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Development of an internet of things based customer water-meter reading system at Arusha city

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DEVELOPMENT OF AN INTERNET OF THINGS BASED CUSTOMER WATER-METER READING SYSTEM AT ARUSHA CITY

Zuhura Hambo Msisi

Project Report Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science in Embedded and Mobile Systems of the Nelson Mandela African Institution of Science and Technology

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ABSTRACT

Water management is a fundamental factor that helps to make sure that water is available and well utilized. Meter reading process is required by Arusha Urban Water Supply and Sanitation Authority (AUWSA) so as to be able to bill the clients according to their water usage. Currently, the process of meter reading is manual which require at the end of each month, meter reading officials from AUWSA have to read all the meters in Arusha, the process which cost AUWSA time and financial resources. The objective of this project was therefore, to develop an IoT based customer water meter system where meter readings can be automated and the readings sent to the cloud. The AUWSA then receives the readings on a weekly basis and can continue with reading verification and billing. The Method used on the development of this system is a Dynamic System Development Method (DSDM) which is one of the methods in Agile methodology. The system is recommended to solve the existing challenges of reading of water meters and improve customer satisfaction in water service and management. Preliminary results of the prototype testing indicate that the system would send readings data to the server as well as the nodes receiving the instructions from the server. The developed prototype would also send weekly messages to customers about their weekly usage. This communication allows any billing issues to be resolved timely. Also, the system would highlight the readings which are doubtful for example zero readings for easily notification and verification.

DECLARATION

I, Zuhura Hambo Msisi do declare to the Senate of Nelson Mandela Africa Institution of Science and Technology that this dissertation is my own original work and that it has neither been submitted nor being concurrently submitted for degree award in any other institution.
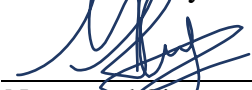
Zuhura Hambo Msisi

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Name and Signature of Candidate   Date

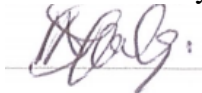The Above declaration is confirmed by:

Dr. Mussa Ally

_____
Name and Signature of Supervisor 1   13th July 2022   Date

Dr. Devotha Nyambo

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Name and Signature of Supervisor 2   July 14, 2022   Date

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CERTIFICATION

The undersigned certify that have read and hereby recommend for acceptance by the Senate of the Nelson Mandela African Institution of Science and Technology, the dissertation titled "*Development of an IoT System for Improved Customer Water-meter reading System at Arusha City*" in partial fulfillment of the requirements for the award of the Master's degree in Embedded and Mobile Systems of the Nelson Mandela African Institution of Science and Technology.

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DEDICATION

I dedicate this project to the memory of my beloved father Mr. Hambo Msisi for his support and inspiration. I also dedicate this work to my family for their sincere love and support during my study.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ABBREVIATIONS AND SYMBOLS

AMR   Automatic Meter Reading

AUWSA   Arusha Urban Water Supply and Sanitation Authority

BLE   Bluetooth Low Energy

CRBM   Customer Relations and Billing Management

D2D   Device to Device

DSDM   Dynamic System Development Method

EWURA   Energy and Water Utilities Regulatory Authority

GPRS   General Packet Radio Services

GSM   Global System for Mobile Communications

IoT   Internet of Things

Km   Kilometers

LAN   Local Area Network

LoRa   Long Range

M2M   Machine to Machine

MCU   Microcontroller Unit

NFC   Near Field Communication

RFID   Radio Frequency Identification

WAN   Wide Area Network

Wi-Fi   Wireless Network

WiMAX   Worldwide Interoperability for Microwave Access

WSN   Wireless Sensor Network

CHAPTER ONE

INTRODUCTION

1.1   Background of the Problem

Water is one of the most crusial and invaluable compounds for living things and has a vital function in the human body, without water life cannot sustain itself and may lead to the spread of diseases (Westall & Brack, 2018). Despite its importance, water has grown limited as a result of population expansion, economic development, and other issues (Liu *et al.,* 2017) and It is projected that 80 percent of the world's population is at risk of water scarcity or biodiversity loss due to water (Bakker, 2012).

In Africa, only a few countries have produces information on water availability. Many African countries lack the basic information required to determine water availability. Falkenmark (1990) examined a theoretical relationship between the availability of water and population size, hence concluding that there is water scarcity in Africa. All of this makes the management of a domestic water supply a fundamental factor (Howard *et al.,* 2003).

Different countries have different authorities that manage water resources, however, most of the East African countries still use manual water-meter reading systems which require a lot of resources including labor, it is low in efficiency, often inaccurate, and very inconvenient (Zhang & Liu, 2010). With technological development, designing and developing a low-cost and highly efficient system that will automate hence simplify the water-meter reading system are conceivable, in fact with a high level of technological development such as that of developed countries, the implementation of such a system becomes possible.

In Tanzania, The Energy and Water Utilities Regulatory Authority (EWURA) is a regulatory authority responsible for technical and economic regulation for energies and water sectors. Under EWURA, there is a total of 26 regional water supply and sanitation authorities, one of them being the Arusha Urban Water Supply and Sanitation Authority (AUWSA).

Arusha Urban Water Supply and Sanitation Authority is an Authority whose main function is to supply water and sewage disposal to Arusha City in Tanzania. Arusha Urban Water Supply and Sanitation Authority's main responsibilities include continuously planning, developing and maintaining the provision of safe, portable and wholesome water in the Arusha Municipality while

conserving water sources for long-term sustainability, and setting realistic water tariffs to collect revenue from consumers for water consumed and waste water generated.

Arusha Urban Water Supply and Sanitation Authority currently has two kinds of meters for billing consumers' clean water supplied, which are either pre-paid or post-paid meters. The pre-paid meters are the most preferred ones by the authority, however currently most of the meters are post-paid meters. Post-paid meters have been used by the authority for the longest time as compared to pre-paid meters, this is because their purchase cost, as well as operation cost, is low compared to pre-paid meters. The process of a postpaid meter has some disadvantages including the process itself of reading meters is long, resource costly and also customers have raised concerns about the monthly charges not correlating with the consumption.

The main aim of this project was to automate the process of the post-paid meters, where its main activities were to design and develop a prototype based on Wireless Sensor Networks and IoT technology (explained in detail in Subsections 1.1.1 and 1.1.2). The idea was to have a network of meters that communicate with multiple coordinator points, the coordinators will be able to transmit aggregated meter data directly to the cloud (an online server that will store data). The AUWSA could access the information and if necessary, continue with the verification process hence the billing procedure.

1.1.1   Internet of Things

Internet of Things can simply be described as physical objects that can interact with the environment as well as other devices and/or system(s) over the internet (Guinard *et al.,* 2010). Computers were connected to the internet to create a network of computers, but now physical objects are no longer disconnected from the internet, they can be given abilities to connect to the internet and exchange information by the use of sensors, software and other technologies (Sachs *et al.,* 2010). People have limited time and talents such as limited attention, precision and memory, therefore they are not very good at acquiring data from the real world, which is where the Internet of Things comes in handy (Ashton, 2009). According to Porter and Heppelmann (2014), these IoT devices have three main elements, a physical component which contains a mechanical part of the device, smart component which comprises devices that makes physical components smart for example sensors, actuators, and system, and connectivity which comprise devices and protocols that enables wired and wireless communications. This project is IoT-based because it covers all the three elements that make up an IoT device. It contains the mechanical part which contains the

external part of devices that makes up an Automatic Meter Reading (AMR), this includes the pipes and the insulation covers. The "smart" part is covered by the devices like Microcontroller Units (MCUs), water flow sensors, and the cloud where analysis will take place. The communication part is covered by LoRa modules and internet, where all these makes the project an IoT based.

1.1.2 Wireless Sensor Network

Wireless Sensor Network (WSN) has been a very powerful tool for different monitoring systems and research activities which results in the availability of many detailed data sets that record different environmental or surrounding factors (Xu *et al.,* 2004). It is a more preferred technology due to its favorable properties which are low cost, low power, small in size with multifunctional sensors networked, and communicating in short and long-range distances (Mao *et al.,* 2007).

The WSN is a critical component of an IoT since it comprises of a collection of sensor nodes connected across wireless channels and capable of providing digital interfaces to the actual world. However, many studies classify WSN applications as IoT applications, ignoring the novel characteristics that define this sector.

The WSN can be used for many applications (Hussian *et al.,* 2013) for example military (Hussain & kyung, 2009), agriculture (Kassim & Harun, 2016), health (Castillejo *et al.,* 2013), environmental (Navarro *et al.,* 2013) and homes (Huiyong *et al.,* 2013). The structure of WSN is simply a networked embedded system (Hac, 2003). A wireless sensor network (WSN) is made up of sensing and computing units, communication devices (usually radio transceivers), and a power source. It also contains a sink node or base station which acts as a gateway between the network of sensors and users. The majority of data is analyzed in the cloud, and users can view the results of the analysis (Matin & Islam, 2012). Sometimes the system can be embedded with an actuating devices which an actuating devices which will react to a certain situation depending on the analysis (Ndiaye *et al.,* 2017). This project will also make the use of WSN knowledge as per Geeks-for-Geeks (2021). Proposed a diagram that better described an overview structure of the Wireless Sensor Network as shown in Fig. 1.
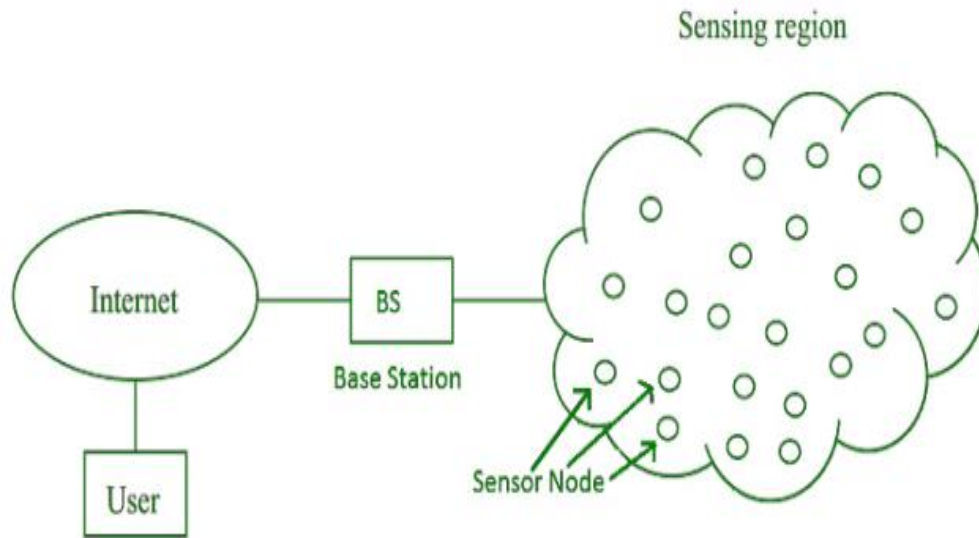
Figure 1: The architecture of WSN

1.2 Statement of the Problem

In the recent past, IoT and WSN technologies have been used to develop automatic meter readings. Howevere, the transfer of data (readings) from the nodes to the cloud, as well as instructions from the cloud back to the node, has proven to be a significant difficulty. In addition, IoT is constrained by the storage restrictions, privacy and security, as well as power consumption (Haroon *et al.,* 2016). As such, despite that the WSN technology takes the advantage of creating a network of sensors, providing an effective way of monitoring critical systems, the communication of WSN is limited with power consumption. This concern requires that any development in the area considers a system that will consume small amounts of power (Nagpurkar & Jaiswal, 2015).

Integrating WSN and IoT would provide a solution for the data transfer from the nodes to the cloud. Instead of direct connection of the node to the cloud which would have been done over WiFi resulting into a massive power consumption, the sensor nodes can be connected with the coordinator over LoRa module and then the connection between the coordinator and cloud will be done over WiFi technology. The LoRa technology uses small amount of power as compared to WiFi technology, therefore, this project proposed a prototype that would reduce amount of power needed for data transmission.

The proposed technology is expected to have a network of meters that transmits their data to nearby coordinator points (gateway). To avoid late reporting of the occurrence of the problems which were previously discovered by the meter's readers (who were vising meters on monthly

4

basis), proposed meters will be uploading data weekly so that if there is any problem it can be determined early and deal with effectively.

1.3 Rationale of the Project

Clean water and sanitation are addressed in United Nations Sustainable Development Goal 6 to ensure their availability and sustainable management for all. The United Nations (UN) report of 2021 (United Nations [UN], 2021) shows that in the world, 2 billion people lack access to safe drinking water and 2.3 billion people lack basic sanitation (UN, 2021) hence management of water supply is significant.

According to the Tanzania National Five-Year Development Plan (2020/21 – 2025/26) released by the Ministry of Finance and Planning, non-revenue water (NRW) for regional centers is thirty percent (30%) (Ministry of Finance and Planning [MOF], 2021). This number is a big loss for government revenue as well as threatens the sustainability of water supply and sanitation authorities including AUWSA. Non-revenue water can be caused by several reasons including: (a) Water theft due to tempering of the meter; (b) Zero reading of meters due to the miss-function of those meters which will be detected on the monthly basis when the meter reader visits the meter for reading; (c) Delay on solving malfunction of the meter problems, and (d) Can be leakage of water especially before water passes on the meter.

The Energy and Water Utilities Regulatory Authority (EWURA) addressed the public during the Sabasaba trade fair of 2021, that one of the challenges facing the water sector is the concerns raised by clients about the monthly charges that do not correlate with the consumptions made (The Citizen, 2021). The EWURA directed the water Authorities country-wide to ensure that water meters are read in a participatory manner to avoid complaints related to water bills.

Despite that at AUWSA, the post-paid meters have been the most used meters with the Authority and the reliable way of a water-provision system, however, the process of reading these post-paid meters to the billing stage can be more automated and simplified. The process requires monthly for a person to go to the sites (homes where meters are installed), download customer's information and store it locally on the smartphone, read the meters and input the data and then upload the information back to the cloud. From the cloud, the AUWSA head office can access the data, go through a verification process and continue with the next process of billing to the point where customers can pay their bills. This procedure has some of the following drawbacks which make the process very long hence needs improvements:

(i)   The monthly cost for people to read all meters at a site includes wages, smartphone costs, internet connections as well as wastage of time, for one person going through over 900 meters each month.

(ii)   If the network is down, one cannot download nor upload the readings hence the whole exercise of reading will not be done till the network is restored.

(iii)   After a year or two, there is a need of changing the phones due to their decline in performance, sometimes the phones come by default hence changing them may be needed even before a year.

(iv)   Some readers are distrustful of reading the meters; hence they are robbing the government of revenue thus causing a decline in the revenue of the Authority and the Government as a whole.

(v)   The procedure of reading meters to the payment is long, takes 15 to 20 days for reading and the circle repeats itself each month.

The current water billing system in water supply authorities, Arusha city as well as other cities in Tanzania needs more improvements in supplying and customer care, the system depends on manual reading or recording of the number of units used by a particular household. Then, the total cost concerning the amount used is calculated usually in the office in absence of customers. This has raised concerns and complaints from customers. Furthermore, the amount calculated or estimated is sometimes too high or too low compared to the amount of water used. Thus, there is a need to revise the current system for customer water-meter reading system to enable it to be automated to record the amount of water used and calculate the instant cost required to be paid by customers. The current customer water-meter reading system will be more efficient, and the running costs will be lower. This project aimed to develop a customer water-meter reading system that is reliable and trustworthy to suppliers and water users.

1.4   Project Objectives

1.4.1   General Objective

The main objective of this project is to develop an IoT-based system for customer water-meter reading system in Arusha City.

1.4.2 Specific objectives

(i)   To collect Data and requirement gathering for developing an improved customer water-meter reading system.

(ii)   To design and build a prototype of the customer water meter system.

(iii)   To test the developed prototype.

1.5   Project Questions

(i)   What are the requirements for developing an improved customer water-meter reading system.

(ii)   What and how prototype of the customer water meter system can be designed?

(iii)   Is the developed prototype work as expected?

1.6   Significance of the Project

1.6.1   Technical Significance

The developed prototype allowed meters to update the readings automatically and hence send the readings to the server by the use of Wireless Sensor Network knowledge, which is expected to reduce the monthly cost that authorities face to get monthly readings. Despite that some studies have been conducted regarding using the same Wireless Sensor Network knowledge, this prototype was also designed in such a way that it can reduce the amount of non-revenue water. This is possible since the authorities can either open or close the water valve allowing water to flow, or not to flow in case there is a problem with the meter (or the readings) while they are in their office and make a necessary follow-up later before opening the valve allowing water to flow normally. This research adds to the body of knowledge around the water meter automation process.

1.6.2   Industry Significance

(i)   Through this study, the authority will have insight into the solution to be deployed to improve the whole process of meter reading. Whether the system will work or not, the AUWSA would have a focus area for the solution to be deployed or what can't work while finding a better solution.

(ii)   Through this study, the authority will have increased water revenue collection. If the project will be successful, the Authority will increase the amount of revenue collected due to the cut down costs like monthly wages for the workers who on monthly basis have to read the meters, smartphone costs as well as distrustful of the readers connecting water illegally.

(iii)   The study will give the Authority better utilization of the resources for example finance, human resources, and time as well as better management of the growth of the population who are the consumers of water resources.

(iv)   The study will improve the performance of AUWSA and manage to make more profit, thus providing a chance for adoption by other Authorities such as DAWASA and RUWASA hence making better revenue collection for the government in general.

(v)   Lastly, the study of this project if successful will solve the EWURA's concerns that were raised by the customer about high-water bills. The system will be uploading data on the weekly basis hence if there is any problem will be determined early and dealt with effectively.

1.7   Delineation of the Study

This study was designed and carried out to cover the following; meter reading process, data storage, and processing, and customer involvement in the amount of water usage by sending the notification on their mobile phones on weekly basis. Furthermore, the project developed a system to notify any abnormalities in readings for early and close follow-ups for example extreme readings and zero readings will be noted in the system. On other hand, the following aspects were considered out of scope in this project; instant cost calculation for the amount of water used, resetting the meter reading to zero when the bill is cleared and no pre-paid meter was developed in the study. In addition, in this project, no payment tracking system and customer ranking systems such as good, medium, and payers customers using a traffic light system that involves three colors i.e. green (good customer with fewer depts), amber (medium customer with medium depts) and red (bad customers with higher depts) were developed. However, these features are important for system improvement thus they are recommended for future projects.

CHAPTER TWO

LITERATURE REVIEW

2.1   Automatic Meter (Water) Reading

Automatic meter reading technologies cut down the cost of a person to read the meter after a certain period for example monthly or weekly as well as solve problems associated with conventional meters like inaccessibility. Automatic Meter Reading (AMR) consists of three main parts that are Meter interface, communication systems, and central office systems (including cloud) (Tamarkin, 1992). The following are different studies conducted on the design, development, implementation as well as feedback of AMR.

Zhang and Liu (2010) developed a design schema for a wireless smart water meter reading system, with the goal of making data collecting from water meters to processing centers as simple as possible. The system used Zigbee technology for communication among water meters and General Packet Radio Service (GPRS) technology for communication between data concentrators and data processing centers.

Moreover, according to Mudumbe and Abu-Mahfouz (2015), Wireless Sensor Networks (WSN) were used to construct a water management system that gives users with real-time data on water consumption. Despite that the system had a short range for communication, the system allowed users to modify the source code to suit their own needs or those of the service provider and it can also be modified for leakage detection and localization. The system creates various visual aids for example graphs of the collected data, after analyzing collected data and representing them in a manner that customers could understand. All in all the system helps users manage their water usage as the system helps too, on top of it users can identify and fix abnormal water consumption.

Additionally, Fikejz and Roleček (2018) proposed a smart water meter for water monitoring and accidental water leakage detection. They used a pulse water meter to provide the amount of water flow, a two-way ball valve for controlling the opening and closing of the water flow, a central control unit that contained a Raspberry Pi, and a backup battery for standby supply of power in case of a power outage, where their measurement of consumption was measured in form of pulses and the calculated cumulative sum was stored in cloud database then transmitted to the server whenever the connection was available.

Based on LoRa technology, Li *et al.* (2017) proposed an intelligent water meter reading system using an intelligent water meter with capabilities of valve control, flow measurement, and data remote. The system also has a multi-level relay concentrator, which used LoRa as a wireless communication protocol for downlink and a GPRS channel for uplink communication. The structure of the whole network for meter reading had three nodes that are meter node, the repeater, and the concentrator.

Likewise, Suresh *et al.* (2017) developed a water meter reading for updating consumption information from the field to the utility office and it permitted both the authority and customers who are the consumers to use smartphones for reading and update billing and payment. They used Customer Relations and Billing Management (CRBM) for billing and utilization of consumption. Smart meter constructed from analog water-meter and converted into digital/ smart water-meter, captured the consumptions, register tamper and unique id of the meter. The electronics module contained a water-meter register, sensors, batteries, CPU and memory, moreover, the communication was done over Wi-Fi or Bluetooth.

On the use of the radio frequencies, Farah and Shahrour (2017) presented a paper that provided feedback about the usage of the automatic meter reading system for leakage detection in a live demonstrator, a case study that was conducted at the University of Lille campus. The study involved 15 km of grey cast iron pipes over 60 years old which also contributed to the loss of water. The study used radio frequency as a communication medium which also resulted in the high loss of signal transmission hence loss of data.

Gosavi *et al.* (2017) presented a paper that proposed a method to watch and forecast the consumption of water in a domestic pipeline through a webserver. They used the Internet for communication which requires high power to operate, not as low as other communication technologies used on IoT (Al-Sarawi *et al.,* 2017). The study also made the use of machine learning knowledge to the study to predict the consumption of water for the future for its users, which also can be used for demand, asset, and leakage management.

Also, Al-Ali *et al.* (2018) proposed a system with a unique network of integrated IoT-based smart utility meters that monitors the consumption of energies that are water, electricity and gas. A network of devices can be remotely programmed to read the consumption of the three meters depending on the frequency set by service providers.

Also, Bhoyar *et al.* (2018) proposed a system that upgraded a conventional water meter system to read digital values with minimum modification. The designed system for meter reading was compared to conventional meters and the reading matched which proved the accuracy of the designed system. The system used the LoRa protocol for communication which has a long-range and requires low power for operation (Al-Sarawi *et al.,* 2017).

Similarly, Sammaneh and Al-Jabi (2019) proposed a hierarchical design water distribution system that when adopted can optimize water distribution. A system had a smart valve that when it receives a signal can open or stop the flow of water depending on the signal received. The amount of water was measured by a smart meter and some sensors could monitor pressure and flow. The analysis of the literature review is done in Table 1

.

Table 1: Literature review analysis matrix

S/N	Title	Author(s)	Contribution	Limitation
1.	An IoT-based smart utility meter	Al-Ali *et al.* (2018)	✓ It can remotely program the devices to read the consumption of the meters. ✓ It can read meters for energy consumption simultaneously. ✓ It tested the accuracy of digital water meters as compared to an analog water meters.	✓ Low security since both service providers and homeowners can access the meters anytime from anywhere. ✓ It does not notify of any abnormality usage of the energies.
2.	Research on Water Meter Reading System Based on LoRa Communication	Li, *et al.* (2017)	✓ It successfully deployed a multi-level relay system. ✓ It has successfully data transmission through LoRa wireless communication.	✓ Users are not included in the notification loop. ✓ Focuses on the single building with floors. ✓ It does not notify of any abnormality usage of the energies. ✓ With a large number of meters, some meters may pass through multiple relays hence reducing meter reading efficiency.
3.	Smart water meter system for User-Centric consumption measurement	Mudumbe *et al.* (2015)	✓ It makes it possible for users to obtain real-time data. ✓ It has visual aids which are translated into easy readability of meter data. ✓ It enables users to modify the source code to suit their own needs or those of the service providers. ✓ It can also be used for other services such as leakage detection	✓ It does not notify of any abnormality usage of water. ✓ It has been no development or correlation of analog water meters with a digital water meter for increasing efficiency and accuracy of both meters respectively. ✓ It used a short range of communication of 100m.

S/N	Title	Author(s)	Contribution	Limitation
			and localization.	
4.	A kind of design schema of wireless smart water readings system based on Zigbee technology	Zhang & Liu (2010)	✓ It successfully provided a schema for a wireless smart meter. ✓ It proposed that when pulses generated are not steady, MCU will be in sleep mode which helps in conserving energy.	✓ It had a short range of communication due to the usage of Zigbee technology. ✓ It does not state the accuracy of the digital water meter used.
5.	Smart water for leakage detection: feedback about the use of automated meter reading technology	Farah & Shahrour (2017)	✓ It presented feedback about the use of the automatic meter reading for leakage detection in a large-scale demonstrator. ✓ It proposed a way to measure water consumption as well as to detect water leakage. ✓ It proposed a way to detect both water utility leakage (i.e. water leakage before reaching the customer). ✓ It proposed a probability theorem that could be used to calculate consumption values that are used to determine the cumulative density function for each meter.	✓ It did not state the amount of power needed for the good performance of the system, as power is one of the constraints of embedded systems. ✓ It had a short range of 300 meters. ✓ It faced a high loss of signal transmission which resulted in the loss of data.
6.	Proposal for a smart water meter for detecting sudden water leakage	Fikejz & Rolecek (2018)	✓ It successfully evaluated water consumption patterns using the software. ✓ It has put an actuator (a valve ball) that closes an inlet when a	✓ It had limited accessibility of information to the mobile devices as compared to the web-based. ✓ It required direct current power

S/N	Title	Author(s)	Contribution	Limitation
			water leak is detected. ✓ It had a backup source of power. ✓ It covered both, web pages and mobile applications for accessibility and analysis of data.	consumption due to the use of the internet (cellular) hence high consumption of power.
7.	Smart water flow monitoring and forecasting system	Gosavi *et al.* (2017)	✓ It can forecast the consumption of domestic water. ✓ It used the internet for communication. ✓ It represents the daily consumption of its users and water distributors.	✓ Usage of the internet (Cellular) is considered a high power consumption protocol.
8.	A novel smart water meter based on IoT and a smartphone app for city distribution management	Suresh *et al.* (2017)	✓ Customers could log in their complaints directly to the CRBM which can directly be accessed by the authorities. ✓ It used both online (cellular) and offline (Bluetooth) communication architectures. ✓ It successfully constructed a smart water meter from an analog water meter.	✓ It required direct current power consumption due to the use of the internet (cellular) hence high consumption of power. ✓ Low security since both service providers and customers can update the database for billing and payment using regular smartphones.
9.	IoT-Enabled adaptive smart water distribution management system	Sammaneh & Al-Jabi (2019)	✓ It has a smart valve that stops the flow of water after the assigned volume of water has passed or the tank becomes full. ✓ It can be implemented even if water is not distributed by the utility or a certain authority. ✓ It can be used by the authorities	✓ It is effective for a known amount of water to be used or stored for example filling a tank.

S/N	Title	Author(s)	Contribution	Limitation
			that have big tanks before distributing them to customers. ✓ It used LoRaWAN which has a long-range of communication.	
10.	LoRa technology-based low-cost water meter reading system	Bhoyar *et al.* (2018)	✓ It had a unique way of reading a conventional meter to digital values and the designed system proved to be accurate. ✓ It used the LoRa communication protocol which has a long-range.	✓ It is not clear about the usage of data collected and stored in the data collector. ✓ It had no connection between the authority/water utility and water users/customers.

2.2   Communication Range

Wireless Sensor Network (WSN) gives the ability for sensors to monitor, infer and analyze environmental indicators. Internet of Things (IoT) is created by the expansion of these devices in a communication network, where sensors and actuators merge harmoniously with the surroundings around us, and data collected is shared across platforms to establish a common operational representation. For the devices to communicate, efficient inter-operational is needed among the communication technologies involved (Bello *et al.,* 2017). Technologies associated with IoT can be grouped into two categories, long-range such as cellular, SIGFOX and LoRa, and short-range such as NFC, Bluetooth and Zigbee. The selection of these communication technologies, as to which can fit a certain project, mostly depends on the power of communication capabilities and the range of communication (Vangelista *et al.,* 2015). For long-range communication, according to Gaddam and Rai (2018), LoRa is the best selection among the technologies with long-range capabilities (10 km and above), low power consumption as well as low cost of operation.

2.3   Power Consumption

The majority of IoT devices are small and they can be moved from one place to another which makes it unable for the gadgets to access electricity at all times. This makes power to be one of the sensitive constraints for these IoT devices (Haroon *et al.,* 2016). When considering power conservation there is no universal solution, some systems are time-sensitive which is quite different from systems the precision of the results is more important despite the delay. Due to the above factors, depending on the nature of IoT device taxonomy energy conservation schemes can be divided into three methods mobility-based, duty-cycling, and data-driven (Abdul-Qawy *et al.,* 2020; Anastasi *et al.,* 2009; Rault *et al.,* 2014). Mobility-based is used on WSNs network architecture that allows explicit or implicit mechanisms for the mobility of sensor nodes to move in space such as underwater or air current (Ahmad *et al.,* 2014). To save energy second energy conservation scheme is the duty cycle, which is utilized to put unused communication interfaces of sensor nodes on low power or in sleep mode for the most of the time and only wake them up regularly (Chung & Hwang, 2010; Shabaneh *et al.,* 2014). The third scheme is data-driven which involves a data prediction model that predicts the next data within some limited error bound (Krishna *et* *al.,* 2018).

2.4 Summary

Regarding the review done above, this project will use a water flow sensor with a working range of up to 30 L/min and a pressure greater than or equal to 1.75MPa (Elprocus, 2021). The project also will use LoRa for communication because it is believed to be the best selection between technologies with low power consumption, long-range of communication, and low cost of operation. The node will contain Arduino as a microcontroller unit, a coordinator will be controlled by the Raspberry Pi and the collected data will be sent to the cloud. To cover for the involvement of customers in the billing process, they will be receiving messages weekly that will notify them about their water usage. Weekly customer notification will help customers to notify the authority about any billing abnormality and the authority could solve problems early.

MATERIALS AND METHODS

3.1   Method

The project used Agile Methodology during its development. Agile methodology refers to the group of methods that centers around the idea of iterative development where requirements and solutions evolve through a relationship between self-organizing cross-functional teams which increases efficiency and enabled delivery of the prototype faster with greater quality. The main characteristics of Agile methodology are adaptive planning, iterative and evolutionary development, rapid and flexible responses to change, and promoting communication (Kumar & Bhatia, 2012). This methodology is guided by the agile methodology manifesto (Beck *et al.,* 2001; Fowler & Highsmith, 2001) which has four values and twelve principles to improve software development processes. Tricentis (2017) proposed a diagram that explains better the Agile Methodology as presented in Fig. 2.
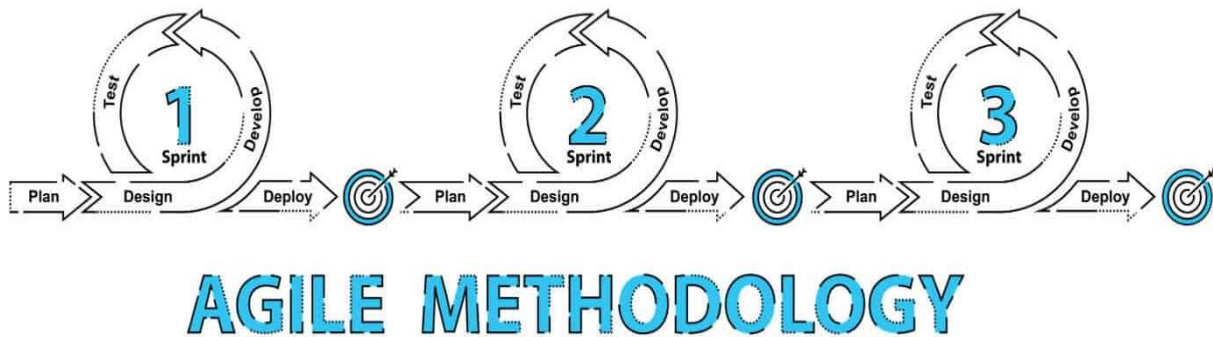
Figure 2:   Agile Methodology Design

There are also more than 8 methods of agile methodology, however, this project used Dynamic System Development Method (DSDM). With this method time and resources can be adjusted hence providing the agility feature, this was one of the main reasons that the researcher selected this method. Due to the time limitation the researcher had of six months from internship to delivery of the prototype, this method could provide the flexibility of adjusting time and the resources required for the project development.

The method has four (4) main phases which are feasibility study, functional model iteration, design and build iteration, and the implementation phase as described by Delima *et al.* (2018) and Sani *et al.* (2013) in a diagram shown in Fig. 3. Delima *et al*. (2018) also describe the phases as feasibility study/ business study mainly deals with data collection. Under this phase which is considered the first phase, the researcher collected all the necessary information about what the

product is ought to deliver including both functional and non-functional requirements. The second phase was functional model iteration where the researcher designed and built the necessary software part of the project including the dashboard and the online server that will be used to analyze and store information received from nodes until when accessed by the user. During a third phase which was system design and build iteration, the researcher was able to develop an embedded system that consist of nodes and a coordinator. The last phase was the implementation phase where the researcher combined the software and the hardware part to function together providing the expected output, the full system was tested and adjusted by repeating phases two (2) and three (3) to provide the output that met the requirements.
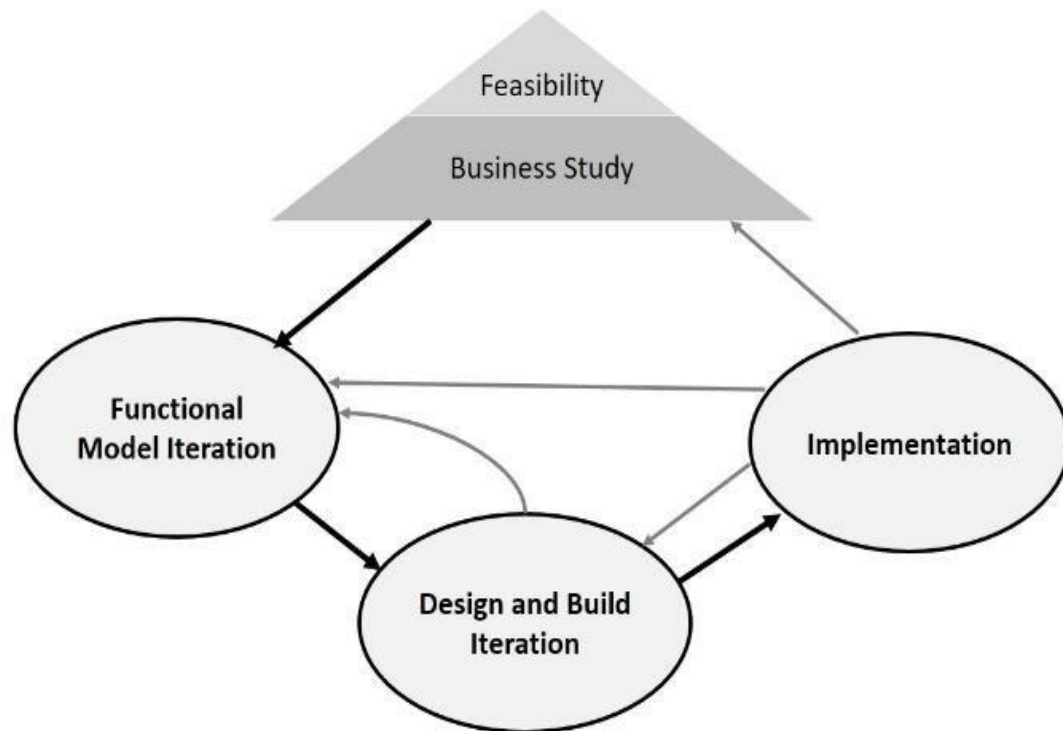
Figure 3: Dynamic System Development Method phases

3.2   Data Collection and Requirements Gathering

3.2.1   Data Collection

To establish the requirements of the system, data was collected. The main way to gather data/information was through semi-structured interviews, however other methods of data collection were used by the researcher to obtain more data. These other methods were focus group discussion, observation; literature review, and some information was shared by the AUWSA upon request of that information. Some other information was obtained through meetings conducted at AUWSA.

Interviews were conducted with the intent of gathering and identifying general information about AUWSA including the function of AUWSA regarding clean water distribution to customers. The interview had pre-defined respondents who mostly were the employees of AUWSA, as this was one of the best ways to acquire accurate and thorough responses for gathering information. Depending on the nature of the information required and the kind of interviewees the researcher had, sometimes the interviewee had no accurate responses and hence would refer to other people who would have more information and accurate answers.

A focus group was conducted at one of the customer's premises which consisted of a researcher who was the facilitator of the discussion, an AUWSA technician, and two customers of the pre-paid meters where the main topic was advantages and problems faced by the pre-paid meters. The focus group discussion was less structured hence the opinions of the people involved in the discussion were extraordinarily valuable, especially on the selection of project focus. This discussion gave more insight into the researcher and the concentration area to kind of meters that she should focus on as well as some details of what the project should pay more attention to.

Among the focus group discussion that was conducted, shown in the picture below (Fig. 4), was a meeting conducted by the AUWSA authority to understand the project the researcher wanted to conduct and also to introduce the researcher to the departments for any other help she would need.

Figure 4:   Meeting conducted for introducing a researcher to the heads of departments for their cooperation during data collection

The observation method was used when a technician opened pre-paid and post-paid meters as shown in the pictures (Fig. 5 and 6). The objective was to view and examine the basic structure of these meters to understand the mechanism of functioning for both meters. This gave more insight

to the researcher to propose a better solution for the time given to the project. The following are some pictures taken when opening the pre-paid meter, analog meters, and the remote used to top up the pre-paid meters.

Figure 5:   Opening the prepaid meters after removing the top cover

Figure 6:   Opening a prepaid meter before removing a top cover

In addition, a literature review was conducted to obtain additional knowledge, especially on a better understanding of AUWSA. Most of the documents were obtained online, however, some of the information was shared by the AUWSA employees upon request for specific information, for example, the total number of customers, coverage of AUWSA services as well as average of non-revenue water that AUWSA has.

In general, the data collection process was limited by the time and fund that was available. A researcher was given a total of one month for an internship and required to make a project proposal presentation soon after the internship. This means within this given time the researcher should have discovered the problem and come up with a solution for solving the problem (project). Delaying permission to conduct research at AUWSA contributed to hindering the process of data collection.

3.2.2 Requirements Gathering

According to Tamarkin (1992), any automatic meter reading system consists of three primary concepts. Hence, the list of the requirements was developed depending on the definitions and the functionality of these concepts.

The first concept is the meter interface module which consists of a power supply, electronics equipment, communication interfaces, meter sensors, and the brain which is a controller. Also, the study suggests two kinds of locations that is a remote location where the remote device will be placed in this case sensor node, which will send data over a communication interface device to the central location. There are a lot of choices of the Microcontrollers; however, this project used Arduino UNO as a Microcontroller and raspberry Pi 4 as a mini-computer. The selection of the microcontroller and the mini-computer was based on the cost and its easy availability to Arusha city besides the delivery of the expected output. Electronics-lab (2021) listed the top 10 popular micro-controllers among makers, the ATmega328 series is one of them and Arduino has a Micro-controller board based on this series. Raspberry Pi 4 Model B has its own microcontroller design RP2040, with enhanced CPU, more RAM and additional external memory space using SD cards with wireless, Bluetooth and Ethernet protocols. All these features made Raspberry Pi 4 Model B a preferred coordinator for the project.

The second component was the communication system that will be used for data transmission as well as control send a signal (signal sent from the control office back to the sensor nodes) for a bidirectional system such as this project. Communication technologies for IoT are categorized into two groups, short-range and long-range networks. Examples of short-range technologies are

Bluetooth, RFID and WiFi; while examples of long-range technologies are cellular networks (2/3G/4G), WiMAX and LoRaWAN (Bello & Zeadally, 2014). Mostly used communication protocols nowadays are radio transvers and proprietary protocols (Reiter, 2014), Lora is one of them and is the used communication technology for this project.

LoRa stands for Long Range communication technology which enables power efficiency for over long-distance communication. One of the typical applications of LoRa is used in the large geographical area collecting sensor readings (Bor *et al.,* 2016) in this case meter reading. According to Feng *et al.* (2019), some of the most used communication technologies used during the development of IoT devices are Bluetooth, RFID, Zigbee and 2G/3G/4G where they are mostly limited by the range of communication as shown in Fig. 7 as compared to LoRa which can go for a very long distance as well as installation and operational cost.
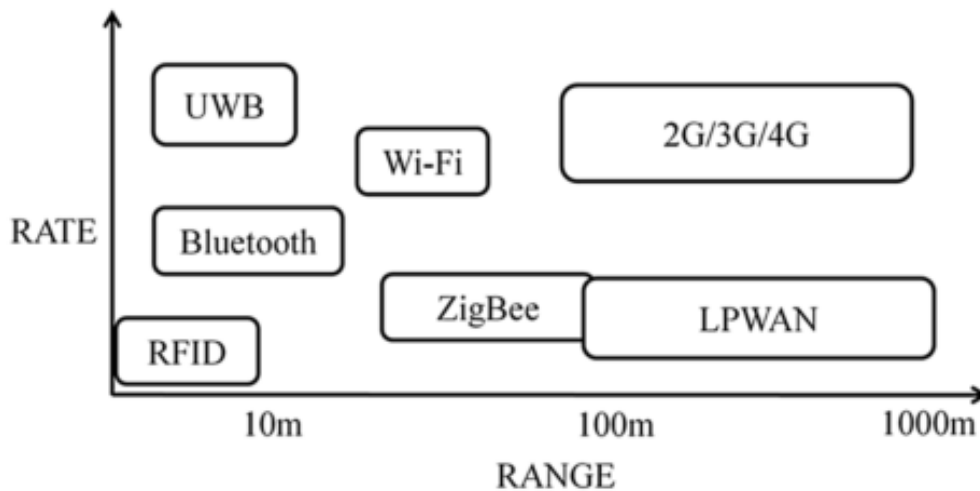
Figure 7:   Range and rate comparison among wireless communication technology

Bluetooth is the best choice when considering power consumption however its communication range is limited (Bluetooth, 2010). Zigbee also is the most preferred choice which offers a communication range of 100 m with low power consumption as well as low cost (Ergen, 2004). 2G/3G/4G has a better speed and data transmission and covers a large geographical area however it has high power consumption as compared to other communication technologies in addition to that sometimes has a problem with data security during transmission (Iqbal *et al.,* 2020). If long-range is the main factor to consider, Lora is the most preferred communication technology where it offers more than 10 km communication range (Andersen *et al.,* 2020) as well as having a low power which serves as a perfect technology to use for applications such as smart metering (Varsier & Schwoerer, 2017).

The third component is the central office systems equipment like the host upload links or a host computer which in this case will use the cloud for the storage of information.

3.3 Study Area

There are three types of water sources used by AUWSA to supply clean water at Arusha City, that are springs such as Olesha-Masama spring, Ngarendoli and Machare, boreholes and rivers such as Nduruma where water quality from all sources are within the required standards and water treatment is also done for more reassurance. All these water sources contribute as follows to the daily production of water, boreholes contribute 30%, springs contribute 50%, and the remaining 20% is contributed by rivers. Despite the large coverage around Arusha city for the majority of the population, there are still areas that AUWSA water supply has not yet reached therefore, those communities use their sources of water (AUWSA, 2021). The picture (Fig. 8) the map of Arusha city and the distribution of water pipes. The scope of Arusha city hence AUWSA as a case study was done due to the geographical closeness of AUWSA and the industry, Wise-future, funds as well as time limitations.
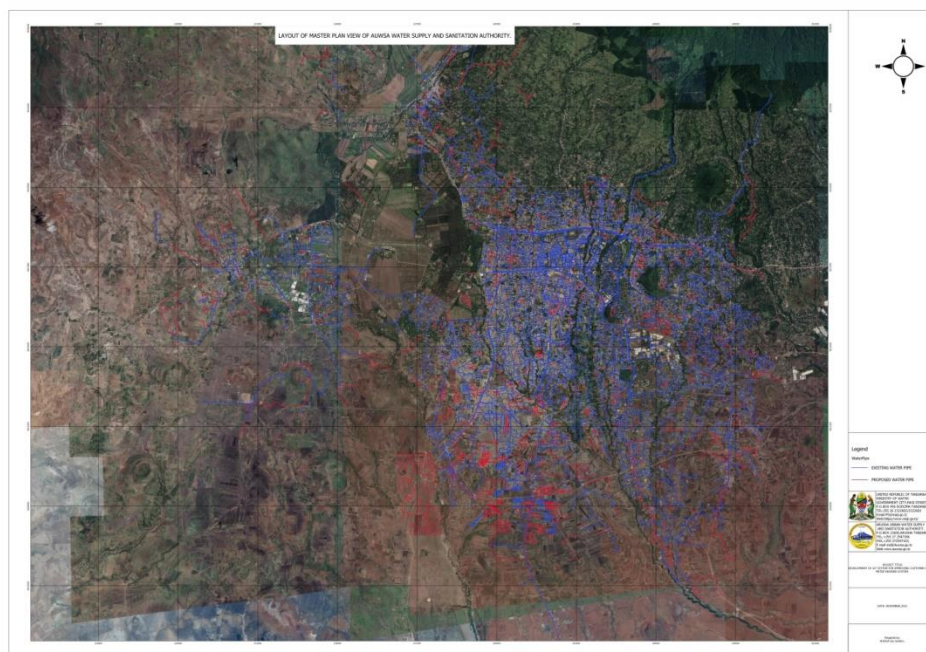
Figure 8: **Map showing a network of water pipes and areas where water pipes are expected to pass in Arusha City**

3.4 Study Population

A total of 15 representative respondents were involved in the study, and they were purposively obtained through snowball sampling. Snowball sampling which sometimes is referred to as

24

network sampling involves each individual drawn from the targeted population being asked to name different individuals from the same targeted population. This procedure continued until a number of samples is reached. This kind of sampling can also be used in various aspects of the relationship presented in the population (Goodman, 1961). Snowball sampling was adopted by the researcher who needed to interview the lead people at AUWSA based on their basic roles and experience. Each respondent nominated the next eligible candidate depending on the kinds of questions asked during the interview, and the nomination would mostly depend on the head of the department responsible or the person responsible.

Six (6) of the fifteen respondents were employees at AUWSA and one (1) of them was a technical manager and was also acting general director at the time of data collection. The rest were as follows: One (1) was a clean water technical engineer, one (1) head of ICT-Unit, one (1) customer billing officer, one (1) zone in charge and one (1) technician and meter reader. During data, collection researcher was able to tag along with the meter reader where she got access to interview the remaining nine (9) respondents who were customers of AUWSA. These customer respondents could further be categorized into two (2) groups, one group had pre-paid meters installed and the other group had post-paid meters installed. These categories were selected based on a better understanding of the AUWSA meters.

3.5   Prototype Design and Development

The main idea of the project was to develop a system that will be able to collect meter-reading data, analyze them and store them so that AUWSA could be able to get the readings and continue with the other process from billing to the payment. To get a better understanding of the layout of the system, the block diagram below gives a pictorial presentation of the system. The sensor nodes were placed on the meters, and the collection of the meters was divided into different zones where each zone had one gateway (coordinator) which then updates data to the cloud where in this case the researcher used an online server. After data is uploaded to the cloud, the authority could retrieve data and do the needful.

Jamil (2008) proposed a model of Wireless Automatic Meter Reading System (WAMRS), where the design and development of this project will follow the model.

3.5.1   Prototype Design

The overall idea of this project is to send the periodical readings of the water consumption to the authorities wirelessly. Coordinators connect the sensor nodes (end nodes) and the cloud. While the

sensor nodes are placed at the consumers, the coordinator will be placed in such a way that each sensor node will be able to communicate with the coordinator. The coordinator placement will depend on the geographical location so the sensor nodes will communicate with it, and cover each geographical area to improve the coverage area. The nodes will be communicating with the coordinators over a long-range transmitter (LoRa), and the coordinator will be communicating with the cloud over WiFi communication.

(i)   Sensor Node

The sensor node consists of an Arduino Uno microcontroller which was a micro-controller unit that controlled all of the activities of the node. Attached to the Arduino MCU were the water flow sensor, LCD, LoRa module and gate valve. Water supplied by AUWSA to a customer went through a water flow sensor that took the readings (liters per minute) which were displayed on the LCD screen. The LoRa module was used as a communication technology between the node and coordinator. The LoRa module was connected to both, the node and the coordinator hence the node was able to send readings after a certain period to the coordinator the information was well received by the coordinator and the information such as opening and closing of the valve that was done at the online server would be sent back to the sensor nodes through a coordinator. The gate valve was used to allow AUWSA due to some reasons they might want to prevent the flow of water to a customer, they should be able to do so. For example, if AUWSA has received a zero reading, they can react to that by closing the gate valve preventing more loss of water, dealing with the problem, and when the problem is cleared the authority can open the gate valve and allow the flow of water as usual to customer.

(ii)   Coordinator

The coordinator which acted as a gateway consisted of the Raspberry Pi connected to a LoRa module. The main function of the coordinator was to collect the readings from the sensor nodes (requests) and send them to the cloud (online server) which could be then accessed by the AUWSA for further processing as well as receiving the responses from the server and forward them back to sensor nodes. There was an internet wireless connection that was provided by the smartphone, which connected the coordinator to the internet and allowed the coordinator to connect with the cloud (online server). The LoRa was used for connection between sensor node and coordinator. The coordinator will also have a memory card to store data for three months in case of any problem.

(iii)   The Cloud (Online server)

The cloud was simply the server was used for computation and data storage, later these outputs could be retrieved by the authority for further processing and billing. The cloud was made into an online server that contained a program that was able to sort data according to AUWSA requirements and distinctive features such as high-water usage and zero readings. These unusual readings such as zero readings were identified and differentiated by the system since they needed immediate care and response so that if there is any problem could be dealt with effectively.

3.5.2   Prototype Development

The development of the system was based on the design of the system to deliver what a system ought to do. The main objective of this project is to develop an IoT-based system that will automate the meter reading process of the post-paid meters. The developed prototype was focused on the functionality of the system to provide the solution to the stated problems which are to reduce the amount of non-revenue water, reduce the number of people who lack safely managed drinking water, and the concerns raised by the clients about their bills not correlating with their water usage. The developed system checked for the functionality of the meter readings being able to allow communication between the sensor node and cloud (Miao *et al.,* 2009).

Also, the development of the prototype was mainly limited by time and funds. Due to the fund margin that the researcher had, the cost of prototype development was considered and there fore the requirements needed were obtained whether in Arusha city or nearby places such as Nairobi Kenya. The time is given to a researcher six months from an internship for problem identification, and data collection up to the development of the project hindered the development of the prototype.

3.6   Prototype Testing

To test for the system's functionality, multiple factors were tested before testing for the whole system. Testing was done as explained in the subsections below.

3.6.1   Testing Water Flow Meter

Selecting the water flow sensor is very important as it is a very important part of the automatic meter reading system. The function of the water flow sensor is to measure the rate of water passing through. The selected flow sensor consists of a water rotor and a hall effect sensor, when water passes through the sensor it rotates the rotor, and the changes can be observed by the speed

of the motor. The change is calculated as output as a pulse signal by the hall effect sensor, which measures the flow of water (Sood *et al.,* 2013). There are two ways of measuring flow, either depending on its volume or its weight (Mwangi, 2016). This project will test the functionality of the flow meter based on its volume.

3.6.2   Testing for the Functionality of the Valve

An electronic solenoid valve was used as a gate valve to either allow or prevent the flow of water. There are two kinds of solenoid valves, the normally closed solenoid valve, and the normally open solenoid valve. The more available solenoid valve around Arusha city is normally closed which opens when electricity passes through. The functionality of the valve was tested to make sure that the valve was able to open and close, that is it is functioning normally.

3.6.3   Testing for the Functionality of the Prototype

The prototypes were subjected to live environment situations and the testing was based on two different parts which are the hardware and the software. The hardware was testing how the network would behave, the performance of the devices, and the efficiency of the output. The software was mainly testing the analysis of the data received where mainly focus was on the receiving the correct data, on time, analysis of the zero reading, as well as the reaction of the, received commands (closing and opening of the valve). The proposed prototype circuit design was first subjected to simulation and followed by the development of the prototype and later tested in a real-life situation.

To test better the prototype, the calibrations of the water flow sensor were adjusted in such a way that 1000 liters would make a 1 unit reading on the database, instead of 1000 liters of water. This made testing the functioning and the performance of the prototype easier.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1   Results

To improve the meter reading process, a water meter was developed that was supported by an online server. The communication that was between the coordinator and the online server was done over the Wi-Fi network while the communication between nodes and the coordinator was done through LoRa devices.

4.1.1   Results of the Requirements Gathering

Devices were selected due to their functionality for example water flow sensor, gate valve and regulators. This project divided the requirements into two main groups, the hardware and software requirements, which are listed in Tables 3 and 4 respectively.

Table 2: Hardware Requirements

No	Item Name	Specification	Qty
1	Raspberry Pi 4	2 Gb Ram	1
2	Lora Radio Module	435 Mhz, External Antenna, 5v Ttl Logic, Uart Communication	4
3	Raspberry Pi Power Supply	5v Adapter	1
4	Raspberry Pi Power Cable	Type C Usb Cable	1
5	Sd Card	32gb	1
6	Water Proofing Box	White Box	4
7	Arduino Uno	8 Mhz, 20 I/O's, 5v Ttl Logic	3
8	Water Flow Sensor	Electromagnetically Sensor	3
9	Solenoid Valve	Normally Close Valve, ¼ Connector	3
10	Nipple	½ To ¼ Reducer Nipple, Brass	3
11	Ips Plastic Connectors	½ Connectors	9
12	Ips Plastic Nipples	½	6
13	Plastic Water Valve	½	3
14	Battery	12 V, 7.5 Ah	3
15	Solar Panel	10 Watts	1
16	Relays	5v, 20a	1
17	LCD	16x2 Characters	3
18	Antenna	Dipole Antenna, Rola Antenna	4

Table 3: Software Requirements

S/N	Software Name	Function
1.	Draw Io	Drawing Diagrams
2.	Fritzing Software	Circuit Design
3.	Arduino Ide	Programming Arduino Uno
4.	Visual Studio Code	Code Writing
5.	Pics Art Photo Studio	Picture Formatting
6.	Browser	Internet Surfing
7.	Raspberry Pi Imager	For Os Installation In The Raspberry Pi
8.	Raspberry Pi Os	Operating System That Used To Configure Pi

4.1.2 Results of Prototype Design and Development

(i) Results of Prototype Design

To provide a general overview of how the system will work, the block diagram was drawn as shown in Fig. 9. The black dots represent the sensor nodes that will be sending data to the coordinator and the coordinator will be sending data to the cloud. The system also is designed in such as way that the data/instructions will be sent back to the nodes through the same way, coordinator.

Also, to provide a clear functionality of the whole system the flow chart diagram is drawn as shown in Fig. 10, which explains how the system works and how the conditions of some decisions were made. Normally the Authorities would send short messages of the billing in a monthly timeline, which is on the same timeline that meters are read. Since the timeline the monthly seems too long, especially if there is a problem for example malfunctioning the meter, the researcher decided to reduce the timeline to a weekly basis, so that the notification and the problems will be dealt with sooner.
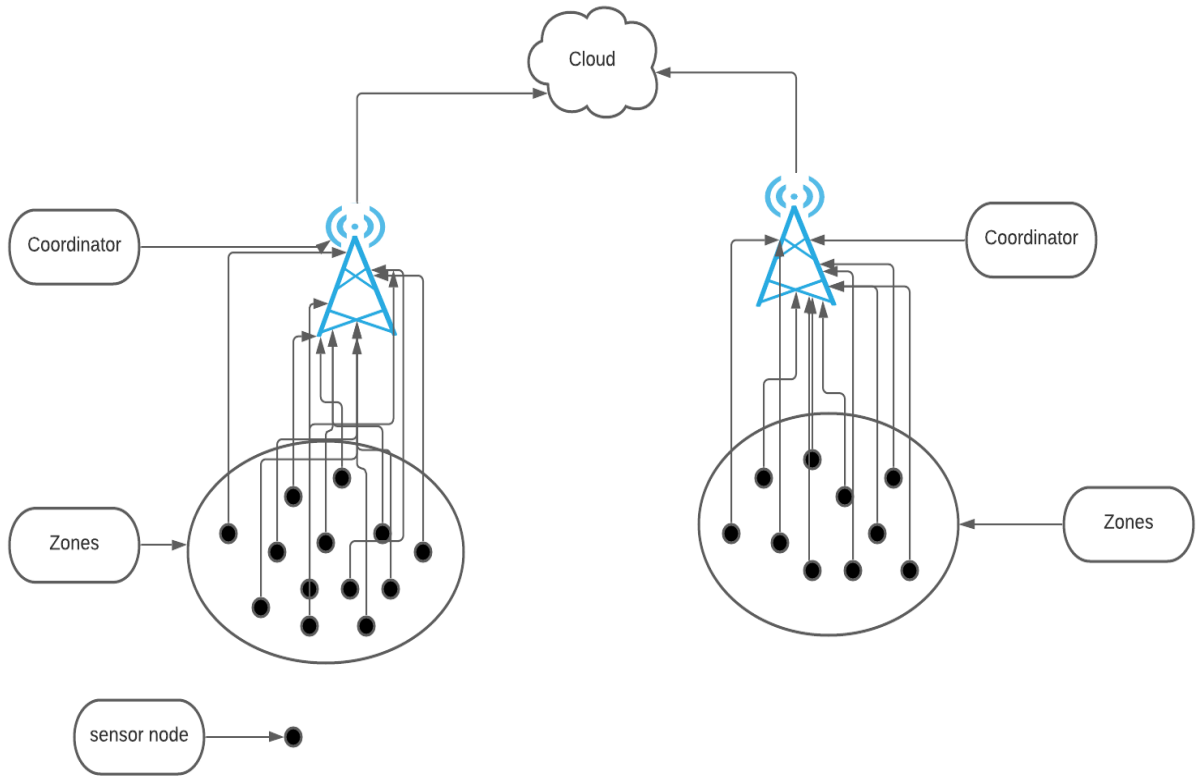
Figure 9:   Block diagram to provide an overview of how the system will work
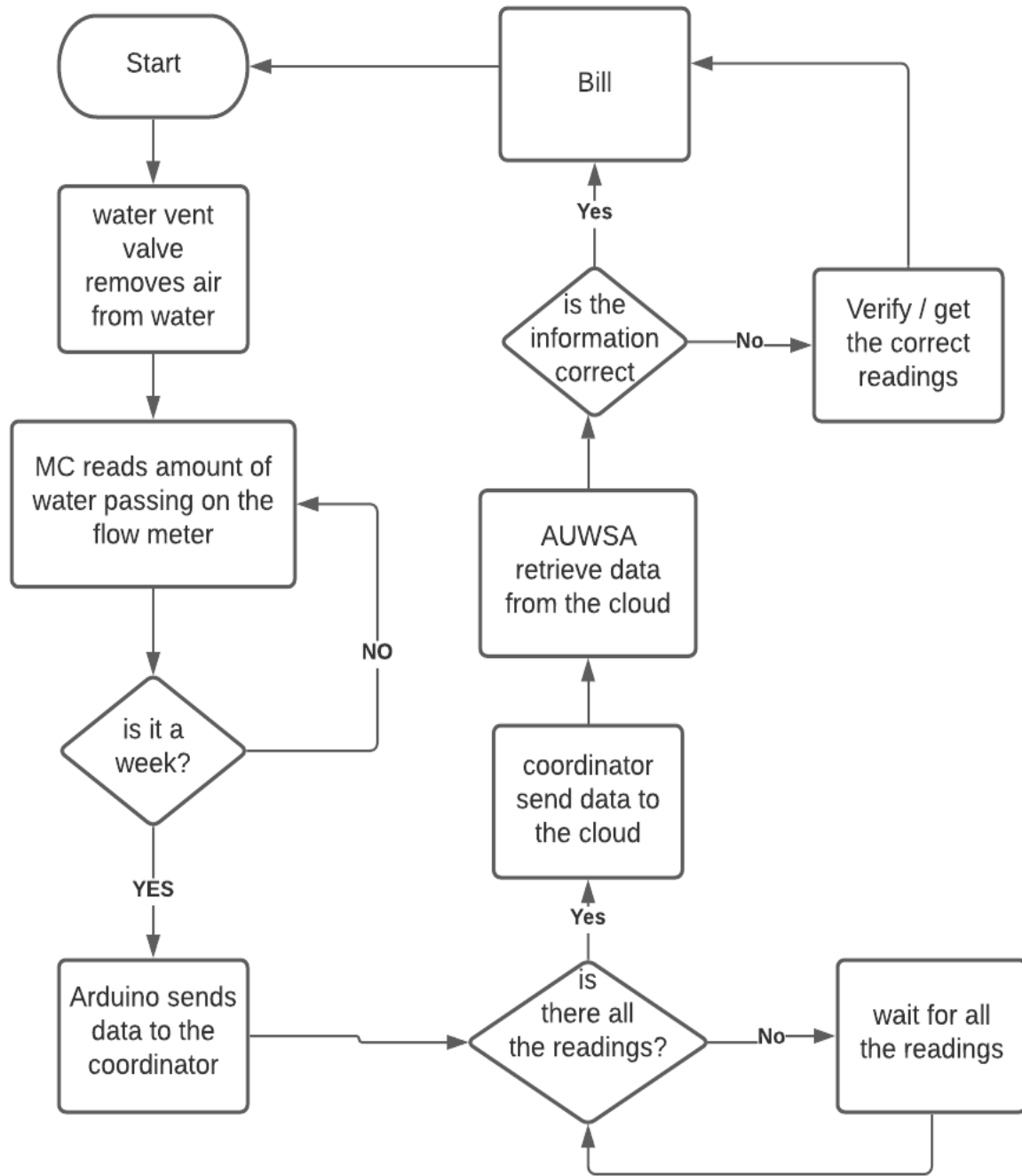
Figure 10:   Flow chart explaining how the developed prototype works

(ii)   Results of Prototype Development

This project had three main parts, the sensor node, the coordinator, and the cloud, whose configurations are explained in following Subsections:

Sensor Node

The schematic diagram was drawn as shown in Fig. 11 to provide a representation of the components with their connection using abstracts (standardized symbols). Furthermore, the breadboard circuit diagram was drawn as shown in Fig. 12, which acted as an instruction manual or map of the circuit so the same circuit was developed as shown in Fig. 13.
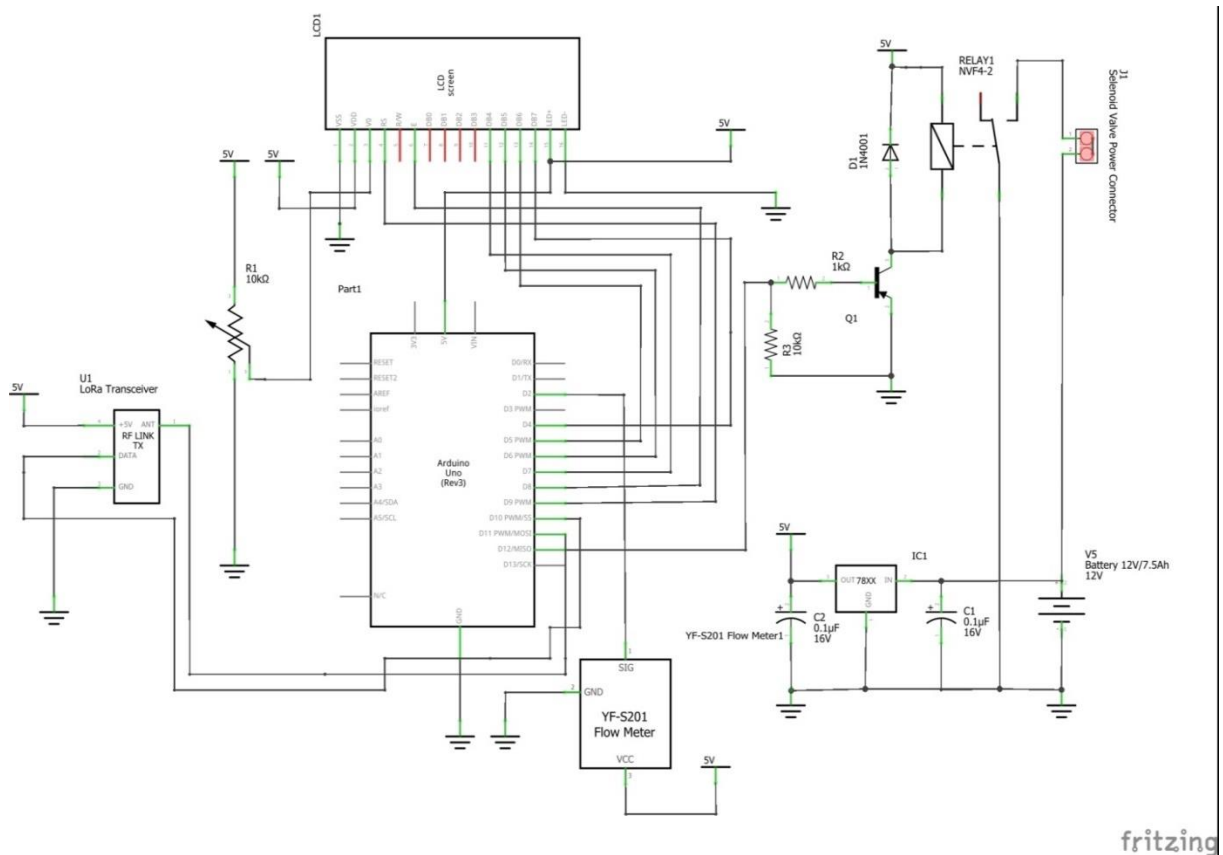
Figure 11:   Schematics circuit diagram for sensor node
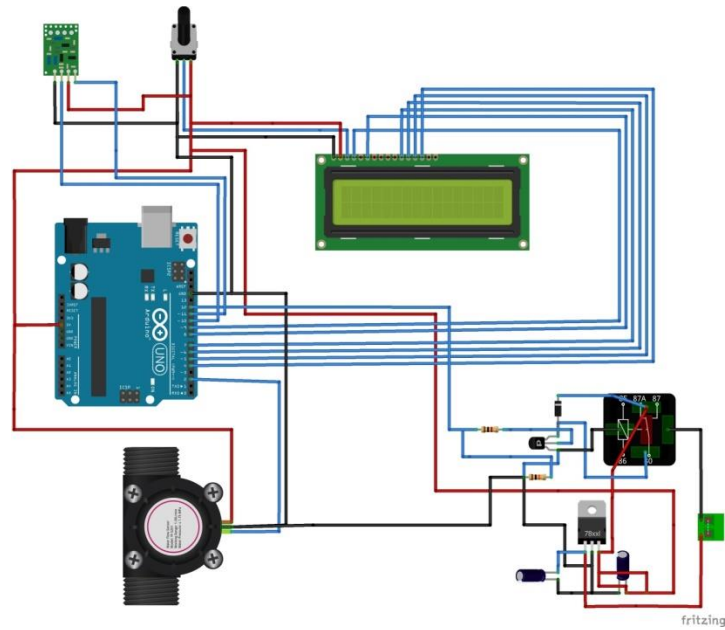
Figure 12:   Breadboard circuit diagram for sensor node showing the connection of devices
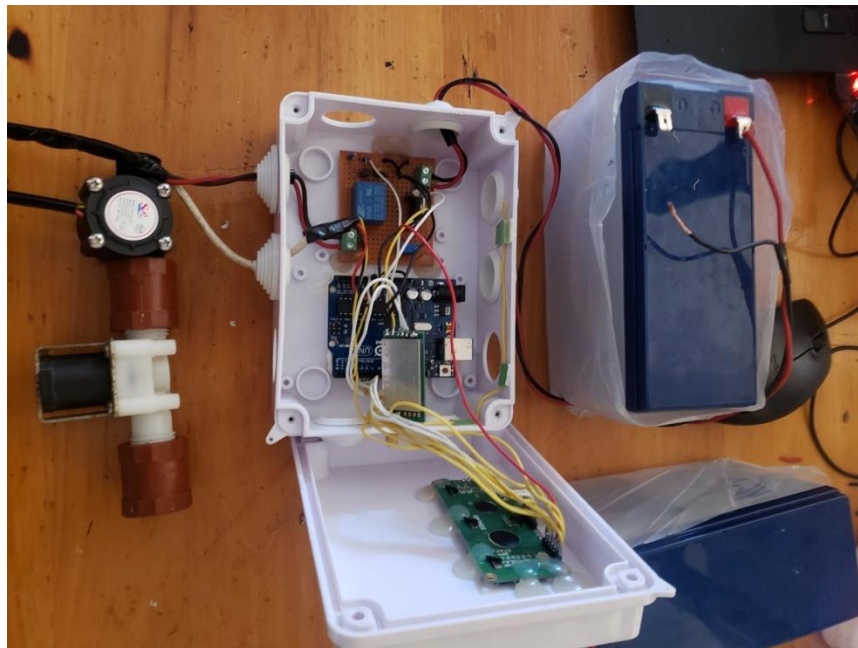
Figure 13:   Internal view of a sensor node

Coordinator Node

Mainly the coordinator node consisted of a raspberry pi (a mini-computer) and a LoRa module. As for the sensor node, the schematic diagram of the coordinator node as well as the breadboard diagram was drawn (as shown in Fig. 14 and 15 respectively) to provide the pictorial representation of the node. Latter on the same circuit obtained from the breadboard diagram was developed as shown in Fig. 16.
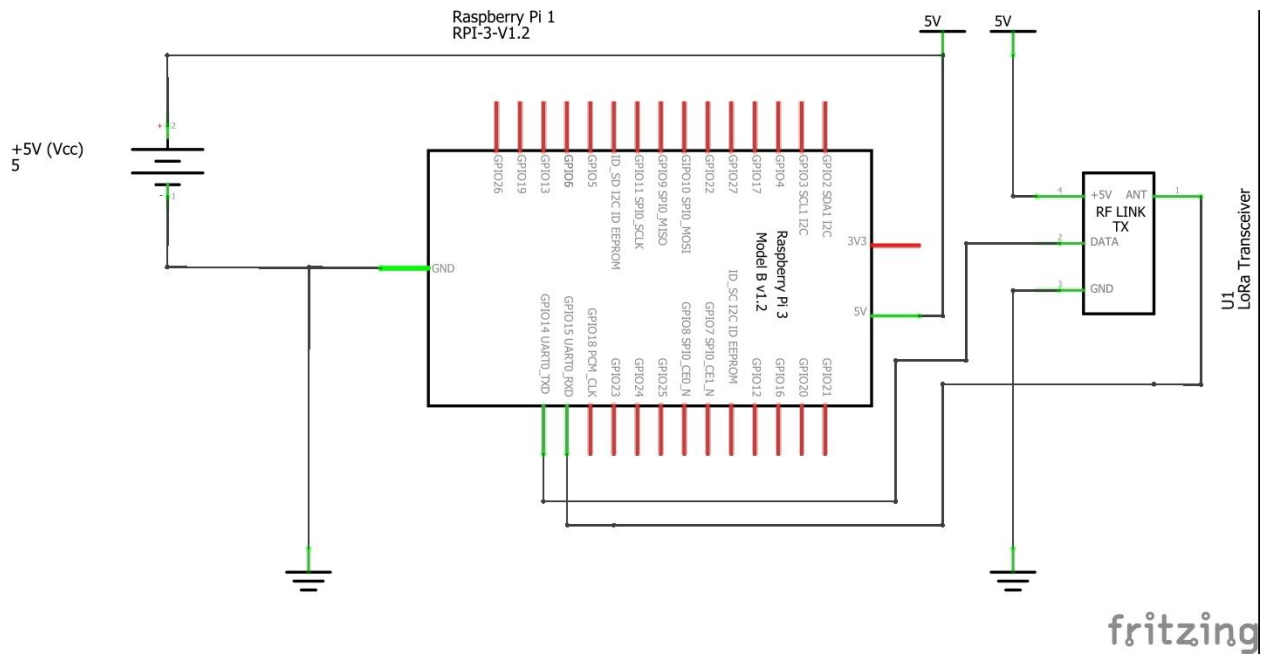
Figure 14:   Schematics circuit diagram for the coordinator node
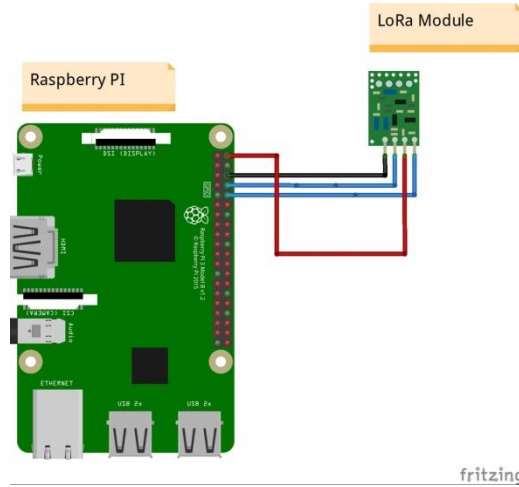
Figure 15:   Breadboard circuit diagram for the coordinator node

Figure 16:   Internal view of the coordinator

The Cloud

The system was developed and hosted at http://waterbill.codeafrica.co.ke/. The Kenyan domain was used because, as stated above the project was limited with time and funds, the Kenyan domain was the cheapest domain the researcher could access at a given time and money.

4.1.3   Results of Prototype Testing

(i)   Testing for Flow Meter Accuracy

The first mechanism was to measure and test the accuracy of the flow meter. To accomplish this, a comparison of the data between the amount of water passing through a water flow meter and a custom water meter was done. According to AUWSA information, 1 unit of water with the conventional meter reads after a 1000 L amount of water has passed through it.

The water meter was calibrated to read 1 unit after 1000 L of water has been allowed to flow through the meter. The same amount of water was then allowed to flow through the flow meter as well as the conventional meter and the following results were obtained as shown in Table 4.

Table 4: Water flow meter test readings

Number of trials	Active vol (L)	Vol displayed by the designed meter (L)
1	1000	980.24
2	1000	1000.00
3	1000	990.92
4	1000	1000.05
5	1000	1000.30

(ii)   Functioning of the Valve

The valve was normally closed, and when enough current was passed through the valve, with the command the valve could be open allowing the passage of water, or could be closed preventing the flow of water. Valves got the command when the nodes send data to the coordinator and synchronized information with the cloud sending back the command to the nodes.

(iii)   Results for Testing the Functionality of the Prototype

When the prototypes were subjected to a real situation, the following readings were captured on the database for 60 hours, the nodes would refresh and update the readings after every 3 hours as

shown in Table 5. As stated above, this reading was obtained after the recalibration of the water flow sensor from 1000 L equals 1 unit of meter reading to 1000 L equals 1 unit of meter reading.

Table 5:   Table showing meter readings

		Prototype Performance Readings			
SN	Meter No	Meter readings		Timestamp	Time taken
1	M003		0	0800 hrs	0
2	M003		1	1100 hrs	3
3	M003		1	1400 hrs	6
4	M003		2	1700 hrs	9
5	M003		3	2000 hrs	12
6	M003		4	2300 hrs	15
7	M003		4	0200 hrs	18
8	M003		4	0500 hrs	21
9	M003		5	0800 hrs	24
10	M003		6	1100 hrs	27
11	M003		7	1400 hrs	30
12	M003		7	1700 hrs	33
13	M003		8	2000 hrs	36
14	M003		9	2300 hrs	39
15	M003		9	0200 hrs	42
16	M003		9	0500 hrs	45
17	M003		10	0800 hrs	48
18	M003		11	1100 hrs	51
19	M003		12	1400 hrs	54
20	M003		13	1700 hrs	57
21	M003		14	2000 hrs	60

Also, the result of the last update was deducted from the result of the current update to get the exact used in between. After getting those readings, which were set to be received on the weekly basis, the message would be sent to the customer (user) as shown in Fig. 17 which contains the exact amount of water used on that week as shown in Fig. 17.
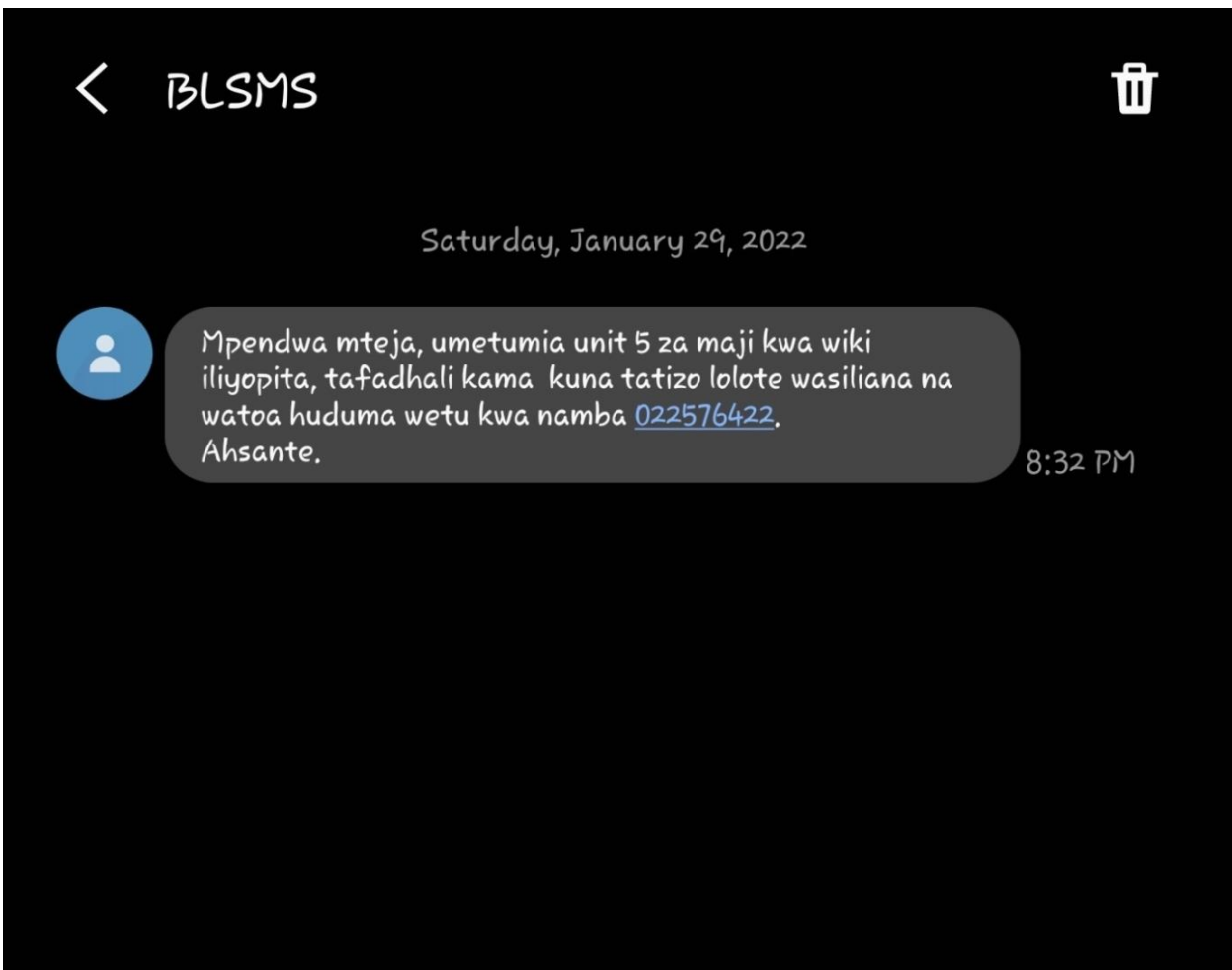
Figure 17:   A screenshot of the weekly by the system message sent to customers

4.2   Discussion

The obtained results were analyzed to check for the performance of the prototype. When the graph of meter readings was drawn against the time is taken, almost a straight line was obtained as shown in Fig. 18. This is because each time people used water from the tap which passed through the prototype's node, water flow meter values would increase meaning some amount of water has been used as shown on the graph below. Therefore, with the obtained result, the prototype was working better and could be reliable to be used in a real-life situation.
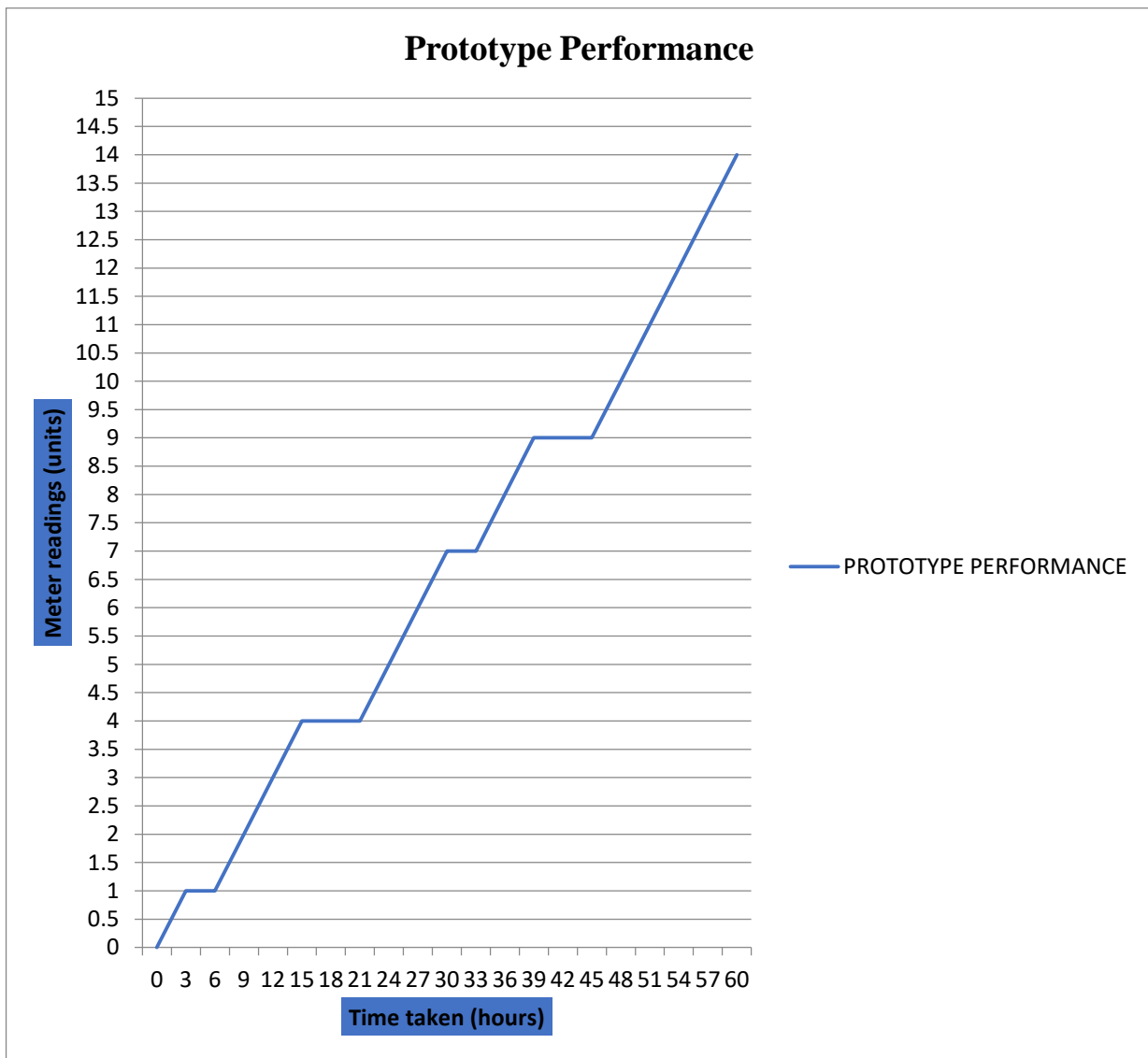
Figure 18:   Graph showing a prototype performance in a live environment

Also, in case the received readings contain zero reading, this will be highlighted on the dashboard for easy notification. When the meter reading value is zero (0) that is considered a zero reading. Zero reading is being highlighted as shown in Fig. 19 because to have the zero reading can mean two things, either customer did not use water or there is a problem with the meter reading system. If the customer did not use water, then the zero reading is ok, however, if there is a problem with the reading system, this will mean that the customer still uses water and readings are not updating which could result in non-revenue water.
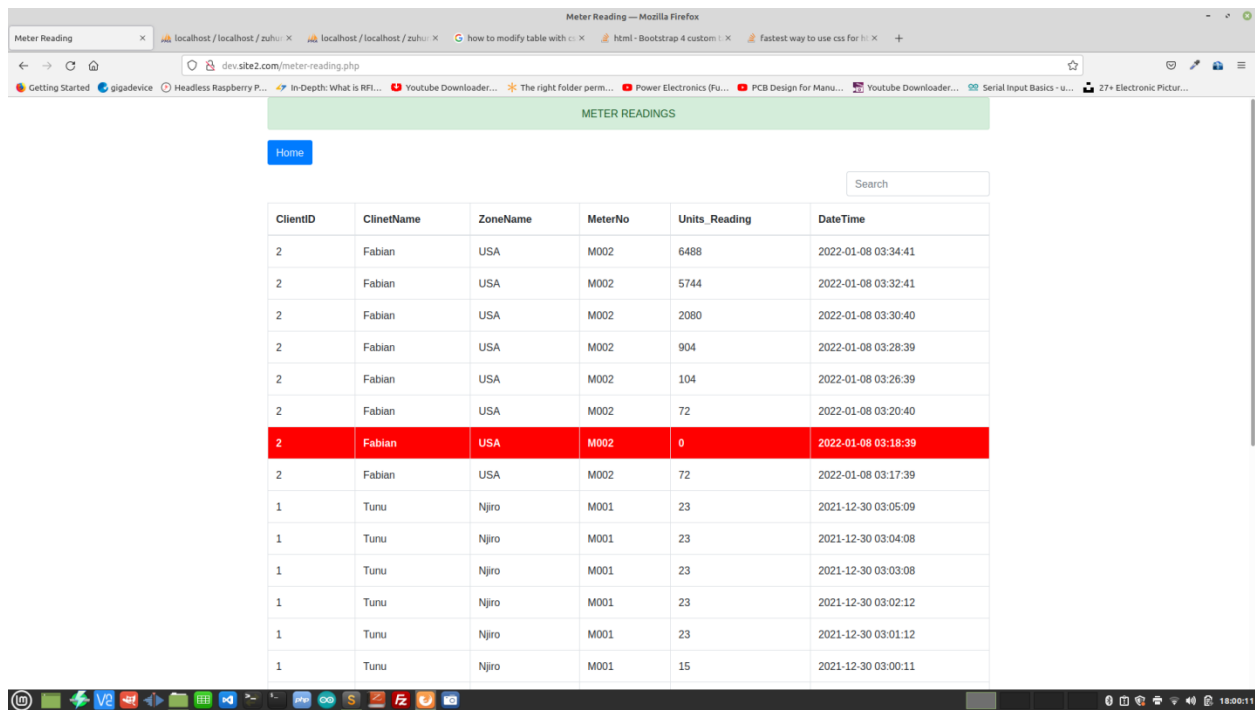
Figure 19:   Screenshot showing highlighted zero reading

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5. 1   Conclusion

The main objective of this project was to develop an IoT system for the customer water-meter reading system at Arusha City. As was stated in the introduction some of the problems that this project ought to solve includes time is taken for the meter reading process, cost of resources, dealing with the customer's concerns on the monthly bills that do not correlate with the consumption, as well as reduction of non-revenue water. Therefore, the development of the proposed system is based on solving the stated problem. On solving the time taken for the meter reading process as well as the reduction of the cost of resources, the system was designed in such a way that it would automatically update the readings on the cloud hence no more time needed for the reading process. Hence, in dealing with the cost of the resources, the system will be able to reduce the number of the workers that were needed for the monthly water reading since the system would directly update the information to the server and receive the responses from the server during the refreshment of the system. Dealing with the non-revenue water, the implementation of the gate valve was used so that if there is any problem on the meter or due to the need of preventing water flow, the AUWSA personnel would be able whether to allow or prevent the flow of water when they are on the office. Hence this would reduce the amount of water lost to the customers, therefore, reducing the amount of non-revenue water. Since the readings are updated on the server depending on the time set, that means it is possible for customers to get the report of their usage of water early for example on the weekly basis and if they find any problem with their consumption, the authority will be able to deal with their problems or concerns as early as possible.

This project used the knowledge of Wireless Sensor Network (WSN) to develop this prototype. The developed system contained three parts, the sensor nodes, the coordinator or gateway, and the cloud or the online server. The communication between sensor nodes and coordinator (gateway) was done using Lora and the communication between coordinator and cloud (online server) was done over Wi-Fi and the communication was bidirectional.

5. 2   Recommendations

This research could have been done differently with more time and other resources such as funds and compatible devices, the following are some of the future work suggestions to improve the

prototype. The sensor nodes could be added with the GPRS sensor to get the locations of the nodes as the data is updated on the server. Also, the study could have been extended allowing sensor node readings to reset to zero after every reading is updated to the server, this would allow users to confirm their water. Also, the system could have been added with the payment tracking system and to any customer whose debt has exceeded a certain amount, the valve could automatically close till when that debt is cleared. On top of that, the prototype could have been added to the customer ranking system for future references on customer behavior. Furthermore, the study could explore other options for solving this problem such as allowing direct communication between the nodes and the server, or even further the study and explore the development of pre-paid meters that will be environmentally friendly with affordable cost.

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APPENDICES

Appendix 1: Gateway / coordinator codes

```javascript
const SerialPort = require('serialport')
const Readline = require('@serialport/parser-readline')
const port = new SerialPort('/dev/ttyUSB0', { autoOpen: false }) //disable auto
open
const axios = require('axios') //third part request library
var serverUrl  = 'http://dev.site2.com/device_API.php'
//for mysql DB
var mysql       = require('mysql');
var connection = mysql.createConnection({
  host     : 'localhost',
  user     : 'root',
  password : 'root',
  database : 'kiosk'
});

//open port
port.open(function (err) {
    if (err) {
      return console.log('Error opening port: ', err.message)
    }
  })

const parser = port.pipe(new Readline({ delimiter: '\r\n' }))
//keep serial on flow mode
parser.on('data', function(data){
    if(!connection._connectCalled ){
    //connect to DB
    connection.connect(function(err){
        //if there is error
        if (err){
            console.error('error connecting: ' + err.stack);
            return;
        }
        });
    }
    //print put data
    var obj = data;
    //console.log(obj);
    obj = JSON.parse(obj);
    console.log(obj);
    //request
    axios
    .post(serverUrl, {
        meter_id: obj.meterid,
        readings: obj.readings
```

```
    })
    .then(res => {
        console.log(`statusCode: ${res.status}`)
        //print feedback
        var response = res.data;
        response = JSON.stringify(response);
        port.write(response+">");
        port.write('\r\n');
    })
    .catch(error => {
        console.error(error)
    })

})
```

Appendix 2: Sensor nodes (Arduino) codes

```cpp
/* Firmware V1.0
Created on 18, December 2021
By Zuhura Msisi
*/
// include the library code:
#include <EEPROM.h>
#include <ArduinoJson.h>
#include <LiquidCrystal.h>
// initialize the library by associating any needed LCD interface pin
// with the arduino pin number it is connected to
const int rs = 9, en = 8, d4 = 7, d5 = 6, d6 = 5, d7 = 4;
LiquidCrystal lcd(rs, en, d4, d5, d6, d7);

#include <SoftwareSerial.h>
SoftwareSerial radio(10, 11); // RX, TX
String data = "";
double readings;
const String meter_id = "M003"; //digits smart meter ID
//timming
unsigned long previousMillis = 0;
const long interval = 1000;
unsigned long timming = 10; //time laps for initializations
unsigned long count_in = 0; //for holding current counts


//hardware pins
const int relay = 12;
const int flow_sensor = 0;

//flow sesnor
volatile int flow_frequency; // Hold no of Pulses
double unit;
double total_unit;
//incomming data
String dataString; //main captured String
// Use https://arduinojson.org/v6/assistant to compute the capacity.
StaticJsonDocument<200> doc;

//EEPROM
 int address = 0;   //Location we want the data to be put.

void setup() {
  //Memory
  total_unit = EEPROM.read(address); //update

  //initialize pins here
  pinMode(relay, OUTPUT); //for relay
```

53

```
  pinMode(flow_sensor, INPUT_PULLUP); //for flow sensor
  //turn off valve
  digitalWrite(relay, LOW);

  attachInterrupt(flow_sensor, flow, RISING); // Setup Interrupt
  sei(); // Enable interrupts

  // Open serial communications and wait for port to open:
  Serial.begin(115200);
  // set the data rate for the SoftwareSerial port
  radio.begin(9600);
  lcd.begin(16,2);
  lcd.setCursor(0,0);
  lcd.print("Smart Meter");
  delay(2000);
  lcd.clear();
}

void loop() { // run over and over
  unsigned long currentMillis = millis(); //for timming
  if (currentMillis - previousMillis >= interval) {
    //update last time
    previousMillis = currentMillis;
    count_in ++;
    //calculate Litres/hour
    unit = unit+ (flow_frequency * 60 / 7.5); // (Pulse frequency x 60 min) /
7.5Q = flowrate in L/hour
    total_unit += unit;
    unit =0; //xero unit here

    flow_frequency = 0; // Reset Counter
    //clear lcd here
    lcd.clear();
    EEPROM.update(address, total_unit);
  }
  //check if time count is reaches
  if (count_in >= timming){
    //yes
    //send request
    send_request();
    //reset counts
    count_in = 0;
    //clear lcd here
    lcd.clear();
  }
  if (radio.available())  {
   char c = radio.read();  //gets one byte from serial buffer
   if (c == '>') {
     Serial.println(dataString); //prints string to serial port out
```

```cpp
    // Deserialize the JSON document
    DeserializationError error = deserializeJson(doc, dataString);
    if (error) {
      Serial.print(F("deserializeJson() failed: "));
      Serial.println(error.f_str());
      return;
    }
    //reset data
    dataString = ""; //clear buffer
    bool A = doc["A"]; // true
    const double B = doc["B"]; // unt
    const int C = doc["C"]; // "5"
    bool D = doc["D"]; // "Y"
    //check updates
    if (A == true){
      //update
      total_unit = B; //updating meter readings
      timming = C*60; //upadting poling time
      if (D == true){
        //turn on valve
        digitalWrite(relay, HIGH);
      } else if (D == false){
        //turn off valve
         digitalWrite(relay, LOW);
      }

    }else{
      //error
      lcd.clear();
      lcd.setCursor(0,0);
      lcd.print("Req Error");
      delay(2000);
    }
    Serial.println(A);
    Serial.println(B);
    Serial.println(C);
    Serial.println(D);
  }else{
    dataString += c; //makes the string readString
  }
 }


//LCD
lcd.setCursor(0,0);
lcd.print(":");
lcd.print(count_in);
lcd.setCursor(7,0);
lcd.print(":");
```

```
  lcd.print(timming);
  lcd.setCursor(0,1);
  lcd.print("Unit: ");
  lcd.print(total_unit);

}
//custom functions
void send_request(){
  //clear LCD
  lcd.setCursor(0,0);
  lcd.print("Sending Data...");
  delay(1000);
  //converting reading to string
  String readings = String(total_unit,2);
  //Sending data
  data = "{\"meterid\":\""+meter_id+"\",\"readings\":"+readings+"}";
  //send data
  radio.print(data);
  radio.println(); //end of sending request
}
 //flow sensor
void flow () // Interrupt function
{
   flow_frequency++;
}
```

Appendix 3: Dashboards Codes

```php
<?php require_once("include/connection.php"); ?>

<!DOCTYPE html>
<html lang="en">
<head>
  <title>Water Bill</title>
  <meta charset="utf-8">
  <meta name="viewport" content="width=device-width, initial-scale=1">
  <link rel="stylesheet"
href="https://maxcdn.bootstrapcdn.com/bootstrap/4.4.0/css/bootstrap.min.css">
  <script
src="https://ajax.googleapis.com/ajax/libs/jquery/3.4.1/jquery.min.js"></script>
  <script
src="https://maxcdn.bootstrapcdn.com/bootstrap/3.4.0/js/bootstrap.min.js"></script
>
</head>


<body>

<div class="container">
    <div class="row">
            <div class="col-sm-12">
                <!--    <center><img src="image/e3alog.png" ></center> -->
                    <center>Logo</center>

                <center>
                    <div class="alert alert-success" role="alert">
                    DASHBOARD REPORT
                    </div>
                </center>

                    <a href="clients.php"> <center><button type="submit"
class="btn btn-info"><b>Client Records</b></button> </center></a><br>
                    <a href="meter-reading.php"> <center><button type="submit"
class="btn btn-info"><b>Meter Reading Records</b></button> </center></a><br>
                    <a href="meterInfo.php"> <center><button type="submit"
class="btn btn-info"><b>Meter Info</b></button> </center></a><br>
                    <a href="#"> <center><button type="submit" class="btn btn-
info"><b>Zone Info</b></button> </center></a><br>
                    <a href="#"> <center><button type="submit" class="btn btn-
info"><b>Reports</b></button> </center></a><br>


            </div>
    </div>
</div>
```

```
</body>
</html>
```

```php
<?php
//header
header('Content-Type: application/json');
//set default time zone
date_default_timezone_set('Africa/Dar_es_Salaam');
//include db conenction here
include_once 'include/db.php';
//check
if (isset($_POST['action'])){
    //post is set
    //get post
    $action = $_POST['action'];
    if ($action == 'node-switch'){
        //update
        //get rest of the data
        $device_id = $_POST['thisId'];
        $value = $_POST['value'];
        if ($value == 'true'){
            $value_b = "Y";
        }else if($value == 'false'){
            $value_b = "N";
        }
        //update
        $update = $conn->prepare("UPDATE client_tbl SET status = :status WHERE
MeterNo = :id");
        $is_updated = $update->execute([
            "status" => $value_b,
            "id" => $device_id
        ]);
        if($is_updated){
            //yes
            $response['success'] = true;
            $response['msg'] = 'Success';
        }else{
            $response['success'] = false;
            $response['msg'] = 'Error on Update';
        }
    }else if($action == 'update-time'){
        //update time
        //get rest of the data
        $device_id = $_POST['thisId'];
        $value = $_POST['value'];
        //update
        $update = $conn->prepare("UPDATE client_tbl SET time_in_minutes = :time
WHERE MeterNo = :id");
```

```php
        $is_updated = $update->execute([
            "time" => $value,
            "id" => $device_id
        ]);
        if($is_updated){
            //yes
            $response['success'] = true;
            $response['msg'] = 'Success';
        }else{
            $response['success'] = false;
            $response['msg'] = 'Error on Update';
        }

    }else{
        //error
        $response['success'] = false;
        $response['msg'] = 'Uknown Request';
    }

}else{
    //error
    $response['success'] = true;
    $response['msg'] = 'Wrong Request';
}
//close connection
$conn = null;
echo json_encode($response);
?>
```

```php
<?php
include("include/connection.php");
?>

<!DOCTYPE html>
<html lang="en">
<head>
  <title>Client Records</title>
  <meta charset="utf-8">
  <meta name="viewport" content="width=device-width, initial-scale=1">

<!-- Latest compiled and minified CSS -->
<link rel="stylesheet"
href="https://stackpath.bootstrapcdn.com/bootstrap/3.4.1/css/bootstrap.min.css"
integrity="sha384-
HSMxcRTRxnN+Bdg0JdbxYKrThecOKuH5zCYotlSAcp1+c8xmyTe9GYg1l9a69psu"
crossorigin="anonymous">
<script
src="https://ajax.googleapis.com/ajax/libs/jquery/3.4.1/jquery.min.js"></script>
```

```html
<!-- Latest compiled and minified JavaScript -->
<!-- This is for search --->
<link rel="stylesheet"
href="https://use.fontawesome.com/releases/v5.6.3/css/all.css" integrity="sha384-
UHRtZLI+pbxtHCWp1t77Bi1L4ZtiqrqD80Kn4Z8NTSRyMA2Fd33n5dQ8lWUE00s/"
crossorigin="anonymous">
<link rel="stylesheet" href="https://unpkg.com/bootstrap-
table@1.15.5/dist/bootstrap-table.min.css">

        <!-- Slider          -->
        <style>
          .switch {
            position: relative;
            display: inline-block;
            width: 50px;
            height: 24px;
          }

          .switch input {
            opacity: 0;
            width: 0;
            height: 0;
          }

          .slider {
            position: absolute;
            cursor: pointer;
            top: 0;
            left: 0;
            right: 0;
            bottom: 0;
            background-color: #ccc;
            -webkit-transition: .4s;
            transition: .4s;
          }

          .slider:before {
            position: absolute;
            content: "";
            height: 16px;
            width: 16px;
            left: 4px;
            bottom: 4px;
            background-color: white;
            -webkit-transition: .4s;
            transition: .4s;
          }

          input:checked + .slider:before {
```

```
            -webkit-transform: translateX(26px);
            -ms-transform: translateX(26px);
            transform: translateX(26px);
          }

          /* Rounded sliders */
          .slider.round {
            border-radius: 34px;
          }

          .slider.round:before {
            border-radius: 50%;
          }
      </style>

</head>


<body>
      <!-- Modal Here -->
      <div class="modal fade" id="action-modal" tabindex="-1" role="dialog" aria-
labelledby="myModalLabel">
          <div class="modal-dialog" role="document" style=" width: 70%;">
            <div class="modal-content">
              <div class="modal-header">
                <button type="button" class="close" data-dismiss="modal" aria-
label="Close"><span aria-hidden="true">&times;</span></button>
                <h4 class="modal-title" id="myModalLabel"><b>Mita Namba:</b> <b
id="meter-id-head"></b></h4>
              </div>
              <div class="modal-body" style="min-height: 150px">
                  <div id="data-show"></div>
              </div>
              <div style="margin-bottom: 20px; text-align: right; padding-right:
30px;">

                  <button type="button" class="btn btn-primary" data-dismiss="modal"
style="font-weight:bold;">Close</button>
              </div>

          </div>
        </div>
      </div>

<div class="container">
    <div class="row">
        <div class="col-sm-12">
          <center>
                <div class="alert alert-success" role="alert">
                    CLIENT RECORDS
```

```php
            </div>
        </center>
         <a href="index.php"><button type="button" class="btn btn-info"
>Home</button></a>
            <table class="table table-hover"  cellspacing="0" width="100%" data-
toggle="table"  data-pagination="true"  data-search="true">
            <thead>
            <tr>
                <th scope="col">Client Name</th>
                <th scope="col">PhoneNo</th>
                <th scope="col">Email</th>
                <th scope="col">MeterNo</th>
                <th scope="col">Action</th>
            </tr>
            </thead>


            <tbody>


            <?php


            $result = mysqli_query($connection,"SELECT * FROM client_tbl" );
            while($row = mysqli_fetch_array($result)) {
            ?>
              <tr>
               <td><?php echo $row['1']; ?></a></td>
               <td><?php echo $row['2']; ?></a></td>
               <td><?php echo $row['3']; ?></a></td>
               <td><?php echo $row['5']; ?></td>
               <td> <button type="button" style="font-weight: bold;" deviceId =
"<?php echo $row['5']; ?>" class="btn btn-danger btn-sm action-btn"
>Action</button></td>
            <?php  }  ?>
                </tr>
            </tbody>
            </table>
        </div>
    </div>
</div>


<!---- For search in Table --->
    <script src="https://code.jquery.com/jquery-3.6.0.min.js" integrity="sha256-
FgpCb/KJQlLNfOu91ta32o/NMZxltwRo8QtmkMRdAu8=" crossorigin="anonymous"></script>
    <script
src="https://cdnjs.cloudflare.com/ajax/libs/popper.js/1.14.7/umd/popper.min.js"
integrity="sha384-
UO2eT0CpHqdSJQ6hJty5KVphtPhzWj9WO1clHTMGa3JDZwrnQq4sF86dIHNDz0W1"
crossorigin="anonymous"></script>
    <!-- Latest compiled and minified JavaScript -->
```

```
    <script
src="https://stackpath.bootstrapcdn.com/bootstrap/3.4.1/js/bootstrap.min.js"
integrity="sha384-
aJ21OjlMXNL5UyIl/XNwTMqvzeRMZH2w8c5cRVpzpU8Y5bApTppSuUkhZXN0VxHd"
crossorigin="anonymous"></script>
    <script src="https://unpkg.com/bootstrap-table@1.15.5/dist/bootstrap-
table.min.js"></script>
    <script type="text/javascript">
        //modified by Tunu Yolim Ngajilo, 2021
        $(document).on('click', '.action-btn', function(){
          $('#action-modal').modal('show');
          var Id = $(this).attr('deviceId');
          $('#device-this-id').val(Id);
          $('#meter-id-head').html(Id);
          $('#data-show').load('update.php?id='+Id);
        });
        $(document).on('click', '#toggle-switch', function(){
          var action = 'node-switch';
          var value = $('#toggle-switch').is(":checked");
          var thisId = $('#meter-id-head').html();
           $.ajax({
              url:"action.php",
              method:"POST",
              data:{action:action, value:value, thisId:thisId},
              success:function(response){
              if(response.success == true){
                  $('#data-show').load('update.php?id='+thisId);
              }

              }
            });
        });
        $(document).on('click', '#update-time', function(){
          var action = 'update-time';
          var value = $('#time').val();
          var thisId = $('#meter-id-head').html();
           $.ajax({
              url:"action.php",
              method:"POST",
              data:{action:action, value:value, thisId:thisId},
              success:function(response){
              if(response.success == true){
                  $('#data-show').load('update.php?id='+thisId);
              }

              }
            });
        });
    </script>
```

```html
</body>
</html>
```

```php
<?php require_once("include/connection.php");

$from = '2017-01-01';
$to ='2021-12-31';


//First Chart on the Report
$query = "SELECT
tblgroup.grpName,
COUNT(*) AS TOTAL

FROM tblstudent

JOIN tblgroup ON (tblgroup.grpNo = tblstudent.grpNo)
GROUP BY grpName";
$result = mysqli_query($connection,$query);
    if (!$result) { die("Query Failed."); }

    while($row = mysqli_fetch_array($result))
    {

        $dataPoints[] = [
            'label' => $row[0],
            'y' => $row[1]
        ];

    //   echo $row[0];
    //   echo $row[1];


    }



// Second chart
$query2 = "SELECT SchoolName,COUNT(*) AS Total FROM data_gover_school group by
SchoolName";
$result2 = mysqli_query($connection,$query2);
    if (!$result2) { die("Query Failed."); }

    while($row2 = mysqli_fetch_array($result2))
    {

        $dataPoints2[] = [
```

```php
                'label' => $row2[0],
                'y' => $row2[1]
            ];


        //echo $row2[0];
        //echo $row2[1];


    }



// Third chart for Compassion
$query3 = "SELECT clusterName,
count(*) AS Total
FROM ci_statistics
WHERE scStartDate BETWEEN '2018-01-01' AND  '2021-12-31'
group by clusterName";


$result3 = mysqli_query($connection,$query3);
    if (!$result3) { die("Query Failed."); }

    while($row3 = mysqli_fetch_array($result3))
    {

        $dataPoints3[] = [
            'label' => $row3[0],
            'y' => $row3[1]
        ];


    //    echo $row3[0];
    //    echo $row3[1];

        //$Course[] = $row[0];
      //$Count[] = $row[1];
    }



// Media chart for E3A
$query4 =  "SELECT  tblmedia.mediaSource,
COUNT(*) AS Total
FROM tblmedia
JOIN tblstudentintake ON (tblmedia.mediaID = tblstudentintake.mediaID)
GROUP BY mediaSource";


$result4 = mysqli_query($connection,$query4);
    if (!$result4) { die("Query Failed."); }
```

```php
    while($row4 = mysqli_fetch_array($result4))
    {

        $dataPoints4[] = [
            'label' => $row4[0],
            'y' => $row4[1]
        ];



    //     echo $row3[0];
    //     echo $row3[1];


        //$Course[] = $row[0];
    //$Count[] = $row[1];
    }


?>
```

```html
<!DOCTYPE html>
<html lang="en">
<head>
  <title>E3EMPOWER AFRICA</title>
  <meta charset="utf-8">
  <meta name="viewport" content="width=device-width, initial-scale=1">
  <link rel="stylesheet"
href="https://maxcdn.bootstrapcdn.com/bootstrap/4.4.0/css/bootstrap.min.css">
  <script
src="https://cdnjs.cloudflare.com/ajax/libs/Chart.js/3.1.0/chart.min.js"></script>
  <script
src="https://ajax.googleapis.com/ajax/libs/jquery/4.4.1/jquery.min.js"></script>
  <script
src="https://maxcdn.bootstrapcdn.com/bootstrap/4.4.0/js/bootstrap.min.js"></script
>
</head>


<body>

<div class="container">
    <!-- First Row start Here --->
        <div class="row">
            <div class="col-sm-12">
                <center><img src="image/e3alog.png" ></center>

                <center>
                    <div class="alert alert-success" role="alert">
                    MAIN REPORT
                    </div>
```

66

```php
                    </center>
                </div>
            </div>
    <!-- First Row Ends Here --->

     <div class="row">

                <div class="col-sm-4" >
                    <?php
                    $query11 = "SELECT COUNT(*) FROM tblstudent";

                            $result11 = mysqli_query($connection,$query11);
                            if (!$result11) { die("Query Failed."); }

                            while($row11 = mysqli_fetch_array($result11))
                            {
                    ?>

                        <div><center><h1
style="color:#668080"><b>Total</b></h1></center></div>
                        <div><center><p style="font-size:80px;
color:#668080;"><b><?php echo $row11[0];?></b></p></center></div>
                        <?php } ?>
                        <div><hr style="height:2px;border-
width:0;color:gray;background-color:gray"></div>

                </div>


                <div class="col-sm-4" >
                    <?php
                    $query8 = "SELECT count(*) FROM tblstudent WHERE Sex = 'M'";

                            $result8 = mysqli_query($connection,$query8);
                            if (!$result8) { die("Query Failed."); }

                            while($row8 = mysqli_fetch_array($result8))
                            {
                    ?>

                        <div><center><h1
style="color:#2C8975"><b>Male</b></h1></center></div>
                        <div><center><p style="font-size:80px;
color:#2C8975;"><b><?php echo $row8[0];?></b></p></center></div>
                        <?php } ?>
                        <div><hr style="height:2px;border-
width:0;color:gray;background-color:gray"></div>

                </div>
```

```php
                    <div class="col-sm-4" >

                    <?php
                      $query9 = "SELECT count(*) FROM tblstudent WHERE Sex = 'F'";

                            $result9 = mysqli_query($connection,$query9);
                            if (!$result9) { die("Query Failed."); }

                            while($row9 = mysqli_fetch_array($result9))
                            {
                     ?>

                            <div><center><h1 style="color:#796680
"><b>Female</b></h1></center></div>
                            <div><center><p style="font-size:80px;
color:#796680"><b><?php echo $row9[0];?></b></p></center></div>
                            <?php } ?>
                            <div><hr style="height:2px;border-
width:0;color:gray;background-color:gray"></div>
                      </div>


                    <div class="col-sm-6" >
                        <div id="chartContainer" style="height: 370px; width:
100%;"></div>
                        <div><hr style="height:2px;border-
width:0;color:gray;background-color:gray"></div>
                      </div>


                    <div class="col-sm-6" >
                        <div id="chartContainer2" style="height: 370px; width:
100%;"></div>
                        <div><hr style="height:2px;border-
width:0;color:gray;background-color:gray"></div>
                      </div>



                    <div class="col-sm-6" >
                        <div id="chartContainer3" style="height: 370px; width:
100%;"></div>
                        <div><hr style="height:2px;border-
width:0;color:gray;background-color:gray"></div>
                      </div>


                    <div class="col-sm-6" >
```

68

```html
                              <div id="chartContainer4" style="height: 370px; width:
100%;"></div>
                              <div><hr style="height:2px;border-
width:0;color:gray;background-color:gray"></div>
                    </div>

                </div>
            </div>
        </div>
</div>


<script src="https://canvasjs.com/assets/script/canvasjs.min.js"></script>
</body>
</html>


<script>window.onload = function() {

// Chart for Other Groups includinG E3A institution.
 var chart = new CanvasJS.Chart("chartContainer", {
     animationEnabled: true,
     title: {
         text: "E3A + Other Groups"
     },
     subtitles: [{
         text: ""
     }],
     data: [{
         type: "bar",
         yValueFormatString: "###",
         indexLabel: "{y}",
         dataPoints: <?php echo json_encode($dataPoints, JSON_NUMERIC_CHECK); ?>
     }]
 });


// Chart for Government school
 var chart2 = new CanvasJS.Chart("chartContainer2", {
     animationEnabled: true,
     title: {
         text: "Government School"
     },
     subtitles: [{
         text: ""
     }],
     data: [{
         type: "bar",
         yValueFormatString: "###",
         indexLabel: "{y}",
```

```php
            dataPoints: <?php echo json_encode($dataPoints2, JSON_NUMERIC_CHECK); ?>
        }]
    });


    // Chart for Government school
    var chart3 = new CanvasJS.Chart("chartContainer3", {
        animationEnabled: true,
        title: {
            text: "Compassion Statistics"
        },
        subtitles: [{
            text: ""
        }],
        data: [{
            type: "bar",
            yValueFormatString: "###",
            indexLabel: "{y}",
            dataPoints: <?php echo json_encode($dataPoints3, JSON_NUMERIC_CHECK); ?>
        }]
    });

     // Chart for Media Source
     var chart4 = new CanvasJS.Chart("chartContainer4", {
        animationEnabled: true,
        title: {
            text: "Media Source Statistics"
        },
        subtitles: [{
            text: ""
        }],
        data: [{
            type: "pie",
            yValueFormatString: "###",
            indexLabel: "{label}",
            dataPoints: <?php echo json_encode($dataPoints4, JSON_NUMERIC_CHECK); ?>
        }]
    });

chart.render();
chart2.render();
chart3.render();
chart4.render();

}

 </script>
```

```php
<?php
include("include/connection.php");
?>

<!DOCTYPE html>
<html lang="en">
<head>
  <title>Meter Info</title>
  <meta charset="utf-8">
  <meta name="viewport" content="width=device-width, initial-scale=1">

<link rel="stylesheet"
href="https://maxcdn.bootstrapcdn.com/bootstrap/4.4.0/css/bootstrap.min.css">
<script
src="https://ajax.googleapis.com/ajax/libs/jquery/3.4.1/jquery.min.js"></script>
 <script
src="https://maxcdn.bootstrapcdn.com/bootstrap/4.4.0/js/bootstrap.min.js"></script
>



  <!-- This is for search --->
  <link rel="stylesheet"
href="https://use.fontawesome.com/releases/v5.6.3/css/all.css" integrity="sha384-
UHRtZLI+pbxtHCWp1t77Bi1L4ZtiqrqD80Kn4Z8NTSRyMA2Fd33n5dQ8lWUE00s/"
crossorigin="anonymous">
   <link rel="stylesheet" href="https://unpkg.com/bootstrap-
table@1.15.5/dist/bootstrap-table.min.css">
</head>


<body>

<div class="container">
    <div class="row">
        <div class="col-sm-12">

          <center>
                  <div class="alert alert-success" role="alert">
                      METER RECORDS
                  </div>
          </center>


          <a href="index.php"><button type="button" class="btn btn-info"
>Home</button></a>
```

```
            <table class="table table-hover"   cellspacing="0"  data-
toggle="table"  data-pagination="true"  data-search="true">
                <thead>
                  <tr>



                    <th scope="col">MeterNo</th>
                    <th scope="col">Action</th>



                  </tr>
                </thead>

                <tbody>

                <?php

                $result = mysqli_query($connection,"SELECT * FROM meter_tbl" );

                    while($row = mysqli_fetch_array($result)) {

                ?>


                  <tr>

                   <td><?php echo $row['0']; ?></a></td>
                   <td><a href="student-update.php?studentID=<?php echo $row['1'];
?>"><button type="button" class="btn btn-info btn-sm" >Action1</button> </a> | <a
href="student-update-marks.php?studentID=<?php echo $row['1']; ?>"><button
type="button" class="btn btn-danger btn-sm" >Action2</button></a></td>


                    <?php  }  ?>

                  </tr>


                </tbody>

            </table>

        </div>
    </div>
</div>


<!---- For search in Table --->
```

72

```html
    <script src="https://code.jquery.com/jquery-3.3.1.min.js" integrity="sha256-
FgpCb/KJQlLNfOu91ta32o/NMZxltwRo8QtmkMRdAu8=" crossorigin="anonymous"></script>
    <script
src="https://cdnjs.cloudflare.com/ajax/libs/popper.js/1.14.7/umd/popper.min.js"
integrity="sha384-
UO2eT0CpHqdSJQ6hJty5KVphtPhzWj9WO1clHTMGa3JDZwrnQq4sF86dIHNDz0W1"
crossorigin="anonymous"></script>
    <script
src="https://stackpath.bootstrapcdn.com/bootstrap/4.3.1/js/bootstrap.min.js"
integrity="sha384-
JjSmVgyd0p3pXB1rRibZUAYoIIy6OrQ6VrjIEaFf/nJGzIxFDsf4x0xIM+B07jRM"
crossorigin="anonymous"></script>
    <script src="https://unpkg.com/bootstrap-table@1.15.5/dist/bootstrap-
table.min.js"></script>

</body>

</html>


<?php
include("include/db.php");
?>

<!DOCTYPE html>
<html lang="en">
<head>
  <title>Meter Reading</title>
  <meta charset="utf-8">
  <meta name="viewport" content="width=device-width, initial-scale=1">

<link rel="stylesheet"
href="https://maxcdn.bootstrapcdn.com/bootstrap/4.4.0/css/bootstrap.min.css">
<script
src="https://ajax.googleapis.com/ajax/libs/jquery/3.4.1/jquery.min.js"></script>
<script
src="https://maxcdn.bootstrapcdn.com/bootstrap/4.4.0/js/bootstrap.min.js"></script
>



  <!-- This is for search --->
  <link rel="stylesheet"
href="https://use.fontawesome.com/releases/v5.6.3/css/all.css" integrity="sha384-
UHRtZLI+pbxtHCWp1t77Bi1L4ZtiqrqD80Kn4Z8NTSRyMA2Fd33n5dQ8lWUE00s/"
crossorigin="anonymous">
    <link rel="stylesheet" href="https://unpkg.com/bootstrap-
table@1.15.5/dist/bootstrap-table.min.css">
    <style type="text/css">
      .zero {
```

```
            background-color: red;
            color: white;
            font-weight: bold;
        }

    </style>
</head>


<body>
<div class="container">
    <div class="row">
        <div class="col-sm-12">


            <center>
                    <div class="alert alert-success" role="alert">
                        METER READINGS
                    </div>
            </center>


            <a href="index.php"><button type="button" class="btn btn-
primary">Home</button></a>


            <table class="table table-hover"   cellspacing="0" width="100%" data-
toggle="table"  data-pagination="true"  data-search="true">
                <thead>
                  <tr>
                    <th scope="col">ClientID</th>
                    <th scope="col">ClinetName</th>
                    <th scope="col">ZoneName</th>
                    <th scope="col">MeterNo</th>
                    <th scope="col">Units_Reading</th>
                    <th scope="col">DateTime</th>

                  </tr>
                </thead>

                <tbody>

                <?php
                $result = $conn->prepare("SELECT * FROM meter_reading_tbl ORDER BY
ID DESC");

                $result->execute();
                //check if there is data
                $is_data = $result->rowCount();
                if ($is_data > 0){
```

```php
                //there is data
                while($row = $result->fetch(PDO::FETCH_ASSOC)) {
                    //get meter number
                    $meter_no = $row['MeterNo'];
                    //select user data
                    $user = $conn->prepare("SELECT * FROM client_tbl WHERE MeterNo
= :meter");

                    $user->execute([
                        "meter" => $meter_no
                    ]);
                    //get user records
                    $user_data = $user->fetch(PDO::FETCH_ASSOC);
                ?>
                    <tr <?php if ($row['Units'] <= 0){echo 'class="zero"';}
?>>

                        <td><?php echo $user_data['ClientID']; ?></td>
                        <td><?php echo $user_data['ClientName']; ?></td>
                        <td><?php echo $user_data['ZoneID']; ?></td>
                        <td><?php echo $row['MeterNo']; ?></td>
                        <td><?php echo $row['Units']; ?></td>
                        <td><?php echo $row['DateTime']; ?></td>

                    <?php  }
                }else{
                  //no data
                  ?>
                   <label>No data Availbale</label>
                  <?php
                }
                ?>

                    </tr>



                </tbody>

            </table>

        </div>
    </div>
</div>


<!---- For search in Table --->
    <script src="https://code.jquery.com/jquery-3.3.1.min.js" integrity="sha256-
FgpCb/KJQlLNfOu91ta32o/NMZxltwRo8QtmkMRdAu8=" crossorigin="anonymous"></script>
    <script
src="https://cdnjs.cloudflare.com/ajax/libs/popper.js/1.14.7/umd/popper.min.js"
```

```
integrity="sha384-
UO2eT0CpHqdSJQ6hJty5KVphtPhzWj9WO1clHTMGa3JDZwrnQq4sF86dIHNDz0W1"
crossorigin="anonymous"></script>
    <script
src="https://stackpath.bootstrapcdn.com/bootstrap/4.3.1/js/bootstrap.min.js"
integrity="sha384-
JjSmVgyd0p3pXB1rRibZUAYoIIy6OrQ6VrjIEaFf/nJGzIxFDsf4x0xIM+B07jRM"
crossorigin="anonymous"></script>
    <script src="https://unpkg.com/bootstrap-table@1.15.5/dist/bootstrap-
table.min.js"></script>

</body>

</html>
```

```php
<?php
//The url you wish to send the POST request to
$url = 'http://dev.site2.com/device_API.php';

//The data you want to send via POST
$fields = [
    'meter_id'      => 'M003',
    'readings'      => 123.90
];

//url-ify the data for the POST
$fields_string = http_build_query($fields);

//open connection
$ch = curl_init();

//set the url, number of POST vars, POST data
curl_setopt($ch,CURLOPT_URL, $url);
curl_setopt($ch,CURLOPT_POST, true);
curl_setopt($ch,CURLOPT_POSTFIELDS, $fields_string);

//So that curl_exec returns the contents of the cURL; rather than echoing it
curl_setopt($ch,CURLOPT_RETURNTRANSFER, true);

//execute post
$result = curl_exec($ch);
echo $result;
?>
```

```php
<?php
```

```php
//header
header('Content-Type: application/json');
//set default time zone
date_default_timezone_set('Africa/Dar_es_Salaam');
//include db conenction here
include_once 'include/db.php';
//get data
$meter_id = $_GET['id'];
//fetch data
$select =$conn->prepare("SELECT * FROM client_tbl WHERE MeterNo = :thisid");
$select->execute([
    "thisid" => $meter_id
]);
//check if there is data
$count = $select->rowCount();
if($count == 1){
 //yes there is data
    //get data
    $data = $select->fetch(PDO::FETCH_ASSOC);
    if ($data['status'] == 'Y'){
        //valve is on
        ?>
        <style type="text/css">
          input:checked + .slider {
            background-color: #990000;
          }

          input:focus + .slider {
            box-shadow: 0 0 1px #990000;
          }
        </style>
          <div class="row">
            <div class="col-sm-4" style="border-style: solid; border-width: 1px;
border-color: lightgrey; padding:10px; min-height: 140px;">
                <label>Funga/Fungua Valve ya Maji</label>
                <div>
                    <label>Status: </label><label style="margin-left: 10px;
color:#990000;">ON</label>
                </div>
                 <div style="margin-top: 30px;">
                    <b style="font-size:11px; font-weight:normal; margin-right:
10px; color: grey;">Zima/Washa</b>
                    <!-- Slider here -->
                    <label class="switch" >
                      <input type="checkbox" style="color: #990000;" id="toggle-
switch" checked = "checked">
                      <span class="slider round"></span>
                    </label>
                </div>
```

```php
            </div>
            <div class="col-sm-4" style="border-style: solid; border-width: 1px;
border-color: lightgrey; padding:10px; min-height: 140px;">
                <label>Update Time:</label>
                <div>
                    <label>Current: </label><label style="margin-left:20px;font-
size:20px"><?php echo $data['time_in_minutes']; ?></label>
<label>Minutes</label>
                </div>
                <div>
                    <input type="text" id="time" value="<?php echo
$data['time_in_minutes']; ?>">
                </div>
                <div style="margin-top:12px;">
                    <button class="btn btn-primary" style="font-weight: bold;"
id="update-time">Update</button>
                </div>
            </div>
            <div class="col-sm-4" style="border-style: solid; border-width: 1px;
border-color: lightgrey; padding:10px; min-height: 140px;">
                <label style="font-size: 30px;">Meter Readings: </label>
                <div>
                    <label style="font-size: 35px; margin-left: 20px;"><?php echo
$data['readings']; ?></label>
                    <label style="font-size: 30px;"> L/h</label>
                </div>

            </div>

    </div>
        <?php

    }else if ($data['status'] == 'N'){
        //valve is off
        ?>
            <style type="text/css">
              input:checked + .slider {
                background-color: green;
              }

              input:focus + .slider {
                box-shadow: 0 0 1px green;
              }
            </style>
              <div class="row">
                <div class="col-sm-4" style="border-style: solid; border-width:
1px; border-color: lightgrey; padding:10px; min-height: 140px;">
                    <label>Funga/Fungua Valve ya Maji</label>
                    <div>
```

```html
                    <label>Status: </label><label style="margin-left: 10px;
color:green;">OFF</label>
                </div>
                <div style="margin-top: 30px;">
                    <b style="font-size:11px; font-weight:normal; margin-
right: 10px; color: grey">Zima/Washa</b>
                    <!-- Slider here -->
                    <label class="switch" >
                      <input type="checkbox" id="toggle-switch">
                      <span class="slider round"></span>
                    </label>
                  </div>
            </div>
            <div class="col-sm-4" style="border-style: solid; border-width:
1px; border-color: lightgrey; padding:10px; min-height: 140px;">
                <label>Update Time:</label>
                <div>
                    <label>Current: </label><label style="margin-left:20px;
font-size:20px"><?php echo $data['time_in_minutes']; ?></label>
<label>Minutes</label>
                </div>
                <div>
                    <input type="text" id="time" value="<?php echo
$data['time_in_minutes']; ?>">
                </div>
                <div style="margin-top:12px;">
                    <button class="btn btn-primary" style="font-weight: bold;"
id="update-time">Update</button>
                </div>
            </div>
            <div class="col-sm-4" style="border-style: solid; border-width:
1px; border-color: lightgrey; padding:10px; min-height: 140px;">
                <label style="font-size: 30px;">Meter Readings: </label>
                <div>
                    <label style="font-size: 35px; margin-left: 20px;"><?php
echo $data['readings']; ?></label>
                    <label style="font-size: 30px;"> L/h</label>
                </div>

            </div>

   </div>
        </div>
     <?php
   }

}else{
   //error
   echo "No Data";
```

```php
}

//close connection
$conn = null;
?>
```

```php
//close connection
$conn = null;
?>
```

Appendix 4: Codes for device API

```php
<?php
//header
header('Content-Type: application/json');
//set default time zone
date_default_timezone_set('Africa/Dar_es_Salaam');
//include files here
include_once 'include/db.php';
$_POST = json_decode(file_get_contents('php://input'), true);
//get post data
if (isset($_POST['meter_id'])){
    //yes device is set, get rest of the data
    $meter_id = $_POST['meter_id'];
    $readings = $_POST['readings'];
    $datetime = date('Y-m-d h:i:s');
    //check if meter exist
    $verify = $conn->prepare("SELECT * FROM client_tbl WHERE MeterNo =
:meter_no");
    $verify->execute([
        "meter_no" => $meter_id
    ]);
    $count = $verify->rowCount();
    if ($count == 1){
        //get full node data
        $node_data   = $verify->fetch(PDO::FETCH_ASSOC);
        $time        = $node_data['time_in_minutes'];
        $node_status = $node_data['status'];
        if ($node_status == 'Y'){
          $node_status = true;
        }else if ($node_status == 'N'){
          $node_status = false;
        }
        //zero reading section here
        $previous_reading = $node_data['readings'];
        $current_readings = $readings;
        //get the difference btn last sent data and current received data
        $cons = $previous_reading-$current_readings //water consumption in Litres
        //check if cons is negative value
        if ($cons <0 OR $cons == 0){
            //is negative equalize (no negative value)
            $cons = 0;
            $zero_reading = 'Y';
        }else{
            //Non Zero Non Negative value
            $zero_reading = 'N';
        }
        //record statistical Data
```

```php
        $insert = $conn->prepare("INSERT INTO meter_reading_tbl(MeterNo, Units,
zero_reading, DateTime) VALUE(:meter_no, :reading, :zero_reading, :datetime)");
        $status = $insert->execute([
            "meter_no"      => $meter_id,
            "reading"       => $cons,
            ":datetime"     => $datetime,
            ":zero_reading" => $zero_reading //recording presence or absence of
zero value on DB
        ]);
        if ($status){
            //data is inserted, updating data on node
            $update = $conn->prepare("UPDATE client_tbl SET readings = :readings
WHERE MeterNo = :meter_id");
            $u_status = $update ->execute([
                "readings" => $readings,
                "meter_id" => $meter_id
            ]);
            if($u_status){
                //success
                //construct response here
                $response['A']   = true;           //response status
                $response['B']   = $node_data['readings']; //unit reading
                $response['C']   = $time;           //time
                $response['D']   = $node_status;    //status

            }else{
                // error
                $response['A'] = false;
                $response['B'] = 'Error on Update';
                $response['C']   = '';
                $response['D']   = '';
            }

        }else{
            //error
            $response['A'] = false;
            $response['B'] = 'Error on Insert';
            $response['C']   = '';
            $response['D']   = '';
        }
    }else{
        //errror
        $response['A'] = false;
        $response['B'] = 'Error, Unkwon Device';
        $response['C']   = '';
        $response['D']   = '';
    }

}else{
```

```php
    $response['A'] = false;
    $response['B'] = "Wrong Request";
    $response['C']      = '';
    $response['D']    = '';
}
//close connection
$conn = null;
//echo response
echo json_encode($response);
?>
```