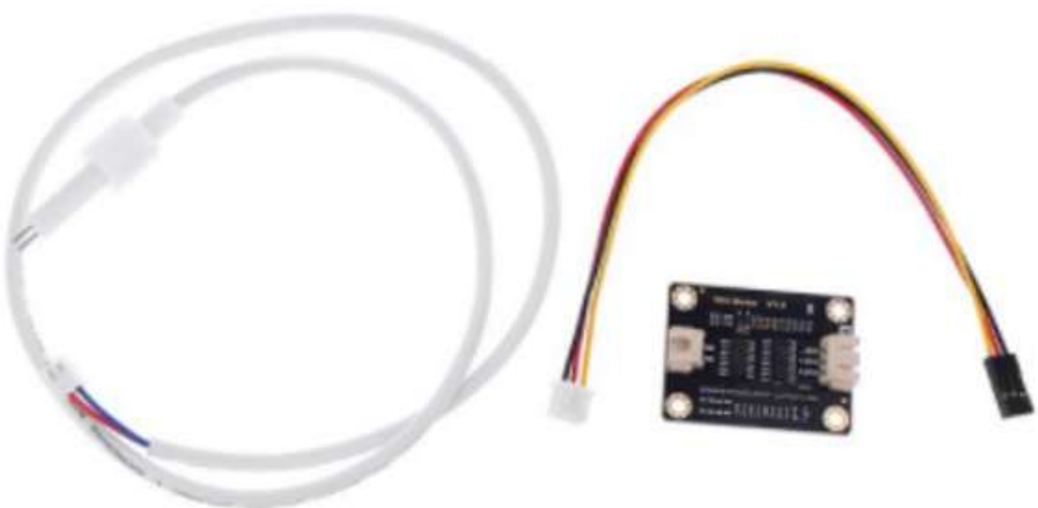


*Figure 3:TDS sensor*

### 2.3.2. TDS meter

(1) DC 3.3-5.5V input voltage

(2) 0-2.3V output voltage

(3) 3-6mA working current

(4) TDS measurement precision is 10% F.S. (25oC)

(5) XH2.54-3P module interface

(6) XH2.54-2P Electrode Interface

## 2.4. pH

The pH refers for hydrogen potential, which really is a measurement of the body's hydrogen ion concentration. This is used in aquaculture and water quality testing. The pH scale goes from 1 to 14, with 7 being considered neutral. Acidic solutions have a pH less than 7, while basic or alkaline solutions have a pH more than 7[15]. Figure 4 indicate the colors that inspire colorful pH scales:


*Figure 4:pH scale*

The pH scale is a numerical scale that determines how acidic or basic water solutions are. It usually falls between 0 and 14, although if sufficiently acidic/basic, it can go higher. The concentration of hydrogen ions in a solution is logarithmically and inversely proportional to pH. If the pH of a solution is less than 7, it is considered acidic. The solution is basic, or alkaline, if the pH is higher than that number. The pH of a solution equal to 7 is considered neutral. You can utilize pH indicators in addition to the mathematical method of determining pH. Litmus paper is the most widely used pH test. It changes color depending on the pH of the fluid it was dipped in.

*Figure 5:PH sensor*

## 2.5. Ultrasonic sensor

The distance between the surfaces of water and the ultrasonic sensor is measured using an ultrasonic sensor that senses the distance between its transmitter and an item. Ultrasonic sensors send sound waves at a target and measure the time it takes for the reflected waves to return to the receiver to determine its distance. This sensor is an electronic device that uses ultrasonic sound waves to detect the distance to a target and then converts the reflected sound into an electrical signal. [16]. The Ultrasonic distance sensor determines the distance to a reflected item by using high frequency sound. Bats detect barriers by emitting high-pitched sound and listening for echoes, which is similar to how humans detect obstacles by emitting high-pitched sound and listening for echoes.

These Ultrasonic distance sensors send out a sequence of Supersonic pulses before looking for echo pulses. Because the speed of sound in the air is constant (340.29 m/s), the time between the transmitted and received signals may be monitored, allowing the distance of the object to be estimated.

The speed attribute of sound is used in ultrasonic distance measurement. The technology sends out several sound waves into the atmosphere [17]. These sound waves bounce off any things they collide with and return as an echo to the source. These reflected sound waves are detected by the system (that is, echoes). The time between the sound waves being transmitted and the echo being detected is measured. The total distance travelled by sound waves is calculated by multiplying the sound's travel duration by its speed. The distance of the object that created the echo is calculated by dividing this distance by two. The ultrasonic distance sensor has the advantage of being less impacted by target materials or colour.

Despite the fact that it does not have the same tight field of view as a laser range finder, it can detect objects within a meter. External disturbances such as vibration, infrared radiation, ambient noise, and EMI radiation are all avoided using these ultrasonic sensors. The price of an ultrasonic rangefinder is determined by the frequency transducer that is used. Ultrasonic range finders with a higher frequency (255 KHz) cost between $100 and $200, whereas those with a relatively high frequency (40KHz) cost less.

Ultrasonic waves are noises that have a frequency greater than 20 kHz and are not audible to humans. The notion is based on the pulse reflection time being measured. As shown in Figure 2, the ultrasonic transducer sends out a wave pulse and receives echoes as a reflection signal. The reflected wave, also known as an echo wave, is rebounded back to the transducer when the transmitted wave pulse finds an item.


*Figure 6:Ultrasonic Sensor principle*

The ultrasonic sensor is mostly employed in distance measurement applications such as level control, but it can also detect most metal and non-metal objects, as well as clear and opaque liquids. If there is an object in front of the ultrasonic sensor, it will generate a 40KHz ultrasound that will bounce back to the module [18].

### 2.5.1. Features of ultrasonic sensor

(1) +5V operating voltage

(2) 2cm to 450cm Theoretical Measuring Distance

(3) 2cm to 80cm practical measuring distance

(4) 3mm precision

(5) <15°is the coverage of measuring angle

(6) 15mA is the operating current

(7) 40Hz is the operating frequency.

### 2.5.2. Ultrasonic sensor pinout

Ultrasonic is sensor that has two pins: Trigger and Echo which measures and calculates the distance of object using ultrasonic waves [19]. Table 2 describe the different pin for ultrasonic sensor.

*Table 2: Pins on ultrasonic sensors are described in detail.*

| **Pin number** | **Pin name** | **Description** |
|---|---|---|
| 1 | Vcc | The sensor is powered via the Vcc pin, which is generally powered by +5V. |
| 2 | Trigger | An input pin is a trigger pin. This pin must be held high for 10 seconds to begin measuring by sending a US wave. |
| 3 | Echo | An output pin is an echo pin. This pin goes high for the amount of time it takes the US wave to return to the sensor. |
| 4 | GND | This pin is connected to the system's Ground. |

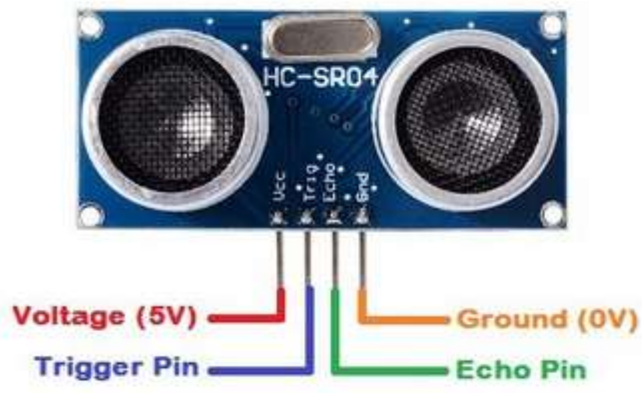



*Figure 7:Ultrasonic sensor pinout*

## 2.6. Turbidity sensor

By measuring turbidity, the turbidity sensor detects water quality. It detects suspended particles in water by measuring light transmittance and scattering rate, which changes as the amount of total suspended solids (TSS) in the water changes. The level of liquid turbidity rises as the TTS rises.[20]. Turbidity sensors are used in studies and operative water quality monitoring projects to quantify suspended particle concentrations in real time [21]. Both analog and digital signal output modes are available on this turbidity sensor. Because the threshold in digital signal mode is customizable, you can choose the mode that best suits your MCU.

*Figure 8:Turbidity sensor*

### 2.6.1. Features of Turbidity sensor

(1) DC5V working voltage

(2) 30mA Operating Current (MAX)

(3) Response time: 500 milliseconds

(4) Resistance to Insulation: 100M [Min];

(5) The output method: 0-4.5V analog output

(6) the signal output: high / low (High: 5V Low: 0V)

(7) Operating temperature: -30°C to +80°C;

(8) Storage temperature: -10°C to +80°C

(9) Gross weight: 55 g

The flavor of water can be affected by the presence of dissolved particles. Panels of tasters have graded the palatability (acceptable taste) of drinking water in relation to its TDS level as follows:

*Table 3:Indicate the level of water whether flesh or not*

| TDS Level (mg/l) | Rating |
|---|---|
| 0-5 | Drinking water/ Flesh water |
| >5 | No Drinking water |

The sensors describe above paints a picture of little research on how to get fresh water from measurement of values indicating alkalinity/acidity using pH, TDS that measure various mineral concentrations in water and Turbidity that detects suspended particles in water. The level of water in tank are measured by ultrasonic sensor.

This thesis focuses on water quality measurement and water tank level in household, offices, schools and so on. So that the tank would be refilled accordingly.

# Chapter 3. METHODOLOGY

The methodology deal with the development of the prototype and its implementation and the system concepts relating to water quality and water level and tank water level notification.

## 3.1. How the existing system works?

**Data collection.**

Data collection method is naturally involved to obtain data require for a phenomenon under study ideally based evidence from difference sources that support the research findings[22]. The conducted research was focused on data finding explaining how the water are kept, learned and tank refilled when the tank has been emptied and how to localize remotely the tank and bring the water to fill it. So different method will be used such as interview, observation and documentation.

The interview as one of the important methods commonly used in performing research studies will be adopted for offering us enormous benefits on water tank refilling and measuring water quality. It is helpful for simplifying and idealizing the interview position based on supposition that interviewees are skilled and producing the data needed that prove the facts resulting in rich data for case study.

To prepare and precede the interview, multiple consideration is taken:

(1) Who to interview,

(2) How many interviewees will be required?

(3) What type of interview to conduct? and

(4) How the interview data will be analyzed?

To achieve the development of this prototype, data collection was conducted respectively from different people in different districts of Kigali City such as Kicukiro, Nyarugenge and Gasabo District about water freshness, keeping and tank refill.

The interview was asked on how people get water when there is a miss of them, how rate the services related to water cleanness and water tank refill. The questions on existing automated technologies currently in use for water cleanness, water quality and tank refill, different challenges and how they overcome, the communication currently uses between citizens, offices and companies responsible for water tank refill.

Table 3 describe the summary of the informal interviews from those who did face services provided to households and institutions to relating to water management.

*Table 4:Summary of the interviews –people and companies*

| Situation / Company | **Water Tank refill /100** | **Water quality measurement /100** | **Problem with water tank refill** | **Automated Technology currently in use** | **Communication media** |
|---|---|---|---|---|---|
| Households | 7% | 40% | -Water tank refill services are not well organized<br>-Communication is not efficiently<br>-People fetch water from anywhere water are. | No one | Mobile phone by calling one another |
| Offices | 20% | 85% | - Communication is not efficiently<br>-Delay in tank refilling | No one | Mobile phone by calling one another |
| Schools | 40% | 80 | -Refilling is done by the owners(schools)<br>- Companies some time refill tanks | No one | Mobile phone by calling one another |

Therefore, from these conversions in combination with the observation done as one of the citizens in Kigali City, the water tank container is managed as follow:

(1) Most of people don't have the water tank

(2) There some citizens still [22]keeping using water without treatment

(3) No communication to the operators was set, each household, offices and schools look where to find water if there is lack of water (from WASAC).

(4) The companies responsible for refilling, haven't an automated communication

(5) No designed place for water keeping(companies)

The existing system that is in currently in use for water monitoring from households, offices, and schools is manual system.

Table 4 shows government documents and internal documents related to water management and monitoring were collected, they are specifically related to policies make and water collection from origin (water generation area).

*Table 5:Documents revised for water management in Kigali City*

| No | Document name | Document source |
|---|---|---|
| 1 | Water and Sanitation 2019/2020 forward looking joint sector review report. | MININFRA, 2019 |
| 2 | Water and sanitation statistics | RURA, 2020 |

The findings describe the policy and regulation for water management, water distribution and water sanitation. Based on the studies, the application to be designed have be conceived to operate in the designated context while abiding to existing rules and regulations.

Offices, households, schools, and colleges utilize such a system to measure water quality and obtain water from companies when their tanks are depleted.

**3.2. Prototype system design**

Views of service providers and service beneficiaries, through interviews, would help to design and elaborate a system for effective water treatment and water tank refill. Experiment method would be undertaken for implementing a prototype.

Experimental research can be made if a relationship stating from the cause in the first way to establish the effects that results in taking decision at the end. The Principle of Replication state that the experiment should be repeated more than once, this result to experimental method to be chosen for the aims, to quantify the services that were provided by attributes.

The microcontroller makes the processing of data and provide response to service beneficiaries. After processing sensed data (in microcontroller), the data are sent to the server for farther monitoring (Ex. Send email message to water tank refilling companies).

Those data are processed and manipulated under the server (ThingSpeak and IFTTT) then the resulting value is compared to what is inside the Tank, if there is no enough water in tank or empty, another process takes place.

### 3.3. System design

In this thesis the system design describes the system technologies, conceptual system architecture, system functionality, prototype parameters interconnectivities development that satisfy the water tank quality and their level monitoring (Kigali city).

In this thesis, there is a desire of developing the prototype application that supports measurement of water in tank and refill of tank once there is no presence of WASAC water using Internet of Things technology mainly for removing various barriers in water cleanness as were as in water tank. Basing on the needs for water tanks beneficiaries, the implementation of prototype will flow the system design as indicated in Figure 8. Prototype will ease the water tank quality measurement and Water tank refilling. The Figure 8 demonstrate the how the prototype will behave, its main parts from the sensing data, communication media, server and data visualization on web application.

The sensors are used to sense data, then microcontroller provide to the water tank beneficially the status of it. After some processing and analysis, the data are sent to the server application using communication channel (**SIM808 GSM**) then some analysis and decision are done for providing the notification to the concerned operators.

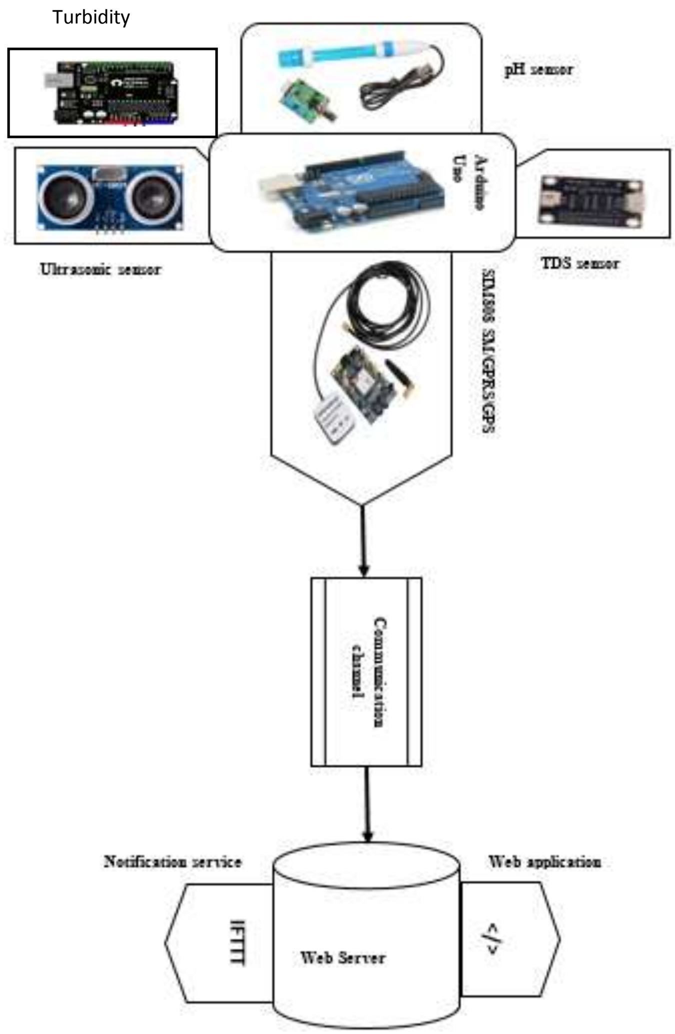



*Figure 9:System design*

### 3.3.1. The system technologies

The study consists of real-time measurement of water tank level and quality that allows people to know the status of water tank and helps in tank refilling. Such application is done through water tank monitoring and management. For that, the following technologies are used:

**(i) Data acquisition technology**

This technology provides the link between the field data being collected by sensors, their monitoring and controlling within its platform [23].

Furthermore, self-adaptive data collection is a data transmission method that aids in the maintenance of critical data in a changing process and regulates by giving data density for critical data. [24]. Data acquisition is a process that converts signal data from physical devices like ultrasonic sensors, TDS sensors, turbidity sensors, and pH sensors into a digital signal that the server can understand.

**(ii) Data communication technology**

The communication between perception layers to network layer to application layer was applied concerning data communication.  Whatever in this system, GSM is used as media for transmitting signal of data from its devices to other devices[25]. GSM is a communication protocol used for sending message, open and digital cellular technology acting by transmitting mobile data services and operates at the 850MHz, 900MHz, 1800MHz and 1900MHz frequency bands. It is module is used to make connectivity.

### 3.3.2. Hardware requirement

The prototype is built on interconnected devices that form a single platform. It is interfaced with SIM808 GSM/GPRS/GPS and the water tank is prepared within pH sensor, ultrasonic sensor, Turbidity and TDS sensor that is able to measure related data that are processed by microprocessor platform (Arduino uno) that is interfaced with ThingSpeak platform through GSM.

### 3.3.3. Software requirement

Thing Speak is an open source IoT platform service and API for storing, visualizing, analyzing, and retrieving data from things over the internet using the HTTP protocol. GSM-enabled ultrasonic, TDS, turbidity, GPS, and pH sensors provide real-time data from the water tank to ThingSpeak. ThingSpeak is an open source IoT platform and API that allows you to save, display, analyze, and retrieve data from items via the internet using the HTTP protocol.[26].

ThingSpeak then create an online visualization of automated data and help to make live analytic of data. The data are stored in ThingSpeak database and are deployed in CSV format. At the final stage, ThingSpeak analyze the real data, then in conjunction with IFTTT, the decision is taken accordingly. IFTTT as web service that allows users to interact with web services via internet.

In this thesis, the IFTTT is used when certain condition met with one service, a trigger goes off and a required or desired action occurs automatically on the other. The user created applets that are connected with ThingSpeak water tank application within database and manage conditional statements that results for email notification to the water distributer.

### 3.3.4. Conceptual system Architecture

The system architecture is depicted in Figure 9. The system is divided into three sections: sensing, data storage, and data and notification. Sensors sense data then with GSM connected to the network send data to the cloud server that stores it. Those data are processed and analyzed by ThingSpeak application platform and a decision is taken.

The data are managed in cooperation of ThingSpeak and If This Then That (IFTTT) platform. The IFTTT is an automation platform that allows tank owner and the company that has the responsibilities of filling tank to connect to water tank application modules, their services, and devices to trigger user action through applets email.

Although this thesis focuses on fine elements of the Internet of Things, five-layer structures were used. Perception layer, transport layer, processing layer, application layer, and business layer are the layers involved [27]. These five layers describe the flow of data from hardware to application as well as to the business services of the application.

In IoT application for water tank quality and level monitoring system, each layer has the function describing to their state and how the data are behaving within its corresponding tasks.

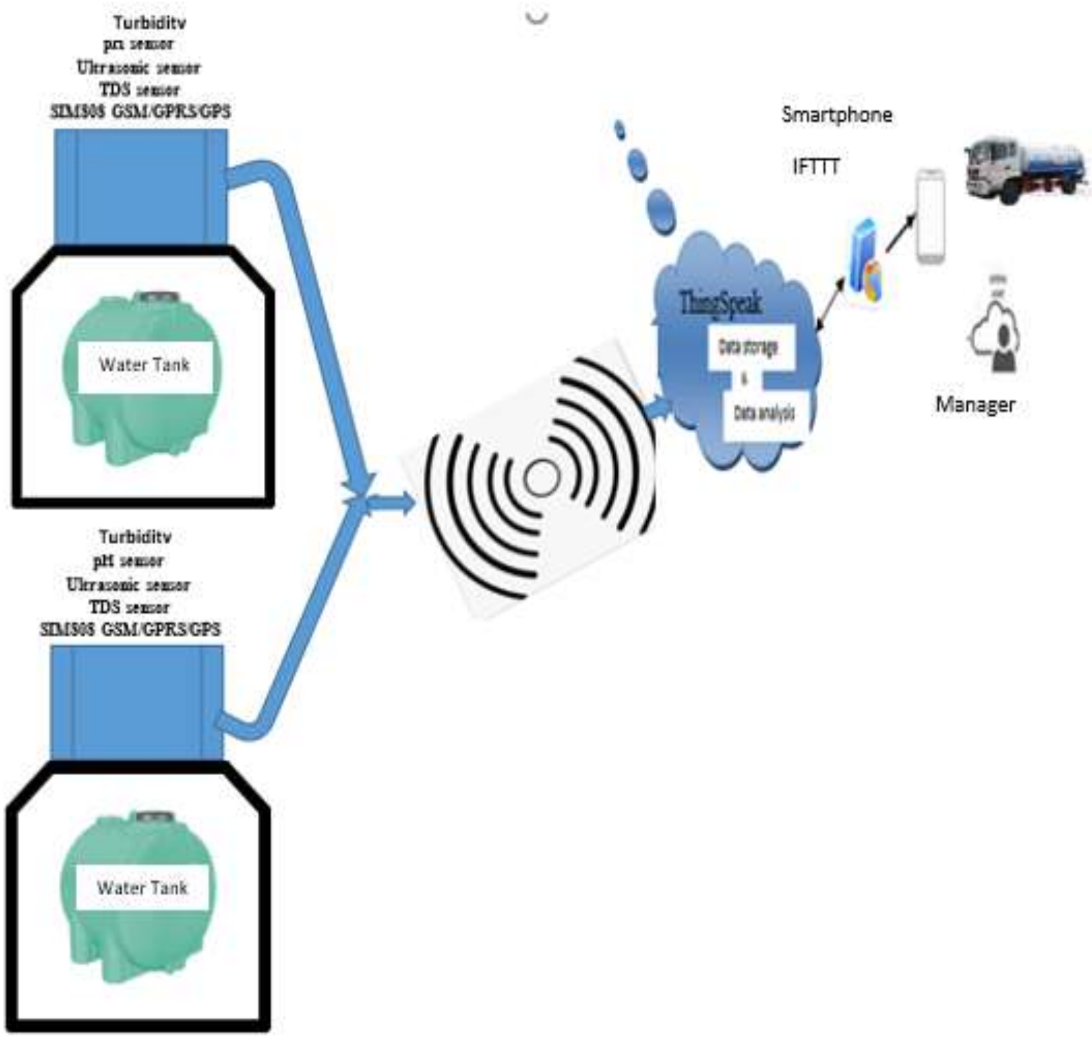



*Figure 10:IoT Water tank quality and level measurement system architecture*

(1) **The perception layer** or the physical layer has ultrasonic, TDS, Turbidity, pH, and GPS sensors for sensing corresponding data such as water level, acidity, ppm, and basicity, as well as tank position, and then sending those levels to microprocessor.

(2) **The transport layer**, using the 2G (Global System for Mobile Communication) network, sensed data is transferred from the perception layer to the processing layer.

(3) **The processing layer,** the data from the transit layer is stored, analyzed, and processed in the processing layer. The data is saved in CSV format, and it is examined before being sent on to the application layer for a decision.

(4) **The application layer** provides unique services to the owner of the water tank and the corporate executives.

Many application services have been established specifically by combining and visualizing data from various services. The Internet of Things was used in this project to create a smart water tank.

(5) **The business layer** is in charge of managing apps based on email notifications and the privacy of users.

### 3.3.5. System functionality

The system functionality shows a set of instructions to perform task starting from sensing to reporting. It describes how the system works step by step using Internet of Things regarding water tank status, quality of water and the location where tank is and also speed water refilling if found emptied. The flowchart is composed of three functions at perception layer, transport layer and processing layer. These functions are water tank level management, water quality management, and the data monitoring and communication with GSM. At application and business layers, various processing and analysis of data gathered are designed based on required activities such as data storage, data manipulation and notification depending on detected data. From the cited point above, the Figure 10 describe step by step on how the application works.

If the tank is emptied of water or if the quality of water is not good, an email notification is sent to company manager and tank holder accordingly. It indicates an algorithm in a flowchart describing how the IoT Water tank quality and level measurement in this thesis is conceptually conceived in terms of functionality as of today. The functionality does not stop; the continuation of monitoring is automated except if there are technical issues. The system functionality is embedded; integrated system is made of software and hardware.

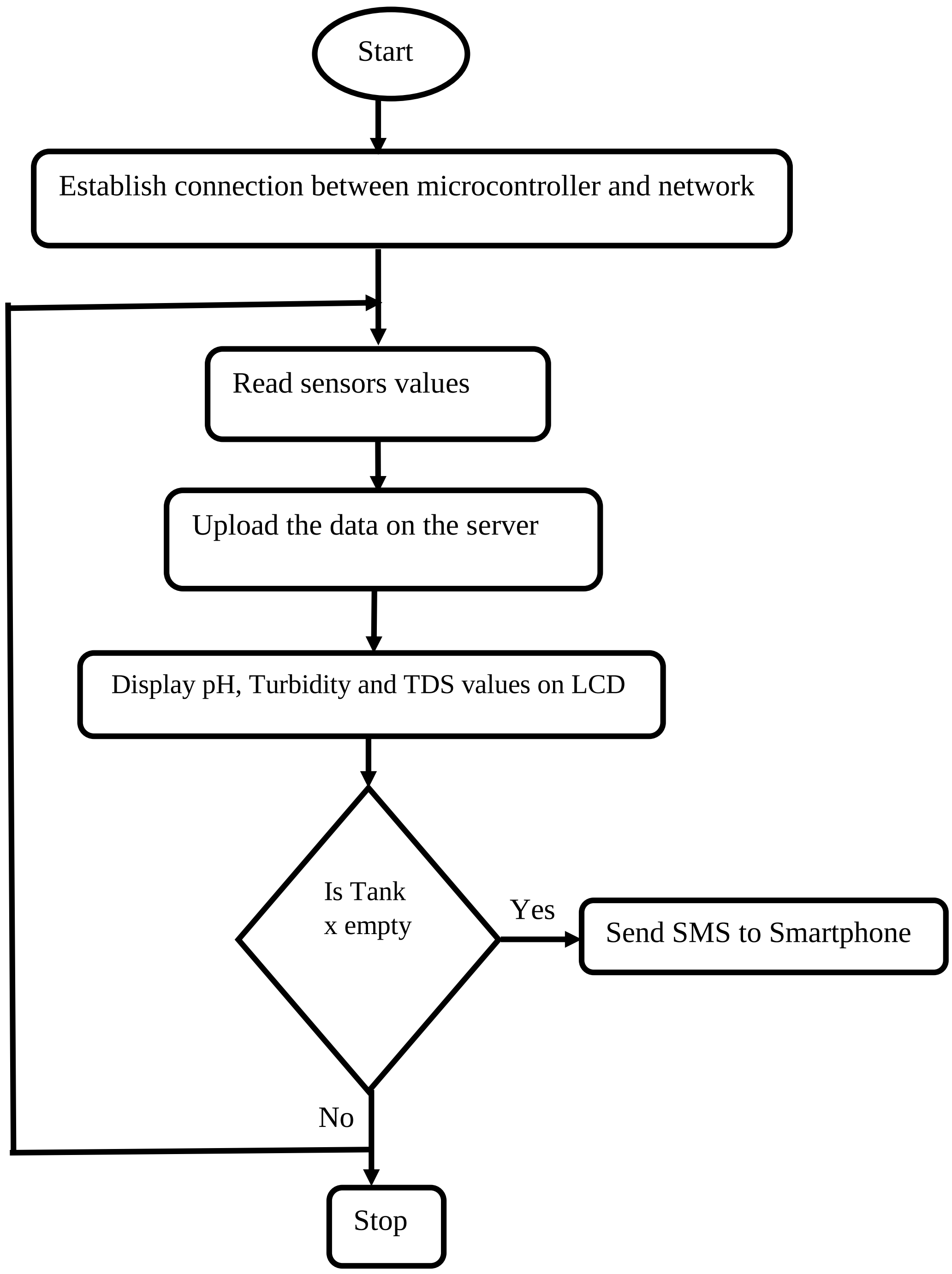



*Figure 11:IoT Water tank quality and level measurement system functionality*

# Chapter 4. IMPLEMENTATION OF THE PROTOTYPE SYSTEM AND ANALYSIS OF THE RESULTS

The system implementation and results analysis from the Water Quality measurement utilizing Internet of Things are presented in this chapter, as well as the considered limitations that were encountered during the prototype implantation and the results findings. The decision that has been made during the selection of prototype hardware, design and area for implementation. The Figure 12 show the prototype components for all system.

*Figure 12:Prototype components and hardware connectivity*

## 4.1. Design purpose and limitations

The goals of designing an IoT application for water tank quality and level monitoring system is get fresh water that make to people good health, particularly Rwanda-Kigali city and to bridge the gap by the creation of new knowledge in designing and implementing new technologies on water quality system.

A such system is not easy to be designed, since the implementation in Kigali city would be in the same context of both urban and rural part of the country. The Thesis impact on economies, reduce poverties, and technology usage. This system focus on increasing and facilitating the way the water quality, due to its functionalities and implementation, the system is feasible regarding to the economics issues in developing countries. In terms of the sensing platform element of the system, the prototype has been constructed and tested, the data has been visualized by citizens/households, and data has been transferred to the server to be processed using an Application Programming Interface (API) with the GET technique. Within the ThingSpeak platform, the data are stored and can be viewed through web interface and also can be processed to the notification about water in tank to the users depending to its responsibilities. The IFTTT application manage users of the systems and on the behalf of each user, the tank is identified by its owner and be located using GPS.

### 4.2. Application testing and results

The test of the prototype is based on two parts, the interface for data visualization and notification parts using IFTTT. The test also includes sending data to ThingSpeak web application. For each water tank, the automated system was developed using ultrasonic (HC-SR04) for measuring the level of water in tank that is visualized through application interface and the others sensors such as Turbidity, TDS, and pH measurements are utilized to assess the water quality in an associated tank and are shown on an LCD.

#### 4.2.1. Interface

The interface as indicated in figure 13 and figure 14. Firstly, it displays all about the water quality that is polluted.

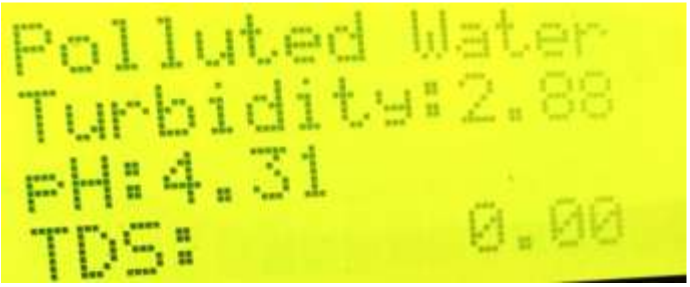



*Figure 13:Polluted water in tank*

And another interface is the visualization of water quality that are flesh data displayed on LCD as indicated by Figure 13.

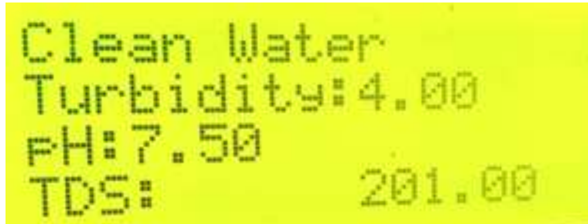



*Figure 14:Clean Water in tank*

Those decisions, are taken according to the ranges that indicate if the water is cleaned or polluted. Means that, if pH is between 6,5&8.5, Turbidity less than 5NTU and TDS is between 50&250ppm, those values indicate that the water is cleaned. Else is polluted.

### 4.2.2. ThingSpeak and IFTTT configuration

ThingSpeak has interface. It shows also the API keys used for getting data from sensing system and at last export for data display in form of CSV. ThingSpeak is an IoT platform which permit someone to visualize, analyze live data and react according to it. ThingSpeak is an open-source application

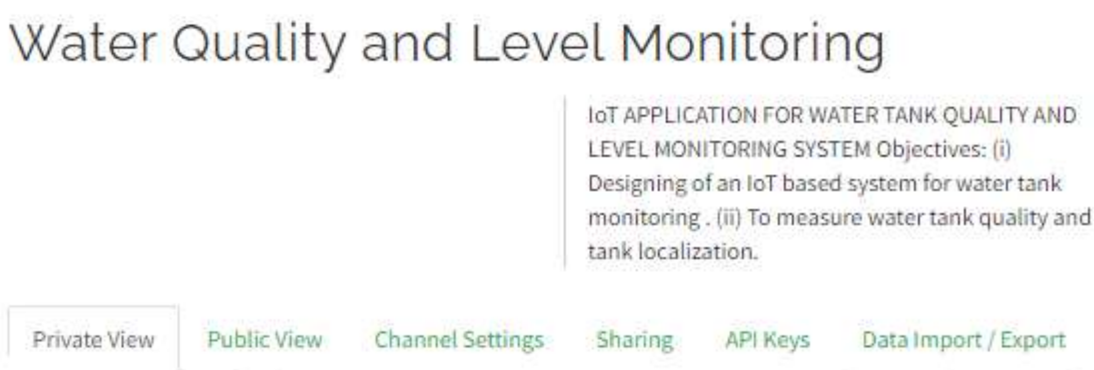



*Figure 15: IoT Water Quality and Level Measurement setting*

### 4.2.3. Results obtained through ThingSpeak Platform.

The gathered information for every source is highly appreciated. Each sensor data corresponds to its view. The four parties display the automated data gathered by sensors.

#### 4.2.3.1. WATER TANK LEVEL RESULT

Figure 16 shows how an ultrasonic sensor measures the amount of water in the tank. When the water level falls below a certain threshold, the firm manager will receive an email notification instructing him to supply water to the house owner or workplace as soon as possible. The message's content will include the name of the water tank as well as its location. The tank's length is 4 meters, and it is given in percentages as shown in figure 16. Only the distance between the water and the sensor is counted in the range of 0 to 100; if the distance exceeds 85 percent (85%), an email is sent to the management; otherwise, the water tank is regarded normal.

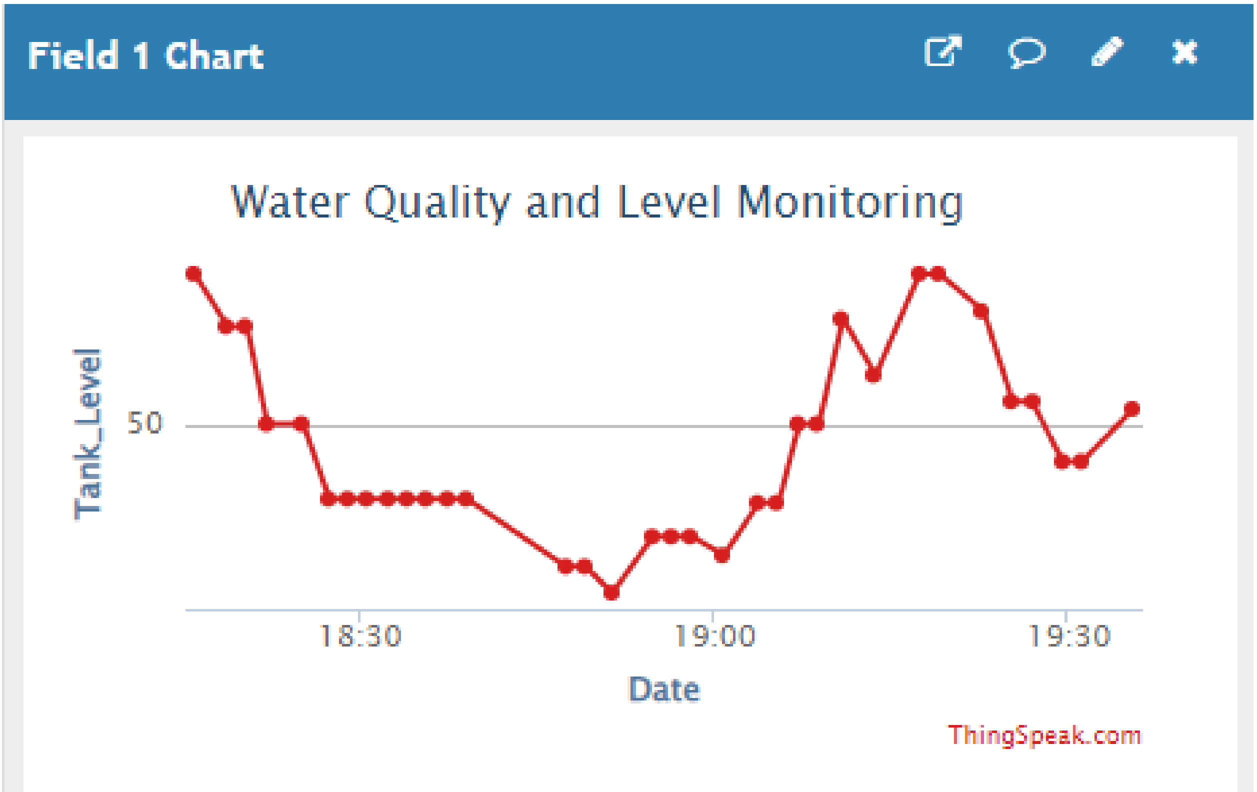



*Figure 16: Ultrasonic sensor for measuring water tank level*

#### 4.2.3.2. WATER QUALITY RESULT

The turbidity sensor measures the number of particles dissolved in water by directing a focused beam into the sample. The cloudiness or haziness of a fluid caused by huge numbers of individual particles that are often undetectable to the human eye is depicted in Figure 17 as a variety of particles dissolved inside the water tanks. When a light is shined through a water sample, turbidity is used to calculate the amount of light scattered by the substance in the water. The turbidity increases as the intensity of diffused light increases.

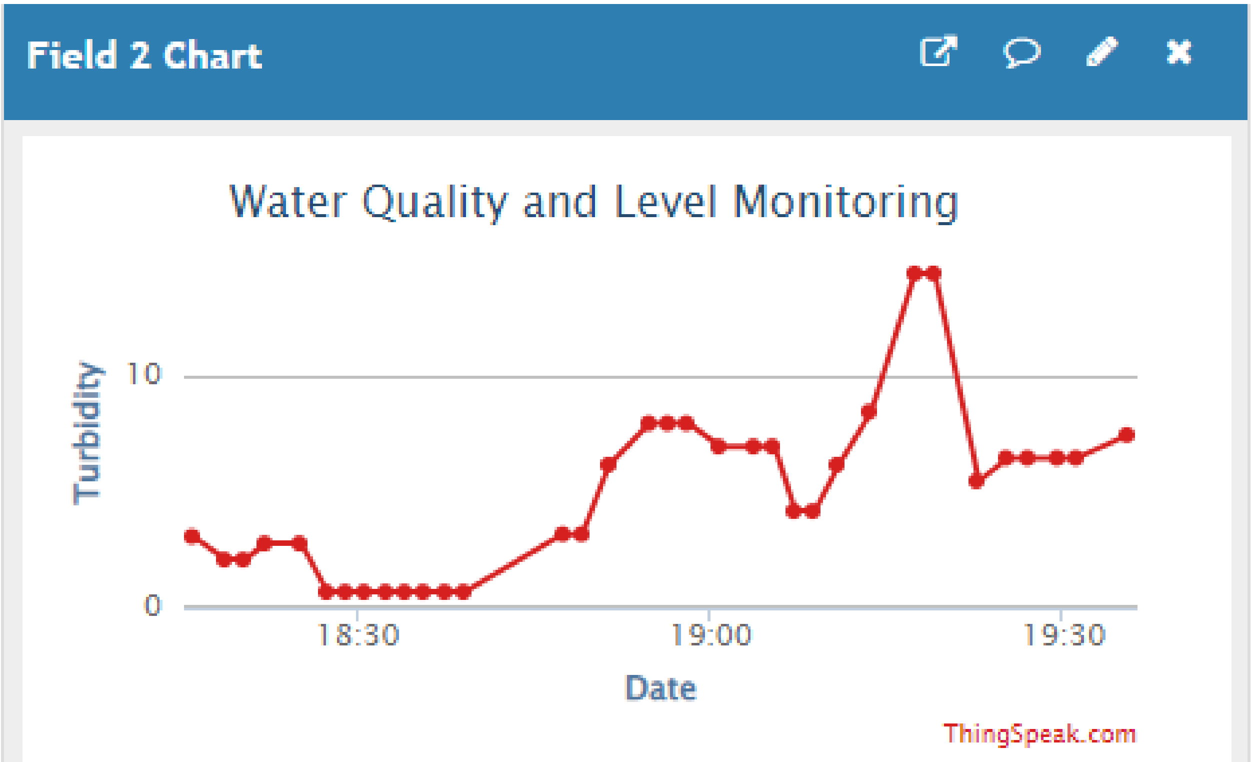



*Figure 17: Measurement of water quality using turbidity sensor*

Figure 18 shows the TDS, which is a measurement of the total dissolved content of all inorganic and organic elements in water. The more chemicals dissolved in water, the higher the TDS value. As a result, greater Total Dissolved Solids (TDS) levels can suggest that water contains more toxins that might be harmful to one's health[28]. The considered range are explained as flow:

- ✓ The water that has values less than 300 are acceptable and excellent to drinks,
- ✓ The water between 300 and 600 are good,
- ✓ The water 600 between 900 are fair
- ✓ The water between 900 and 1,200 are poor
- ✓ The water above 1,200 is unacceptable.

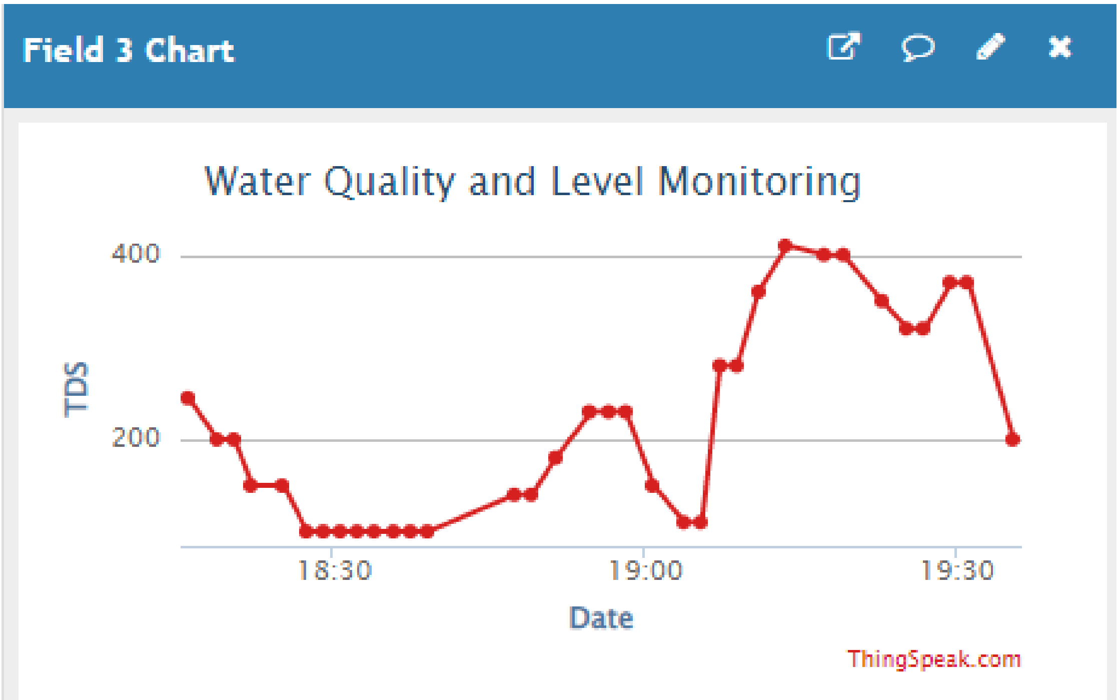



*Figure 18:Measurement of water quality using TDS sensor*

Finally, pH, which is often used for water testing, is a measure of acidity and alkalinity, or the amount of caustic and base in a solution, as shown in figure 19. A number scale ranging from 0 to 14 is commonly used to express it. Water with a pH less than 7 is considered acidic, whereas water with a pH greater than 7 is called basic. In surface water systems, pH should be between 6.5 and 8.5, and in groundwater systems, pH should be between 6 and 8.5. With rising alkalinity, the numbers on the scale rise, but with increasing acidity, the numbers fall. A tenfold change in acidity or alkalinity is represented by each unit of change. The negative logarithm of the hydrogen-ion concentration or hydrogen-ion activity is also equivalent to the pH value. Figure 19 shows how pH levels in water are displayed.

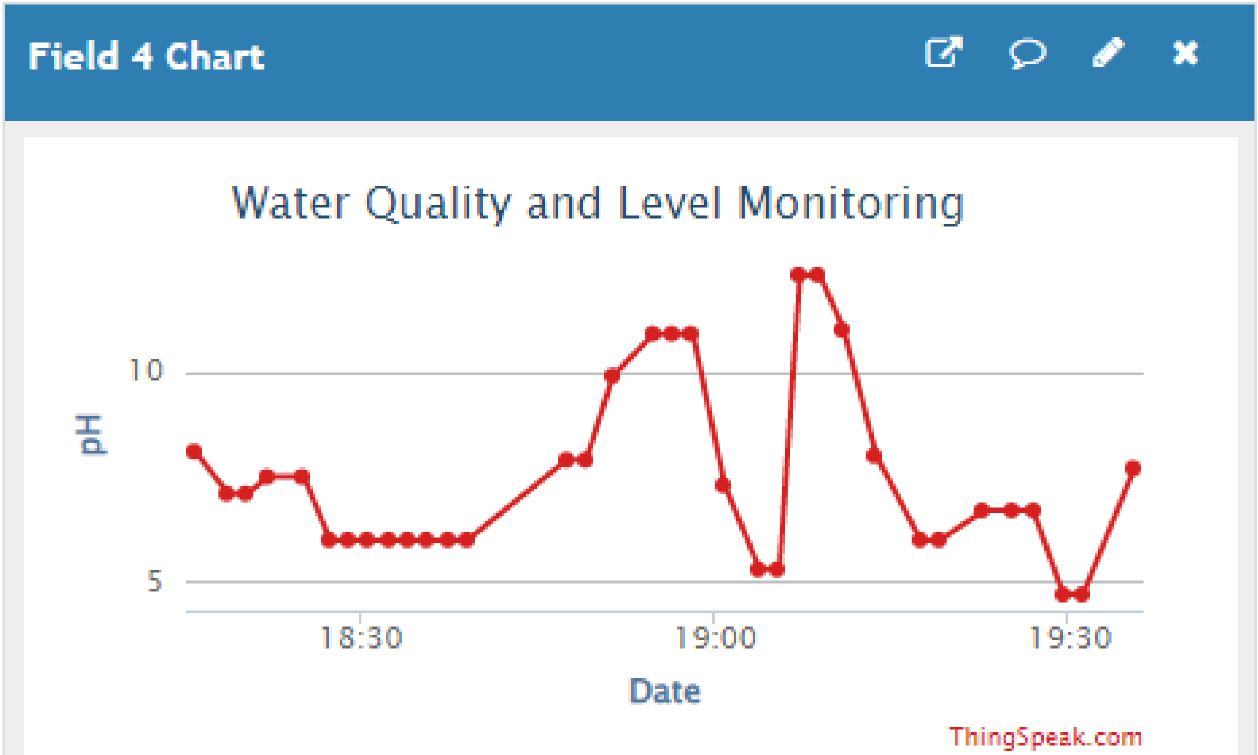



*Figure 19:Measurement of water quality using pH sensor*

As describe above, sensors like PH sensor, Turbidity and TDS are used to measure water where their results may be flesh or clean water or polluted water. All of these sensors are placed inside the water in tank.

If PH sensor contains between 6.5&8.5, Turbidity less than 5 NTU (Nephelometric Turbidity unit) and TDS (Total Dissolved Solid) between 50&250 ppm. If water contain this result means that the water is cleaned. On the other hand, the water is polluted.

The status of tank is shown based on the quantity of water in tank as indicated by figure 16. Through IFTTT in connection with Thing HTTP, the users such as water tank filling get message about the status of water

| Name | Created |
|---|---|
| Water Level in Tank<br>View Edit | 2021-11-22 |

*Figure 20:ThingHTTP for configuring email notification to users*

The automated SMS notification is sent to selected users i.e. the owner company who has responsibility of water refill and the tank owner.  Each user is controlled in IFTTT server and within the defined relationship with ThingSpeak server through ThingHTTP and React, the data are analyzed and the decision are taken depending on the level water in tank. The Figure 21 describe various activities that are carried out in React application. Those activities include:

**(1)** **Condition type**: This is designed based the types of data gathered by sensors

**(2)** **Test frequencies:** Choose whether to test the condition every time news data enter to the system. The test is made every time news entries appears.

**(3)** **Condition:** Choose channel, field and condition to be considered in React,

**(4)** **Action:** The ThingHTTP is chosen as it gets users using GET method.

**(5)** **Option:** as this system is automated, it requires to send notification each time condition is met.

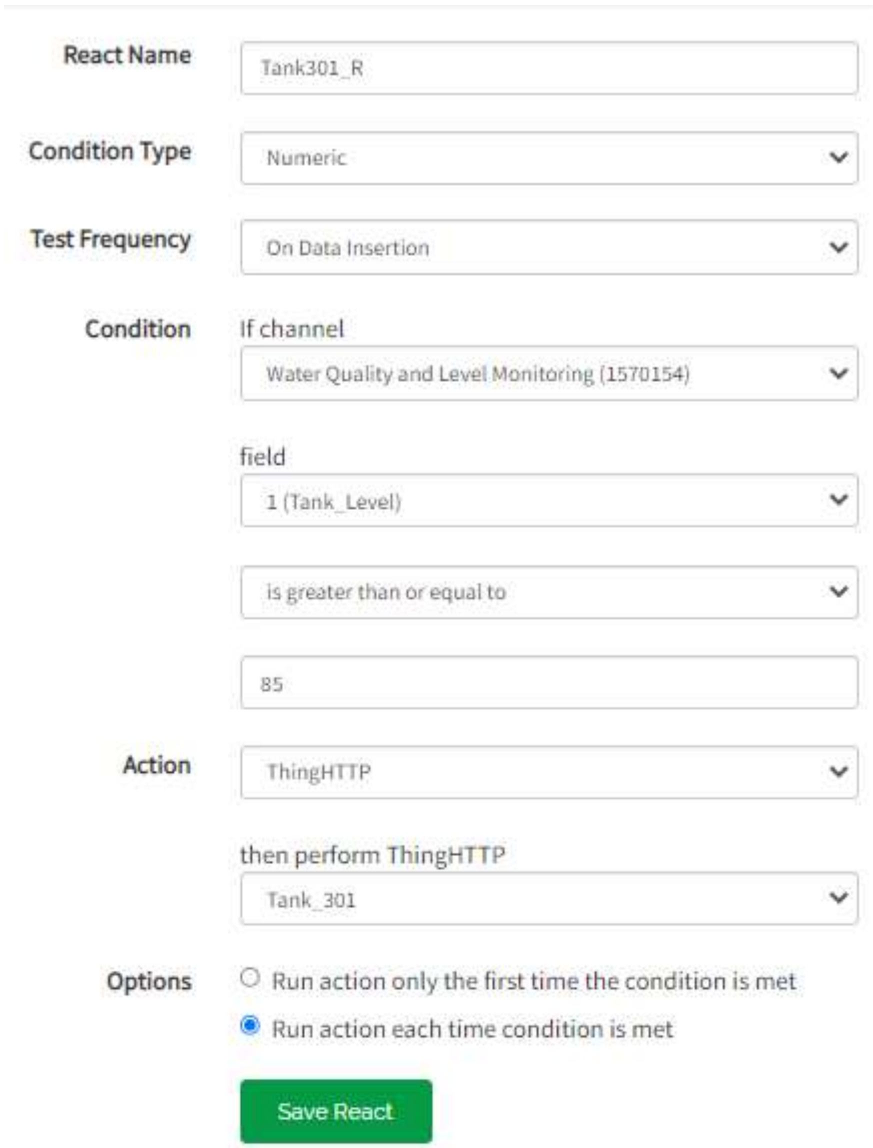



*Figure 21:Decision making through React web page from ThingSpeaks*

The notification service setup is presented in Figure 21. The description of the notification rules is included in the notification rules of React. The system user can set rules depending on its analytics and decision make relating to waste collection services for better collection and transport accordingly.

#### 4.2.3: EMAIL NOTIFICATION

The figure 22 shows the email notification from IFTTT that interact with ThinkSpeak that receive the data from the hardware parts. The email message is sent when the water tank is less or equal to 85%. This threshold values in considered to be empty tank.

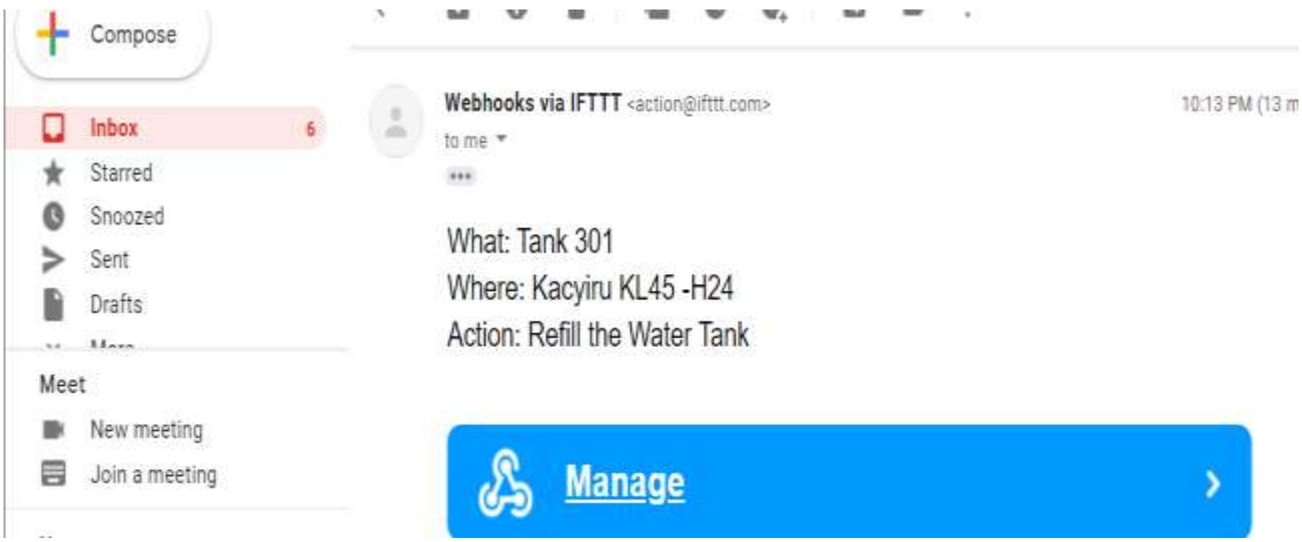



*Figure 22:Email notification for water tank level and tank location*

# CHAPTER 5. CONCLUSION AND RECOMMENDATION

The chapter includes the conclusion and recommendation that compare the existing system and work done, and also focus on conclusion of the project along with work with the scope

## 5.1. CONCLUSION

Issues related to water quality measurement is done only by WASAC, once there no water from the cited sources, the problems arise in household, where the alternative / refilling of tank is difficult to be applied, and the water filled must be measured for identifying if they are flesh or not. Research based on technologies describe how people can get water from different companies and be able to measure if this water coming from these companies are safe and cleaned to be drunk by human being, Regarding the use of technologies, IoT technology was used in this thesis to find out the solution. The system prototype was tested and the expected results are good enough. The prototype would be the way to flow for making a real time system for having flesh water all time for all people in Kigali city. The application system will help to the citizens to have flesh water in their home or office. Based on the status of regarding level of water in tank, the prototype sends notification message to the company's distributor of water notifying them which tank to be refilled and the location of tank. This is accomplished through Internet of Things (IoT) technology, which helps to monitor water tanks and refill them as needed, thereby improving the well-being of Kigali residents and achieving sustainable development goals such as good health and well-being, clean water and sanitation, and sustainable cities and communities.

## 5.2. RECOMMENDATION

Due to time, I would not implement this system in the real context but I come up with a prototype and I recommended

- ✓ Other research to continue with the implementation of the system in real-context.
- ✓ The future research to design algorithm that make a decision for notification based on data prediction not an automatic data.
- ✓ To make a prototype other research may use artificial intelligent for data analysis and decision making

### 5.3. Feature work

The developed prototype has some limitation; therefore, some tasks should be added in the future. For instance, system functionalities like hardware security against theft, measurement of water temperature and design embed system for better protected hardware and incorporate easily with tank.

**REFERENCES:**

[1] S. I. Yannopoulos *et al.*, "Evolution of water lifting devices (Pumps) over the centuries worldwide," *Water (Switzerland),* vol. 7, no. 9, pp. 5031–5060, 2015.

[2] J. G. Natividad and T. D. Palaoag, "IoT based model for monitoring and controlling water distribution," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 482, no. 1, 2019.

[3]George, Grinson, et al. "Citizen scientists contribute to real-time monitoring of lake water quality using 3D printed mini Secchi disks." (2021).

[4] Siddula, Sai Sreekar, Phaneendra Babu, and P. C. Jain. "Water level monitoring and management of dams using IoT." *2018 3rd International Conference On Internet of Things: Smart Innovation and Usages (IoT-SIU)*. IEEE, 2018.

[5] Choumert-Nkolo, Johanna, Jesper Stage, and Claudine Uwera. *Access to water as a determinant of rental values: A hedonic analysis in Rwanda*. HAL, 2015.

[6]Pande, Aanchal M., Krishna K. Warhade, and Rajkumar D. Komati. "Water quality monitoring system for water tanks of housing society." *Int. J. Electron. Eng. Res* 9.7 (2017): 1071-1078.

[7]Lambrou, Theofanis P., et al. "A low-cost sensor network for real-time monitoring and contamination detection in drinking water distribution systems." *IEEE sensors journal* 14.8 (2014): 2765-2772.

[8]Pasika, Sathish, and Sai Teja Gandla. "Smart water quality monitoring system with cost-effective using IoT." *Heliyon* 6.7 (2020): e04096.

[9]Geetha, S., and S. J. S. W. Gouthami. "Internet of things enabled real time water quality monitoring system." *Smart Water* 2.1 (2016): 1-19.

[10]Myint, Cho Zin, Lenin Gopal, and Yan Lin Aung. "Reconfigurable smart water quality monitoring system in IoT environment." *2017 IEEE/ACIS 16th international conference on computer and information science (ICIS)*. IEEE, 2017.

[11]Radhakrishnan, Varsha, and Wenyan Wu. "IoT technology for smart water system." *2018 IEEE 20th International Conference on High Performance Computing and Communications; IEEE 16th International Conference on Smart City; IEEE 4th International Conference on Data Science and Systems (HPCC/SmartCity/DSS)*. IEEE, 2018.

[12]Chowdury, Mohammad Salah Uddin, et al. "IoT based real-time river water quality monitoring system." *Procedia Computer Science* 155 (2019): 161-168.

[13]Zeng, Jun, Minbo Li, and Yuanfeng Cai. "A tracking system supporting large-scale users based on GPS and G-sensor." *International Journal of Distributed Sensor Networks* 11.5 (2015): 862184.

[14]https://www.freshwatersystems.com/blogs/blog/what-is-tds-in-water-why-should-you-measure-it [Accessed on 30/07/2021]

[15]Priya, S. Kavi, G. Shenbagalakshmi, and T. Revathi. "Design of smart sensors for real time drinking water quality monitoring and contamination detection in water distributed mains." *International Journal of Engineering & Technology* 7.1.1 (2018): 47-51.

[16]MUKAMANA, Florentine. *IoT Flood Monitoring System in Rwanda*. Diss. College of Science and Technology, 2021.

[17]Mohammed, Saleem Latteef, et al. "Highly accurate water level measurement system using a microcontroller and an ultrasonic sensor." *IOP Conference Series: Materials Science and Engineering*. Vol. 518. No. 4. IOP Publishing, 2019.

[18]Latha, N. Anju, B. Rama Murthy, and K. Bharat Kumar. "Distance sensing with ultrasonic sensor and Arduino." *International Journal of Advance Research, Ideas and Innovations in Technology* 2.5 (2016): 1-5.

[19]Channe, Ms Pranjali P., Ms Rasika M. Butlekar, and D. B. Pohare. "IOT Based Garbage Monitoring and Sorting System." *Research Journal* 5.01 (2018).

[20]World Health Organization. "Water quality and health-review of turbidity: information for regulators and water suppliers." (2017).

[21]Bilro, L., et al. "Turbidity sensor for determination of concentration, ash presence and particle diameter of sediment suspensions." *21st International Conference on Optical Fiber Sensors*. Vol. 7753. International Society for Optics and Photonics, 2011.

[22]Benbasat, Izak, David K. Goldstein, and Melissa Mead. "The case research strategy in studies of information systems." MIS quarterly (1987): 369-386.

[23]Tseng, Chwan-Lu, et al. "Feasibility study on application of GSM–SMS technology to field data acquisition." Computers and Electronics in Agriculture 53.1 (2006): 45-59.

[24]Zhu, Xing, et al. "A self-adaptive data acquisition technique and its application in landslide monitoring." *Workshop on World Landslide Forum*. Springer, Cham, 2017.

[25]Prabha, C., R. Sunitha, and R. Anitha. "Automatic vehicle accident detection and messaging system using GSM and GPS modem." *International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering* 3.7 (2014): 10723-10727.

[26]Maureira, Marcello A. Gómez, Daan Oldenhof, and Livia Teernstra. "ThingSpeak–an API and Web Service for the Internet of Things." *World Wide Web* (2011).

[27]Sethi, Pallavi, and Smruti R. Sarangi. "Internet of things: architectures, protocols, and applications." *Journal of Electrical and Computer Engineering* 2017 (2017).

[28]SYAHPUTRA, WENDY HARIS, and Zaenal Husin. *RANCANG BANGUN SENSOR TDS PADA FILTER AIR BERBASIS ATMEGA328*. Diss. Sriwijaya University, 2020.

[29] Rubogora, F. "Persistent water shortage in Kigali city: who are the most affected?" *Arts Soc. Sci. J* 8.02 (2017): 8-11.

[30]Rajashekar, Anirudh, Marion Richard, and Dimitri Stoelinga. "Economic Geography of Rwanda." Laterite study, International Growth Centre, Kigali. Retrieved from https://www. theigc. org/project/economic-geography-of-rwanda (2019).