UNIVERSITY OF NAIROBI

A QUERY SYSTEM BY USE OF INTERNET OF THINGS TO MONITOR WATER AVAILABILITY AT WATER POINTS IN ARID AND SEMI-ARID LANDS IN KENYA

By

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P53/65824/2013

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A Report Presented to The School of Computing and Informatics at the University of Nairobi in Partial Fulfillment for the Award of a Degree of Master of Science in Distributed Computing Technology.

NOVEMBER, 2016.

DECLARATION

I, Emmanuel Kipkoech Rop, do hereby declare that this research project is entirely my own work and where there is work or contributions of other individuals, it has been duly acknowledged. To the best of my knowledge, similar research work has not been carried out before or previously presented to any other educational institution in the world of similar purposes or form.

Sign: ---------- Date: ----------

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This project has been submitted in partial fulfillment of the requirement for the Master of Science degree in Distributed Computing Technology of the University of Nairobi with my approval as the University supervisor.

Sign: ---------- Date: ----------

Dr. Andrew Kahonge

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DEDICATION

I would like to dedicate this study to my wonderful family, my wife Vivian, my future children, dad Mathew Tonui, Mum Rebecca Tonui, my sisters Dr. Florence Tonui, Zeddy Tonui; Brothers Gilbert, Enoch, Shadrack; Sisters-in-law Audrey, Florence, Edna; Nieces: Kalia, Cherchech, Chere; Nephews: Roni and Remi.

“

ACKNOWLEDMENTS

I would like to first thank God for the giving me the might and good health as I pursued this degree. Secondly, I thank my supervisor Dr. Andrew Kahonge for having seen me through this entire process and accommodating my impromptu visits to his office for guidance. I also wish to pass my warmest gratitude to my parents for their daily encouragement and inquiry and round the clock availability for financial support. I want to sincerely thank my wife Vivian for having to put up with my working late as I worked on this project as well as her words of encouragement. I thank Uganda Ltd., for having provided me with the resources especially hardware equipment used in this project. Oscar Obuobu won't be forgotten. His skills with the electronic hardware was so invaluable and I thank him for that. And last but not least all my OCHI AGC church leadership, relatives and friends who always had me in their prayers and often-sent their words of encouragement each and every time.

ABSTRACT

At the end of 2011, an estimated 768 million people did not use an improved source for drinking-water. 84% of the people who don't have access to improved water, live in rural areas, where they live principally through subsistence agriculture.

Kenya has a population estimated at 38.6 million, 80% of Kenya is classed as ASALs. Water is a scarce resource in arid and semi-arid areas resulting to it being highly sought among people living within.

Nonetheless some people in ASAL have to trek for long miles in order to find this precious commodity for drinking, daily use and for their livestock. Most of the time they end up on empty water points.

This research sought to find ways to develop a query system using IoT, integrated with SMS applications to provide timely and accurate information to users through the feature phones.

The study used descriptive research method while interviews and questionnaires coded into ODK was the mode of data collection.

It was then sampled using Microsoft Excel software and the findings presented in graphical representation and tables. Level of water at two water points were put under watch using the sensors and it became evident that approximately 112 hours can be saved in every 30 people per day. It was also noted that the GPRS module connected to the sensor and an Arduino board has a successful submission rate of 98%.

LIST OF ACRONYMS

API - Application Programming Interface

ASALs Arid and semi-arid Lands

WSN - Wireless Sensor Networks

WP - Water Point

IoT- Internet of Things

WPM - Water Point Mapping

GSM - Global System for Mobile Communications

GPRS – General Radio Packet Service

SMS - Short Messaging Service

LORA - Long Range

ODK – OpenData Kit

WHO -World Health Organization

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1. INTRODUCTION

In the world today, 84% of the population lives in the driest half of the planet. 783 million people do not have access to clean and safe water. Of them, 37% are within the Sub-sahara.

About 443 million of school going days are lost every year due to water-related illnesses. 84% of the people without improved water sources, live in rural areas, where they live mainly through subsistence agriculture and pastoralism. The World Health Organization notes that by 2025, 1800 million people will be living in countries or regions with absolute water scarcity, and two-thirds of the world population could be under stress conditions (UNDP, 2009).

In the arid areas, about 2 million people are permanently on famine relief and it could rise to 5 million during extreme droughts. Acute malnutrition rates are experienced by over 15 percent in children under five. Kenya has a population estimated at 38.6 million (Kobo, 2010).

Approximately 80% is classified as Arid and Semi-Arid Lands which could be approximately which is estimated at twelve million people. With these numbers, there is hardly a good informational system to pass accurate information to the people who utilize the watering points.

1.1. Background

Almost two-thirds, 64% of households have the women sourcing water when there's a shortage at home. By having clean water to the homes, its estimated that 411 million days will be gained with healthy status.

According to the Joint Monitoring Program's 2012 report, access to safe water supplies throughout Kenya is 59% as to that of improved sanitation is 32% (JMP, 2012). With the changing weather patterns, water provision becomes a challenge leading to high need for water both in the rural and urban areas.

Lack of water has also led to diseases such as pneumonia and causing deaths to children less than 5 years.

Children waste learning precious time in seeking water as some water points may have dried up or have insufficient water. Accessibility to some of the diminishing resource water points have led to conflicts among the people in protecting/fighting for the little available water.

In a bid to couple these upcoming technologies with how they can be implemented to solve our daily problems, we are enabled the problem in-depth which concluded that IoT may greatly help solve some of the problems experienced in water scarce areas. This environment was also interface with an SMS query application where queries can be submitted in a specified structure. The system checks for the latest logged value in the database corresponding to the water point inquired then responds accordingly, even informing a user of options when the water point has no water or is dysfunctional.

1.2. Problem Statement

Water and sanitation is essential for public health and the achievement of sustainable social and economic development. In cognizance of this, the Kenyan government has enshrined the right to safe water and adequate sanitation in the Constitution. Over the last decade, government and non-state actors have been implementing programs to increase water coverage in the country. However, the progress has been slowed by inadequate information for use in planning that has led to duplication of interventions in some areas whereas other areas remain underserved.

According to the United Nations, Kenya is one of the struggling populations in the world. With an approximation of 46 million, the country's poverty index has also continued to steadily rise (Shonaya, 2015).

Women walk for miles to fetch water from water points which could not have clean water. The average distance to watering points for households was 5.4 km. Main water sources in use for domestic and livestock in the county were: Pans Dams (47%), Natural Rivers (35%), springs and Wells (9%) (NDMA, 2014).

The United Nations estimates that Sub-Saharan Africa alone loses 40 billion hours per year collecting water; the same as an entire year's labor in all of France.

Therefore, is need to develop a query system that works well in these harsh conditions and can accurately work to get information to the people so as to reduce the average waste of time spent on searching for water.

1.3. Research Questions

1. What are the various ways in which communities living in the ASAL know about water points?
2. What information would people want to know about a water point?
3. What average time taken by a person to access another water point in an event of not getting water in the first water point?
4. How can IoT be used to inform the people for them to make informed decision?

1.4. Objectives

The overall objective was to first understand the various ways in which residents in ASAL areas access information which will guided the research to get the best possible means to provide this information to residents.

1. To know how people, get information regarding water points.
2. To determine the information required from a water point for effective communication.
3. To reduce the average time taken to locate and access the next water point.
4. To develop a query system that can read water level values and relay relevant information to the users.

1.5. Justification of Study

The use of the upcoming technology of IoT and sensors shall also prove that indeed science and technology has come of age in solving the common problems facing people in the society, just as

it has been successfully in other similar circumstances. The use of SMS based query system shows that a wide no of users are reached regardless of the phones they are using.

1.6. Relevance of study to Science

The use IoT in hardship environments has changed the way things are done making it a lot easier to study the environment and 'things'. With these gadgets powered by solar panels or long lasting battery packs, it makes it easier to deploy and remotely manage them.

IoT utilizes the use of embedded systems which makes electronic the basis, transmission of data which involves telecommunication and programming this circuit board as well as data mining and analysis which is covered in computing.

1.7. Relevance of study to the people living in ASALs

With the outcome of this study, it is important to note that there is an alternate solution which is accurate, quick and timely in getting information about water points.

This will directly impact their livelihoods, better health, poverty reduction and more time to do other activities, e.g. going to school for children, agricultural activities etc.

(Akpata, 2014) finds out that after learning how to harvest water in Matuna, classes are full again. Schools affected by water trekking for many Kilometers in the past have established environmental clubs that educate children about water shortages and environmental conservation.

1.8. Relevance of study to the Governing authorities

With an extension to this system, the authorities now have a channel to understand and better manage the water resource with a better understanding on the various patterns of usage of water point and how it impacts the society and how to better enhance utilization of these water points.

1.9. Scope

The research was carried out to establish the channels of how locals get information on water points and water availability as well as time taken to trace the next water point.

It focused on borehole type of water point during implementation of the application.

A query system application was developed and integrated to an IoT environment to monitor water availability and relay the information to the people via GSM network to a mobile phone in a form of SMS.

1.10. Assumptions

It was assumed that all water points are within the research area and water point are boreholes.

2. LITERATURE REVIEW

In the world today, technologies have evolved and does our way of life. We are witnessing a growth of smart systems, smart grid, smart cars, intelligent homes, smart water networks, intelligent transportation, agricultural systems are infrastructure systems that virtually connect our world more than we ever thought possible. Embedded devices are knit together to present a smart way to monitor the varid environment with much intervention. In such a sophisticated and closely knit yet dynamic system, devices are interconnected to relay useful measurement information and control instructions via sensor networks. When all these hardware and software are put together, it gives rise to IoT which is revolutionizing the way the environment is monitored.

Sensor networks on the other hand are designed to perform a set of high-level information processing tasks such as detection, tracking and reporting of data. There has been a wide range of use including detecting false alarms, quality trail. As sensor networks get widely adapted, the can vary in use and the modes to which they are deployed and how they are powered, either by solar, rechargeable/ non-rechargeable battery packs.

Water scarcity to people in AS-ALs has direct impact on Education, health, hunger and indirect effect to conflicts. Among the Maasai - similar to many parts of Africa - men own water. Water was pointed out as the biggest issue in the Mara River basin conflict. Women are allowed to fetch water after animals have had their share (Mulenya, 2011).

2.1. Water Point Mapping

The rural sub-sector, however, lacks reliable data to establish the functionality levels of existing water systems, identify the coverage levels of safe and accessible drinking water, and monitor increments and progress against set targets to improve water service delivery. In its 'IMPACT'

Report (2010), the Water Services Regulator Board (WASREB) indicated that there was no details yet for the rural areas for water supply and sanitation coverage.

This information gap continues to make it impossible to respond to key indicators in the water services sub-sector that are in place to protect the right of Kenyans to access safe drinking water, as enshrined by the Constitution 2010. The evident rural data gap that makes it difficult to improve access of rural communities to safe drinking water is one of the reasons why the Water Point Mapping (WPM) was carried out in 8 Counties in Kenya. Contents The information on water point mapping contains the following, among others:

1. Information on coverage levels, up to sub-location level

2. Distribution of water points up to sub-location level

3. Functionality levels

4. Information on Management and maintenance of water points

5. Basic information on who developed/who funded, type of water source, year of construction

6. More information on whether users pay for water, walking distances to source and quality of water

7. Picture of project can be viewed.

2.2. Internet of Things (IoT)

Impactful IoT interventions in development can improve efficiency (achieving similar levels of impact with fewer resources) and/or enhance effectiveness (increasing impact with similar levels of existing resources). In advancing global development, IoT interventions are helping to improve research, public policy, basic service delivery and the monitoring and evaluation of programs across a range of different sectors (Somayya, 2015). This report discusses examples of

use cases of the IoT in healthcare, water, agriculture, natural resource management, resiliency to climate change and energy.

Overall, IoT and various related technical developments (including convergence, cloud services, data analytics and the proliferation of sensors) are escalating to:

1. Greater monitoring and measurement of humans, machines and things; as well as

2. A shift from human-to-human communication to M2M, something-to-everything, and everything to-everything communications.

3. Greater and more rapid awareness of and information about status, function, and environment.

2.3. Emergence of IoT

The strong growth currently observed in IoT applications is attributable to several major underlying trends that are just now coming to fruition:

- The reduction in the cost of computing (including sensors) and the growth of Wi-Fi are enabling factors driving growth in IoT applications;
- Growth in mobile and the deployment of data-friendly 3G networks from 2001 onwards, as well as the expansion of network connectivity across the world, and from urban to rural settings (including Wi-Fi, but also macro cell connectivity);
- The rise of software development, partly attributable to economies of scale; and
- Systems that require low power to work.

According to the ITU GSR 2015 Discussion Paper on regulation and the Internet of Things, one possible explanation for why the IoT is advancing rapidly now is that it is moving from a position where it delivers incremental efficiency improvements to existing business models to one where it positively impacts new business models and processes as well (Popper, 2014).

In terms of realizing processes, the IoT can improve and enable a broad range of applications — from more efficient manufacturing, logistics, counterfeit detection, monitoring of people, stock,

vehicles, equipment and infrastructure, to improved healthcare, traffic management, product development and hydrocarbon exploration.

In addition, the IoT is now also enabling the exploration of new business models such as car and truck rental clubs, whose members can book and use vehicles parked around their neighborhood almost on-demand; or "pay-as-you-drive" insurance based on driving patterns, behavior, and risk. For marketers, the IoT enables brands to gather more information about their customers, and create "truly compelling, magical experiences."

2.4. IoT functionality

Functionality for any IoT scheme, a number of trade-offs are involved in performance, efficiency, reliability, robustness, flexibility, power supply, scalability, interoperability, ease of authentication, preservation of privacy, extensibility, mobility support, and modularity. For example, trade-offs may arise within the following:

- Complexity versus robustness (e. g. of sensors and connectivity modules);
- Range, data throughput, and cost (e.g. Wi-Fi vs. LTE vs. LoRa vs ethernet);
- Battery life versus data throughput. According to Cisco, new models of electrical generation and transmission (including batteries, simple chemical reactions, energy harvesting devices, etc.) are required to power the devices;
- High reliability levels may prove very important in large-scale systems using hundreds of thousands of sensors, devices and/or readers (e.g. for seismic monitoring networks around nuclear plants, but not necessarily for RFID tags on livestock).
- Low latency -time for data transmission- becomes all the more vital when doing high level computing (such as high-definition video conferencing), where an interrupt or delay in data transmission can have major consequences. The choice of final specifications among the different options available depends on the aims of the deployment, and the challenges to be solved.

Figure 3: Overview of wireless sensor nodes in a farmland

2.5. Related studies and Applications

Currently, some of the most extensive uses of the IoT in developing countries are in projects where the objectives include the improvement of clean water delivery and/or sanitation.

In Bangladesh, a biosensor network of 40 manual arsenic sensors it being used to monitor water quality. In Jiangsu, China, water supply is being monitored by adding IoT sensor devices at key points to register data on water usage and flow rates. In India, Sarvajal has developed low-cost reverse osmosis technology to provide clean water in rural areas, as well as smart meters to remotely monitor the quality and quantity of water. Additionally, a wireless sensor network (WSN) is being used in the country to improve water management in poor and semi-arid areas. The wireless COMMONSense Net has been deployed over a small area of two acres to measure temperature, humidity, ambient light, and barometric pressure in rural Karnataka. Soil moisture has been measured with a special probe since April 2005 (Panchard, 2007). Data from the sensors are visualized on the project's website for real-time monitoring.

In Africa, water service reliability is closely correlated with extreme poverty and water insecurity in rural areas. Around one million hand pumps supply water to over 200 million rural water users across the continent, yet as many as one third of all hand pumps are thought to be broken on any given time, with 30-70% of pumps breaking within two years. The Smith School Water

Programme at Oxford University launched a 12-month 'smart hand pump' trial in Kyuso, Kenya, in 2013 in an attempt to resolve problems related to broken water pumps and to test a new maintenance model for universal and reliable water services.

Using a basic accelerometer, similar to that found in a mobile phone, to capture movement of the pump handle, the team developed a robust transmitter which fits into the handle of existing hand pumps, opting for "field readiness" over technological sophistication (e. g. using SMS rather than 3G to transmit data), as their need for more robust, reliable data outweighed that for data with advanced functionality. The team opted for non-rechargeable batteries, with a replacement lifetime longer than the pump maintenance cycle. An advantageous mobile package and efficient use of the SMS message format has resulted in relatively affordable data costs.

From the initial question of whether the pump was working or not, the team quickly realised that they could remotely monitor a host of data relating to water supply and demand, including hourly flow rates, usage data, hand pump performance, seasonality, and peak periods for demand. Based on these data, a more evidence-based approach to policy decision-making has been achieved. It is no longer the village that "shouts loudest" or that has the best social connections that ultimately receives service. The project has been able to provide evidence about where and when the greatest needs for water are experienced.

The team emphasizes that the project has led to a shift in mindset. Although the Kenyan water regulator had an existing mandate for regulating water supply in rural areas, it was not able to engage effectively, as it lacked concrete data about the situation. Now that more data are forthcoming, the water regulator is better able to manage resources. Performance-related pay has also been introduced for maintenance staff, who now know that pumps are being monitored remotely, and who are generally more keenly engaged and responsive in repairing pumps.

MoMo is a similar, but fully mobile, device with a sensor that collects data to track infrastructure and improve accountability in the developing world. Broken pumps are identified using this device alerting the repair teams. The data from MoMos can be used to inform the setting up of investment programs in the future.

In Rwanda, SWEETSense uses sensor technology developed by Portland State University's SWEETLab (Sustainable Water, Energy & Environmental Technologies Laboratory) to monitor pump performance and water flow, notifying technicians via SMS and emails. SWEETSense technology uses sensors to provide continuous data on usage and performance of programmes in water, sanitation, household energy and rural infrastructure programmes with diverse partners including USAID, the UK's DFID, Mercy Corps, the Lemelson Foundation, Gates Foundation and DelAgua Health in India, Nepal, Indonesia, Kenya, Rwanda and Haiti. Indeed, SWEETSense technology has been used for:

- Water pumps in Kenya;
- Cooking stoves in India;
- Latrine monitoring in Bangladesh; and
- Water filters for hand-washing station in Indonesia.

These sensors use Wi-Fi or cellular via GSM using a local SIM card (in East Africa, Airtel or MTN or Safaricom offer data plans for around KSh 60-100 a month to transmit data). The data is then integrated into SWEETStats™, an Internet database monitoring summary statistics on performance and usage to front-end users. Sensors currently cost more than KSh. 10,000 but this should fall relatively quickly, as demand increases.

For either/manufacture volumes of several hundred thousand of sensors at a time, price reductions can begin to be realised, which will help boost scale.

In Rwanda, sensors may add 10% to the cost of a hand pump but may enable uptime to increase by some 80-90%, significantly reducing the cost per unit of water per 10,000 litres delivered. Sensors are subjected to very harsh conditions, typically resulting in some 12–18 months of battery life. In Kenya and Rwanda, the regulatory challenges have proven relatively limited so far, and the requirement for large-scale connectivity are nascent.

Water flow sensors are also being used in sanitation projects focused behavior change. For example, in one water, sanitation, and hygiene programme in Indonesia, flow sensors were combined with motion detectors to measure the impact of behavior change training, with the aim of increasing hygienic actions (i. e., washing hands after latrine use). The study found community participants were washing hands after latrine usage, but that the survey responses (those who indicated they wash their hands after using the latrine) were significantly higher than the data captured by the motion sensors, suggesting that over-reporting had occurred in the verbal and self-reported surveys. Similar techniques can be used to remind staff of basic hygiene techniques in homes, clinics, and hospitals.

These applications discussed above depict only that innovation via technology has an endless limit which can solve some of our daily needs.

2.6. People 's reaction to sensors

Although project staff were initially worried about vandalization of the equipment, once people saw that the technology worked and that it contributed to the pump being repaired more quickly, local social structures of respect and trust extended to include and protect the transmitter.

Due to these factors, over its lifetime, this project has helped achieve: a ten-fold reduction in hand pump downtime (measured by the number of non-functional days); a shift to 98% of hand-pumps functioning (up from 67%); leading to a fair payment structure which also strengthens the delivery of services as well as providing metrics to regulate reforms.

2.7. Conceptual Framework

The conceptual framework presented below depicts a situation in which the various variables relates to each other.

Figure 2: Relationship of variables

A whole network of devices was knit together to form a transparent system to the user.

Sensors were placed at strategic positions in a mimicked water point This sensor will be connected to an arduino board. An arduino board is a microcontroller-based kits for building digital devices and interactive objects such as sensors. This device has the capacity to get readings from a sensor and sending it via a communication module connected to it e.g. GPRS, wi-fi or ethernet. For this case, we used the GPRS communication shield. The arduino board can be powered by various sources e.g. a battery cell, a solar panel or usb shield. It has the capability to store offline data in an sd-card when the communication shield is incapable of transmitting.

Once the arduino board received the reading, data was transmitted to thingspeak.com server via an API which wrote to specific channels corresponding to the sensor. A java application was written to consume the readings of the sensors from the server channels and saved in a MySql database. An SMS application was used as an interface to the user where a query is issued using an SMS to a modem connected to the system, whereby this query would be processed and relevant information was sent back to the user via same means.

System Flow Scenario

For instance, user A goes to a water point A and find water and goes back home.

User B goes to a WP 2 and realizes there's no water or not sufficient for them. Then heads out to search for water at WP 3 which could even be disappointing than the WP2. User B then decides to go back to WP2 of head home.

These two laid down scenarios of two users both acquiring water at different WP's shows how information link really is a missing component in acquiring right information about these water points.

User A manages to get water at WP1 and heads back home. User B on the contrary may experiences challenges when acquiring water at both point 2 and 3. But with the introduction of a system, it could drastically reduce amount of time with the right information at hand.

These challenges could include that

1. There's no water
2. Water available may not be fit to be used,
3. There are longer queues at this point etc.

It's quite clear that information link was missing for these users thereby wasting a lot of time. There have been cases of school going children missing classes because they are out to search for water. This gap presents itself in such a manner that it has ceased negative effects to the community.

Water points include Rock catchment, Sand/Sub-surface dam, Rainwater (harvesting), Unprotected Spring, piped into dwelling/plot/yard, Surface water(lake), Protected Spring, Public tap/standpipe (stand alone or water kiosk, unprotected dug well, protected dug well, Dam/Pan (runoff harvesting), Tube well or borehole.

Figure 3: Effects after a query system

Figure 3 above demonstrates a layout of the variables discussed above and their relationships. That if there is less time in acquiring water from a water point then consequently there will be more time to do other constructive engagement, e.g. farming, attending classes for children, less conflicts as a result of even resource-sharing etc.

3. METHODOLOGY

3.1. Introduction

The chapter seeks to define a clear pathon the research of this project. The type of research used was descriptive research method. We also described the target population, the sample and sampling technique employed, data collection tools as well as data processing and analysis of the findings.

3.2. System Architecture

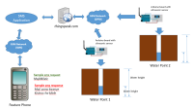

Figure 4: System Architecture

3.3. The Solution

A whole network of devices was knit together to form a transparent systemto the user.

Hardware components

Arduino board – Sodaq Mbili

HC- SR04 Ultrasonic Sensor

SimSIM GPRSbee shield

Battery Lithium Polymer 2200 mAh

1W Solar Panel 80.X100

Software environments

Arduino board – C language with some libraries done in C++

SMS Application – JAVA with smslib library for the SMS functionality

MySql Database for data storage

Thingspeak.com – free environment for collecting data from sensors. It also provides an API to get data in specific format. In this study, we used JSON data structure.

Sensors were placed at strategic positions in a mimicked water point This sensor will be connected to an arduino board. This device has the capacity to get readings from a sensor (see Appendix A for code) and sending it via a communication module connected to it e.g. GPRS, wi-fi or ethernet. For this case, we used the GPRS communication shield stated above. The arduino board can be powered by various sources e.g. a battery cell, a solar panel or usb shield. It has the capability to store offline data in an sd-card when the communication shield is incapable of transmitting.

Once the arduino board received the reading, it was transmitted to thingspeak.com server via a GPRSbee shield to an API which fed to specific channels corresponding to the sensor. A java application was written to consume the readings of the sensors from the sensor channels and saved in a *MySql* database (see Appendix E). AnSMS application was used as an interface to the user whereby when a query is issued using an SMS to a modem connected to the system, this query would be processed and relevant information sent back to the user via same means.

3.4. Application of Descriptive research

The study being conducted had its problem statement well stated. Therefore, it's prudent to describe the already available information. Currently the problem at hand was residents had a hard time locating alternate water points when there intended location may not have water. To understand this scenario, the study sought to find and implement the alternate methods to availing accurate and timely information to the people.

This study endeavored to gather quantifiable information that was used for statistical inference on the target audience through data analysis. The research questions were majorly be closed-ended questions. Though however, in some cases, observation came in handy to actually see the containers and check capacity of the water carried per person.

3.5. Target Population

Improved sources of water comprise of protected spring, protected well, borehole, piped into dwelling, piped and rain water collection while unimproved sources include pond, dam, lake, stream/river, unprotected spring, unprotected well, jaba, water vendor and others.

Narok North constituency has a population of 175,588 (kobs, 2010). 20% of residents use improved sources of water, with the rest relying on unimproved sources.

$n= (Nz^2p (q-p)+d^2(N-1))$

where$(n=$sample size, $N=$population is 175,588 (kobs, 2010), $cv=$coefficient of variation (took 0.5), $d=$tolerance at desired level of confidence, took 0.05 at 95% confidence level (Newman, 2000) which is 99.9 approximated to 100.

3.6. Data Collection methods

The study collected data mainly using structured interviews to the users of the water points. Interviews seemed appropriate because of the nature of the target population.

Data collection mostly targeted three community owned water points. Community owned simply implies that it its owned by people living around the area and is open for their use.

Observation

Getting the physical aspect of the study was well important to check out the general behavior of the people. We were very cautious not to interfere with their natural behavior at the water point when they realized they are being watched.

An android app was used to identify various locations of the mapped water points and the type of points they were.

3.7. Data Collection Tools

There are various tools that were used to collect data for this exercise which were chosen for their effective means of use and relay of data.

They include:

Open Data Kit (ODK) which It is a set of tools that is used to

1. Build it a platform in which data collection forms or survey are coded in a specified manner (XLSForm is recommended for larger forms);

   We used Microsoft Excel for this cause to develop this forms.

2. Collect it an android app the was user to capture the data on a mobile device and send it to a server.
3. Aggregate it the server side application running on a server where the collected data was stored useful formats of data was extracted.

Data that was collected was mostly quantitative with the aim of gathering as much data to help guide the research understand how best to develop the system. Various analysis tools were utilized with using Microsoft Excel and ONA aggregate tool for data visualization.

4. Results and Discussion

Research Results

Data Collection was conducted from the 30th August 2016 to 2nd September 2016 where data collected from the field was sent to the server via data collection mobile phones.

Three key areas were targeted which contained the study areas. These areas are concentrated within the central Narok county which are classified as semi-arid areas. Water Points range in ownership from private, public, organizations (e.g. self-help groups), community owned etc. These areas were suitable targets because they have community owned water points which are our targets. Children/respondents were not subjected to this exercise.

The main mode of data collection tool was interview questions which were directed to the locals.

The sample size was approximately 100 respondents which we managed to gather data from 72 respondents.

Respondents per region

Olmbogshi – 18 Rotosi– 22 Katukala – 32

Figure 5: Gender of water point users

The chart above shows the gender rating of the users of the water points. This result was found after observation during data collection. Women are the majority users of the water points at 70.4% with men taking the remainder. Men were mostly observed using donkey carts to carry

water with about 12 jerry cans of 20 litres each on board but this means of transport is limited to these water points with a good terrain.

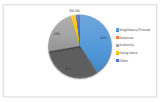

Figure 6: Means of getting information of water points

The figure above shows the source of information amongst the respondents and the results indicate that information is passed majorly passed on among themselves with neighbors and relatives copying the list.

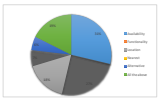

Figure 7: Information that respondents would like get about a water point

The figure above shows the percentage in which respondents wished to know about a water point. Availability of water is the most sought in these water point followed by functionality.

Figure 8: Respondents who have ever found a water point empty

The figure above shows that percentage of respondents who have found water to those have found empty boreholes.

Figure 9: The rate of those respondents who searched water elsewhere

The chart above shows the number of respondents who missed water at a water point and proceed to another water point. These results we selected from a portion (44.4%) of those who didn't find water shown in figure 8.

Figure 10: Respondents who admitted to have a mobile phone or ex-user a phone with a spouse.

A mobile phone is increasingly becoming a necessity within every part of the country. Within the study location 58.3% admitted to be having a mobile with the country's population of approximately 90% is covered by a telco's network coverage. This show the level at which the country has progressed in terms of cover and being connected.

Figure 11: Respondents who know someone around them with a phone

Out of the 41.7% shown in figure 10 i.e. those who don't have mobile phone, 87.9% said they knew someone within their reach or living near them who has a mobile phone. This question was put to test reachability of the respondents to a mobile phone.

From this result, we can conclude that an SMS application can be implemented to be used by these people.

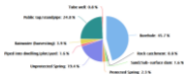

Figure 12: Sources of water

The majority of water point used in the boreholes according to the figure above. This is attributed to its ability to be reliable even at dry seasons.

Figure 13: Respondents who wish to get information upfront

In summary, there is a positive acceptance of people wanting to get information of upfront before heading to a water point at 69% even though most of them have never missed getting water a water point. Narok is a semi-arid area (UNDP, 2013).
Most of them however raised the concern of wanting the service to be free of charge.

The main objective of this exercise was to find out if the people in the target area have problem in locating access point and how information is passed on to the community so as to ascertain if an application by the use of an IoT application can help reduce time for searching or accessing water. Of the respondent, there is a high chance of it being useful to the users.

Average walk time

People walk at an average 30-45 minutes per kilometer with a generally fair terrain. This was realized after participating on the walk following a group of respondent to and from a water point. This translates to hours being lost per week for the 44% of people who at some point do not find water.

It has also been determined that more than 50% have to fetch water daily with others having to fetch twice a day. Most of the people who fetch water twice a day have used water sources within a radius of 3-5 km.

Technology

It is also noted that out of the 41.7% who didn't have mobile phone knew someone within their close reach who has a handset. Amongstthem, majority of the indicated that they have a fair signal with a handful saying they have poor network.

A majority of the respondents with to be getting information on the water points just before heading to it with them requiring to get information on availability of the water resource as their priority. Followed by functionality of the water with a similar number wishing to get all the relevant information.

Test Results

The prototype was fitted on a piece of bottle which mimicked a typical borehole which had its level known and the amount of water it can hold also known. The sensor was coded to get readings every 5 minutes (could be changed) which are then sent over to thingspeak.com channel. It is from this channel that a RESTful API is generated that is consumed by our SMS-based application to have this data ready to convey to the users. The sms-based application was written in java and connected to a Modem that acts as our gateway for sms connections.

Simulation of the boreholes

Test were conducted on two environments which mimicked two water points. The structure of the system included the three sections which are the SMS-based application which handles sending and receiving sms to and from user and the application. The section part is the combination of the IoT equipment which comprises an ultrasonic sensor which checks on the water level, an Arduino board for managing the

different peripherals, a GPRS shield to manage sending data from the sensor, a rechargeable battery pack connected to a solar panel.

Data extracted from Arduino ultra-sonic sensor is sent to thinkspeak.com. The sensor acquires the level of the fluid in centimeters which can be calibrated to the no. of litres from the test equipment. The sensor was mounted on top of a plastic bottle of two litres was used where by the level achieved was reduced from the height of the bottle when empty.

Measurements

In this case, it was measured that the height of this bottle was 60cm. So, if the sensor reported a distance of 2 then the final reading would be 58cm which helped us to track the fluid shown as it was used.

If the application checks and finds out that the level of water a water point is below threshold, it will send the user other options including the location and distance from the water point in question. This level of technology indeed saves many people in ASAL areas in save precious time while searching for water.

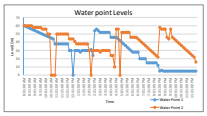

Figure 14: Sensor data submitted

The above figure shows data streamed in every 10 minutes from two sensors mounted on two bottles of water that simulated the water points.

0 cm means that the board failed to submit the reading which could be an internet glitch. The fact that a sharp 30cm spiked, happened when the 'well' was topped up with water.

Which is shown in the next inhabition in Figure 11.

Submission	Total Submissions	Failed Submissions	Success Rate
Water Point 1	96	4	95.8%
Water Point 2	96	4	95.8%

Figure 11: Submission rate by the GPRS shield module

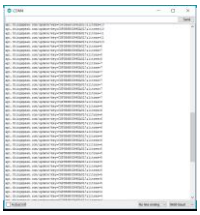

Figure 10: Screenshot of the console of plain-text as intervals of 5 minutes

The Arduino board is set to get readings using the sensor at intervals of 5 minutes and sent to thingspeak.com API ready to be consumed.

Time-Lapsed Results

Scenario	Distance	Time-Lapsed
No water in WP 1	7 to WP 2- approx. 30 km (A shortest Route coordinates)	Walk - 6 hr 30 minutes + 4 hr travel/queue daily Bicycle - 2 hr 30 minutes + 4 hr travel/queue daily Bus/Matatu- 1 hr 30 minutes + 4 hr travel/queue daily Car- 1 hr + 4 hr travel/queue daily Will Return for 30 people

Figure 17: Tabulation of time to travel

User queries

A user is supposed to send in an SMS in specified e.g. Maji#katulula and send it to a specified number which is installed in the modem. With this request, the user will receive information about the specified water point and any other water point that may be relevant to the query.

The responses are in Swahili since it widely understood by the users.

System Tests

A tabulation of the available scenarios and how each case was handled by the application.

Test Case	Example entry	Response
Blank SMS	""	Tuma jina la kisima au maji #Mfano wa jina la kisima: Mfano #maji#katulula au katulula
Name of water point	Katulula 1 (with point having water)	Maji #yaanisa kwenye kisima cha katulula 1
	Katulula 3 (with point NOT having water)	Maji #yaanisa kwenye kisima cha katulula 3 kiwe zaidi ya kilo 2 # Iko katulula mmbale 3.9km
Sending the word water — gets the list of water points with water	Maji (say water)	Tafadhali subiri Katulula 1 – katulula katulula 2 – Nzaisanika Katulula 3– Ilikisaya
Unknown character	*(#&%***@@	Hakuguelikani Tuma jina la kisima au maji #Mfano wa jina la kisima: Mfano #maji#katulula au katulula

Figure 18: Responses by the systems to various queries

Some requests that users sent over to the system and their corresponding responses. Any request that was not understood or not found had a specified message with relevant information as the response.

User test results

Tests were conducted to determine what the users thought after testing the system. From five respondents two respondents had some idea that it would make the systems more usable if it was a free service as well as localizing the language.

1: Strongly disagree 2: Disagree 3: Fair 4: Agree 5: Strongly Agree

	Usability	Functionality	Reliability	Notes
User 1	4	4	5	It takes time to add contacts on typing, Free service
User 2	4	4	4	Language localization
User 3	4	4	5	There's need to capture their contacts for easy broadcast
User 4	4	2	4	Need to handle more requests from one
User 5	2	2	5	Localization, Free service not well implemented, Free server

Figure 39: Test results for various system requirements

5. Conclusion

As seen from the test results above, it's evident that this approach has a high reliability to read valued data with very low rates of failure. This portrays the fact that IoT can be reliable and trusted to create complex systems that can solve common man's problems.

It is therefore concluded that people in rural areas do not have proper informational systems to get details of water points with 43% getting information from their Neighbours/friends and relatives. The authority too takes a chunk at 29% which shows that it can play a key role in disseminating and managing the water points data.

Among the information that respondent wished to know about the water points, availability of water was their top priority at 34% with functionality following at a close range which denotes that people want to access water in a functional water point.

With approximately 28 hours lost every week per person, the application gives alternate water points to the users with the details which can greatly reduce the hours lost in searching for water.

An SMS query based system developed with integration to IoT, its evident that users can now access relevant information from the system.

It's case be proven from the above test results that near real time data can be availed to the users at the convenience of their locations.

With all these combination of SMS, IoT and web applications, it is evident that IoT is changing the way people do things. Being able to get information at your mobile before making decision can really impacts people's live positively. The people in affected locations i.e. the arid areas can really benefit directly and indirectly to such use of technology saving them for wasting quality hours just searching for the precious commodity- water. With the research and results of the technologies utilized here, the utilization of the any mobile phone can greatly save ease from walking miles away to find an empty water point. Therefore, He impacts other people with knowledge of developing technologies which would in one way or another impact another's and even saving the e lives.

6. Recommendation

Water points & Management

This study focused more on boreholes while there are a number of different water points that are used by people to get their daily source, so it's important to study more on how various sensors can be utilized for different types of water points.

Further to that, a web portal could be developed for the managing authority to manage different water points data for matters like load balancing on these points.

Wide usage technologies

Further research into this study can include engaging more technologies like LoRA to better help in coverage of connectivity of these data that they can be deployed even on areas without telco presence. Also, the utilization of gadgets like HMCK which connects internet to remote locations.

Packaging

It's important to further check the best way of build, package and install these gadgets to withstand any external challenges and still be able to function optimally.

Free service

Lastly, it's recommended that this project could even impact more lives if it's incorporated as a fee-based service to the users so that it can benefits all regardless of their inability to contain anytime. It can be managed and maintained by various authorities in conjunction with both county and national governments.

Localization

Further work that can be done in this application is to localize the language used so that it can be deployed easily in any part of the world.

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∞

Appendix A: Questionnaire

Location
- Olmbaagishi
- Ilmisoi
- Kimbalsi

Gender

What types of water sources do you have access to?
- Borehole
- River
- Rock catchment
- Sand/hole-surface dam
- Rainwater (harvesting)
- Shallow well
- Unprotected Spring
- Piped into dwelling/plot/yard
- Protected Spring
- Public tap/standpipe (stand alone or water kiosk, unprotected dug well, protected dug well, flumePan (runoff harvesting)
- Tube well

How far is the water point that you mainly get water from? (KM)
- Onsite/ plot
- 1km
- 10km
- 20km
- 25Kmor more

How often do you go to a water point?
- Thrice a day
- Twice a day
- Thrice a week
- Once a week
- Never

How do you get to know of a new water point has been developed?
- Neighbours/friends
- Relatives
- Authority
- Goingthere
- Other

How do you know that a water point does not have water?
- Neighbours/friends
- Relatives
- Authority
- Goingthere
- Other

Have youever reached a water point and find no water?

Did you go to search for water inanother water point?

How far is ANOTHER water point that you mainly get water from? (KM)
- 1km or less

- 5km
- 10km
- 20km
- 25Kmor more

Do you think it's helpful if you knew there was no water upfront in wp?
Does anyone in your family sell gas?
Does anyone in your family/village have a phone?
How is the network coverage?

- Good
- Fair
- Poor
- Non availible

Do you want to get information of a wp just before going to it?
What information would you like to know about a water point?

- Availability
- Functionality
- Location
- Nearest
- Alternative
- All the above

m

Appendix B: Class to receive and send SMS

```
public void process(Service src, String gatewayId, MessageTypes messageType,
            IncomingMessage msg) {
        String text;
        text = msg.getText().toLowerCase();
        sender = msg.getOriginator();
        /* Check if the message is valid or msj ikiformu ne jiwa la
hiolma. Where msj[0]status or batabola*/
        /*        Not correct format          */
        if (text.equals("") ) {
            sendText(sender, "Failingathana. "+format);
        }
// Right format
        else {
            String[] parts = text.split("#");
            if (parts.length == 2
                && parts[0].equals("getFacilityStatus(parts[0])//name is known
            } else if (parts.length == 2 &parts[0].startsWith("ha")) {
                msg=jeng = query.getFacilityStatus(parts[1]);
            }
            QueryHandler query = new QueryHandler();
            text = query.getFacilityStatus(text);
            if(text.equals("")){
                text=format;
            sendText(sender, text);
        }
    }
```

Appendix C: Method to check for water point information

```
public String getFacilityStatus(String name) {
        String message="";
        int thresholdOf3,thresholdOf2,value3,value2,status3,status2;
        String message="";
        try{ String sql="SELECT f.name,f.status,f.thresholdid,l.value FROM logger l "
                + "JOIN ICDS facility f on l.facility_id = f.id where f.name='" +
name+"' ORDER BY l.id DESC LIMIT 1";
        String sql1="SELECT f.name,f.status,f.thresholdid,f.subloss,l.value FROM
logger l "
                + "JOIN ICDS facility f on l.facility_id = f.id where f.name='" +
name+"' ORDER BY l.id DESC LIMIT 1";
            System.out.println("Query:" + sql);
            Datastore ds = Datastore.queryTable(sql);
            ResultSet rs = datastore.queryTable(sql);
            ResultSet rs2 = datastore.queryTable(sql1);
            try {

                if(rs.next()||!rs2.next()){
                    return "";
                }
                else {if (rs.next()) {
                    thresholdOf3 = rs.getInt("thresholdid");
                    value3 = rs.getInt("value");
                    status3 = rs.getInt("status");
                }
                if (rs2.next()&&rs.next()) {
                    thresholdOf2 = rs2.getInt("thresholdid");
                    value2 = rs2.getInt("value");
                    status2 = rs2.getInt("status");
                }
                }if(status3!=0){
                    message = "Kisima cha "+ rs.getString("name")+" haifanyi kazi kwa
sasa!! Huna haa kisima cha "+rs2.getString("name")+" iliobo
"+rs2.getString("subcounty");
                }
                else if(status3==status2&&value3<value2){
                    message = "Kisima cha "+ rs.getString("name");
                }else if(status3==status2&&value3>value2){
                    message = "Hali hayawi kwenye kisima cha "+ rs.getString("name") +"
sahihi yani "+ rs.getString("name");
                }


            } catch (SQLException e) {

                e.printStackTrace();
            }

            return message;
    }
```

Appendix D: Class to read from the sensor and send to Thingspeak.com

```
#include <Wire.h>
#include <SPI.h>
#include <SD.h>
#define PING_PIN 6 //Use digital pin 6 for the range finder
#define READ_DELAY 1000 //Delay between readings in milliseconds

//SDHAQ RMoll libraries
#include <RTCTimer.h>
#include <Stdmm_DS1231.h>
#include <GPSBase.h>

//The delay between the sensor readings
#define READ_DELAY 5000

//Digital pin 10 is the MicroSD slave select pin on the RMoll
#define SD_CS_PIN 10

//The data log file
#define FILE_NAME "DataLog.txt"

//Data header
#define DATA_HEADER "TimeDate, Distance"

//Network constants
#define NET_SSID "YourNet"
#define NET_SSIDPASS "xxx"
#define NET_PASSWORD "data"

//SparkThings constants
#define URL "api.thingspeak.com/update"
#define WRITE_API_KEY "C1FDKHBSIPKDAL7" //Change to your channel's key

//Operators
#define FIELD_KEY "f"
#define SIMPLE_KEY "k"
#define DATA_SIGN_KEY "="

//Data labels, current change for ThingSpeak
#define LABEL1 "Level"


//RTC Timer
RTCTimer timer;

void setup()
{
    //Initialize the serial connection
    Serial.begin(9600);

    //Initialize sensors
    setupSensors();

    //Setup timer events
    setupTimer();

    //Setup GPSBase
    setupCommon();
```

```
    //Echo the data header to the serial connection
//  Serial.println(DATA_HEADER);

    //Take first reading immediately
    takeReading(getNow());
}

void loop()
{
    //Update the timer
    timer.update();
}

void takeReading(uint32_t ts)
{
    //Create the data record
    String dataRec = createDataRecord();

//  //Save the data record to the log file
    logData(dataRec);

    //Echo the data to the serial connection
//  Serial.println(dataRec);

    //Get the data records as a URL
    String url = createDataURL();

Serial.println(url);
    //Send it over the CPRS connection
    sendURLData(url);
}

void setupSensors()
{

    //Initialize the DS3231 RTC
    rtc.begin();
}

void setupLogFile()
{
    //Initialize the SD card
    if (!SD.begin(SD_CS_PIN))
    {
      Serial.println("Error: SD card failed to initialize or is missing.");
      //Hang
      while (true);
    }

    //Check if the file already exists
    bool oldFile = SD.exists(FILE_NAME);

    //Open the file in write mode
    File logFile = SD.open(FILE_NAME, FILE_WRITE);

    //Add header information if the file did not already exist
    if (!oldFile)
    {
      logFile.println(DATA_HEADER);
    }
```

```
    //Close the file to save it
    logFile.close();
}

void setupTimer()
{
    //Construct the RTCTimer how to get the current time reading
    timer.setDefaultTimezone(gpsZone);

    //Schedule the reading every second
    timer.every(READ_DELAY, takeReading);
}

void setupComms()
{
    //Start Serial1 the Neo port
    Serial1.begin(9600);

    //Initialise the GPRSBee
//    GPRSBeeClass gprsBee=
//      gprsBee.initAutosenseSIM900(Serial1, -1, BEEDTR, BEECTS);
//    gprsBee.setDog(Serial1DOG);
//    GPRSBeeClass gprsBee=
//      gprsBee.initAutosenseSIM900(Serial1, -1, BEEDTR, BEECTS);

    //uncomment this line to debug the GPRSBee with the serial monitor
    //gprsBee.setDog(Serial);

    //This is required for the Switched Power Switched2Off(true);
}

String createDataRecord()
{
    //Create a String type data record in csv format
    String data = getDateTime() + ",";
    String data = getDateTime() + ",";
    data += String(getDistance());
    return data;
}

String createDataURL()
{
    //Construct data URL
    String url = URL;

    //Add key followed by each field
    //url += String(LABEL_DATE_KEY) + "Test";
    url += String(LABEL_DATE_KEY) + String(DATE_ADC_KEY);

    url += String(COMMA_KEY) + String(LABEL);
    url += String(LABEL_DATA_KEY) + String(getDistance());

    return url;
}

void sendURLData(String url)
{
    char result[20] = "";
    gprsBee.doHTTPGET(APN, APN_USERNAME, APN_PASSWORD, url.c_str(), result,
sizeof(result));
```

```
    Serial.println("Received: " + String(result));
}

String getDateTime()
{
    String dateTimeStr;

    //Create a DateTime object from the current time
    DateTime dt(rtc.makeDateTime(rtc.now().getEpoch()));

    //Convert it to a String
    dt.addToString(dateTimeStr);

    return dateTimeStr;
}

uint32_t getDur()
{
    return millis();
}

int getDistance()
{
    //Set Ping Pin to OUTPUT mode
    pinMode(PING_PIN, OUTPUT);
    //Send a HIGH signal for 5 microseconds
    digitalWrite(PING_PIN, HIGH);
    delayMicroseconds(5);
    digitalWrite(PING_PIN, LOW);

    //Now read back the distance as a time value (microseconds) using the
name of
    pinMode(PING_PIN, INPUT);
    long duration = pulseIn(PING_PIN, HIGH);

    //Convert the time into a distance
    long cm = microsecondsToCentimeters(duration);

    //Output the distance to the serial monitor
//    Serial.println("Distance in cm: " + String(cm));

    return cm;
}

long microsecondsToCentimeters(long microseconds)
{
  //The speed of sound is 340 m/s or 29 microseconds per centimeter
  //The ping travels twice the distance, there and back and we divide by 58
  return microseconds / 58;
}
```

Appendix E: Method to read sensor data from Thingspeak

```
String url = "https://thingspeak.com/channels/163063/feed.json";

public static JSONObject readJsonFromUrl(String url) throws IOException,
JSONException {
    InputStream is = new URL(url).openStream();
    try {
//      BufferedReader rd = new BufferedReader(new InputStreamReader(is,
Charset.forName(url).forName("UTF-8")));
        BufferedReader rd = new BufferedReader(new
InputStreamReader(is,Charset.forName(url).forName("UTF-8")));
                    .openConnection().
                    .getInputStream(), Charset.forName("UTF-8")));
        String jsonText = readAll(rd);
        JSONObject json = new JSONObject(jsonText);
        return json;
    } finally {
      is.close();
    }
  }
```