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Automatic power meter reading based on Arduino micro-controller unit: case of the Kenya power and Lighting Company

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Automatic Power Meter Reading Based on Arduino Micro-Controller Unit: Case of the Kenya power and Lighting Company

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Declaration

I declare that this work has not been previously submitted and approved for the award of a degree by this or any other University. To the best of my knowledge and belief, the thesis contains no material previously published or written by another person except where due reference is made in the research proposal itself.

Keere Samuel Ondieki

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9.06.2017

Approval

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Dedication

I would like to dedicate this Dissertation to my Family Members starting with my Lovely Wife Beatrice. Secondly, I would like to appreciate all my children: Charles, Isaac and Jacob for the marvellous support that they showed me during the entire period. The understanding that I would not be readily available on family commitments meant real a lot. God bless you.

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May the Lord bless you all.

Abstract

Automatic Meter Reading (AMR), is the technology of automatically collecting data from metering devices (electric, water, gas) and transferring that data to a central database for billing and/or further analysis. Power utility firms have an obligation to bill their customers based on actual meter readings taken. However, provision of these services have had challenges. This leads to the issue of estimated readings and an inconvenient billing method that is based on incorrect readings. This is normally evident during the power meter-reading period when some power consumers influence clerks to evade paying their power bills. A common phenomenon in some cases is either where the same field clerks take wrong readings or end up over/underestimating the customer's consumption. This ends up inconveniencing customers budgeting. In a bid to address this issue, Kenya Power Company has resorted to retrofitting the existing conventional post-paid meters with prepaid meters. This is however expensive and would take a long time to implement. This study proposes a solution for automatic meter reading by use of an ATmega328P MCU. This will entail an ACS712 current sensor that will be connected onto a power meter coupled to a LoRa gateway through a LPWAN for transmission of data to a cloud server for subsequent upload and analysis. Agile software methodology was used which allowed faster iteration and more frequent release with subsequent user feedback. This solution would not require replacement of the existing meters, making it cost effective and fast to implement. This study provides a solution that can enable the users have information on their readings, rate of billing and be able to report on any power issues affecting them. This will also help the power providers have their customers' advice, which would aid in decision-making processes.

Keywords: *Automatic Meter Reading (*AMR), *Real-time data*, *Low Power Wide Area Network* (LPWAN), *Microcontroller Unit* (MCU), *Current Sensor* (CT), *Long Range module* (LoRa).

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Abbreviations/Acronyms

AMI	Advanced Metering Infrastructure
AMR	Automatic Meter Reading
CT	Current Sensor
ERD	Entity Relationship Diagram
GCM	Google Cloud Messaging
GPRS	General Packet Radio Service
GPS	Global Positioning System
GSM	Global System for Mobile
KPLC	Kenya Power and Lighting Company
KWH	Kilowatt Hour
LCD	Liquid Crystal Display
LED	Light Emitting Diode
LoRa	Long Range Module
LPWAN	Low Power Wide Area Network
MCU	Microcontroller Unit
SDLC	Software Development Life Cycle
SMS	Short Message Service
UML	Unified Modelling Language
USB	Universal Serial Bus
USSD	Unstructured Supplementary Service Data

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Chapter 1: Introduction

1.1 Background

Power Utility companies have several ways of collecting readings of consumed energy from their connected customers. They include the use of field officers to collect the reading data, pre-paid metering systems, and automatic reading of meters. Automated reading of meters in most utilities is a problem which requires new solutions. This is in a bid to reduce costs and provide improved services to the consumers. Recent developments in wireless communication networks like GSM and LPWAN have also created opportunities for developing applications with wide geographical coverage. The motivation of this research is that Automatic Meter Reading (AMR) can let energy companies keep track of the consumption of a power meter remotely without sending a field clerk to collect data, which in turn can save money for the firm (Cabioc et al., 2011).

Secondly, it also helps the customer track his/her readings and consumption usage and this can help the customer manage his/her power better. With a case of the Kenya power and Lighting Company in Kenya, as the main electricity utility company, at least 30% of the monthly readings are estimated (ERC, 2013). This leads to inconveniencing of customers and poor decision making by companies based on the unreliable billing data available for planning.

The Kenya power and Lighting Company is tasked with distribution of power in Kenya to various customers according to demand and proximity (Kenya Energy Act, 2006). Among the many duties involved in distribution, metering and billing of customers is key. The Company has a total of over slightly 5 Million customers. Out of this number, 6,000 customers are large power consumers who are majorly metered on smart meters. 2.2 Million Customers are metered on prepaid meters. The remaining close to 2.79 Million customers are metered on post-paid meters, which require to be read monthly (ERC, 2015). With the insufficient number of staff and the wide geographical area, coverage of all these meters and accurate reading is a challenge. This has led to estimated readings over a period leading to bill disputes and some unresolved issues ending up in courts of law (Mungai, 2016).

Electricity access in Kenya is low despite the government's ambitious target to increase electricity connectivity from the current 15% to at least 65% by the year 2022 (Ministry of Energy, 2015). Kenya's current effective installed (grid connected) electricity capacity is 1,429 MW against a demand of 1,600 MW. This continues to pose challenges of demand and its access, (ERC, 2015).

1.2 Problem Statement

Power utility firms use meters to record consumption in premises. In order to bill their customers, the utility firm sends its field officers to site physically to read meters for billing purposes. More often than not, the field officers end up not picking the correct readings either because they find the premises locked or are influenced by consumers to record lower readings in a bid to aid them pay less. This method is also largely ineffective because of the large number of clients and the extensive geographical area to be covered, which makes it time consuming and a costly exercise. Conventional meter reading can also pose problems for the consumer and the service provider when for example, inadvertent reading of meters reduce or increase the customer's bill (Cabioc et al., 2011).

Paper-based entry of readings into the utility providers system can also lead to errors. The customers also lack information on power pricing and the tariffs, power outages, payments and disconnection information among others. The proposed solution to this problem is the use of automatic meter reading technology using an ACS712 current sensor and an Atmega3218p microcontroller. This will capture the real-time readings and send them via an IC880A Long Range LPWAN radio gateway to a cloud server for ease of access by both the customers and the power company. This solution will also provide an end-to-end interaction between the consumers and the utility firm on other important information that may be necessary.

1.3 Research Objectives

The main objective of this research is to analyze the challenges facing Meter reading in Kenya. The study will seek to develop an automatic power meter reading system that would assist in overcoming these existing challenges. The specific objectives are:

i. To investigate the challenges facing power provision and metering in Kenya.
ii. To investigate on the various techniques used to automatically read meters.
iii. To design a model for automated meter reading.

iv. To test a prototype of an automated meter reading system.

1.4 Research Questions

i. What are the challenges facing power connectivity and meter reading in Kenya?
ii. What are the various techniques used to automatically read meters?
iii. How can a model for automated meter reading be designed?
iv. How can we test a prototype of an automated meter reading system?

1.5 Justification

Utility firms are faced with the need to reduce the operating costs and increase profitability by adopting Automated Meter Reading (AMR) (Galle, 2010). Some systems that automate the meter reading work by using smart meters with existing network infrastructure such as GSM networks and Bluetooth from the customer to the power utility servers are now in place. This infrastructure is referred to as Advanced Metering Infrastructure (AMI) and has the key benefits of reducing costs and improving the quality of service to the customer (Galle, 2010).

AMRs are becoming a popular solution because of the inherent problems with the traditional analogue and ordinary digital meters, which depend on a paper-based meter-reading process. Some of the disadvantages of the paper-based systems are: the introduction of human errors which often leads to over/undercharging the customers, the practice by field clerks of simply estimating consumption and the huge amount of time consumed by the utility firm personnel in commuting from premise to premise. (Salim et al., 2014).

AMRs are however costly to implement. This is because process involve replacing all the existing post-paid meters with smart meters. Setting up of a network infrastructure for transmitting of the readings is also an added task. This means an added expenditure to the utility firms. This informs this study on the need to explore technologies that can achieve similar benefits but in a more cost-effective manner.

The proposed system will not require replacement of existing meters or acquisition of a new network infrastructure for the transmission of the meter readings. With the regular readings, which is essential for real time consumption power supply firms can be able to monitor the power meters and recommend preventive maintenance leading to minimized power failures and billing disputes. The automated power meter reading will also provide accurate data collection mechanisms.

1.6 Scope

This study will focus on challenges facing power supply in Kenya with a case study of KPLC as the main Power Utility firm in Kenya. It will also focus in developing an automated power metering and management system for real-time power meter readings, billing, and consumer-to-utility firm communication.

1.7 Assumptions

There are assumptions of this research. Key among them is that all customers shall have access to an Android Smartphone and will be willing to access this information. Secondly, the study will assume that the utility providers will trust the data sent by the automated meter reading system. There is also an assumption that the correspondents of the interviews and questionnaires shall give their honest and fair opinion towards this research.

Chapter 2: Literature Review

2.1 Introduction

This chapter covers the Literature on power supply and billing systems. It contains the challenges facing the power supply sector and mainly its access and Metering challenges. It also covers on applications with emphasis on power billing and supply service management. The chapter reviews similar applications and their shortcomings. This study looks at systems whose efforts have been geared towards automated power metering and billing Infrastructure. Most Utility providers have embraced the use of Automated Meter Reading (AMR) systems in the process of reading utility meters ranging from gas, water to electricity.

2.2 Power Metering in Kenya and Challenges facing the Sector

There are a number of challenges facing the power supply sector in Kenya. Key among the challenges is provision of information about the power supply management, power provision, and methods of charge in pricing. Lack of power in many homes and locations in Kenya is a challenge that has already been envisaged as one of the milestones for Kenya's vision 2030 goals. According to the German-Dutch-Norwegian Partnership - Energizing development (2012), Kenya's current effective installed (grid connected) electricity capacity is 1,429 MW. Current electricity demand is 1,600 MW and is projected to grow to 2,600-3600 MW by 2020.

The Kenya Power and Lighting Company is tasked with the role of supplying power to people living in Kenya (Ministry of Energy, 2007).Besides the milestones the company has achieved, there are a number of challenges that face the sector. The achievements include the increased connectivity of supply to more homes in Kenya and especially Nairobi and its environs. For example, there has been increased power supply provision to the informal setups in Nairobi especially in Kibera and Mathare areas (World Bank, 2014). Challenges however do exist and they include corruption, poor quality supply, and poor billing methods.

It costs approximately Ksh 35,000 to connect to the national grid and about Ksh. 12.5 equivalent per KWh of electricity service. These relatively high costs pose a major obstacle to the expansion of electricity connections to low-income households and small businesses. This in itself shows that access to power and information about it is scarce. Only about 15% of the total population of about 47 million people has access to power.

The Kenya power and lighting company has over 5 million customers currently translating to about 5 million meters. Out of this, only 6000 large industrial customers have smart meters. Another about 2 million customers are on pre-paid metering system. The prepaid meters have however continued to face challenges due to a high failure rate, its exorbitant cost, vandalizing and bypassing of meters. Approximately 2.9 million customers are on post-paid meters (Mungai, 2016).

According to the Business daily of November 2016, most of these post-paid meters are not read monthly due to various factors. Key among them is lack of access to customer premises and the minimal number of meter reading staff available for the exercise. This leads to an upsurge of the number of estimated readings on the monthly billing cycles and subsequent adjustments.

2.3 Types of Power Meters and Metering Systems

Once customers are supplied with power, utility firms have a way of billing them based on the amount of power consumed. To help record the quantity of power used, the customer has to be metered. An energy/electric meter is a device that measures the amount of electrical energy consumed by a residence, a business, or an electrically powered device. There are many types of meters. They can be subdivided into either analogue, digital or smart meters. Their classification can also be based on the way they operate and how the customer pays for the utility. They broadly however can be grouped into either single phase or three phase depending on the mode of connection. The following types of meters can be identified in the literature:

2.3.1 Conventional Meters

Conventional metering is where the service provider installs meters at the customer's side and sends monthly bills based on actual or projected consumption (Zyl, 2011). The service providers employ personnel to collect meter readings at intervals of say a period of one month. This method is however prone to errors and sometimes the personnel may not get access to the customer premises. McNabb (2011) has documented other methods used to overcome the difficulty of accessing the customer premises. One of them is to connect the meter to an electronic unit outside the customer premises where the meter reading personnel can read the meters using handheld devices. Another method is to connect the meter to a radio frequency transmitter and the meter reading personnel can drive around the customer premises and automatically pick the meter readings using a handheld device. These conventional meters can be either analogue or digital as attached in appendix 111.

2 .3.2 Prepaid Meters

This category of meters has built-in processing units that automatically disconnect a customer's supply (Zyl, 2010). The customers buy the power units in advance, and by use of a token or electronic signal. The amount purchased in units is then uploaded into the meter. The meter automatically disconnects once the amount purchased is exhausted. This type of metering has therefore no need of personnel employed to read the meters or handle disconnection of non-paying customers as seen in the conventional meters.

However, Zyl, (2010) alludes that the main prohibitive factor with the prepaid meters is the cost of the meters due to additional gadgets that must be incorporated for the meter to work. These meters also have more components that can fail and thus do require regular maintenance and checking. Some customers are also not comfortable with these meters as they feel they do not trust their operation mechanism. A pre-paid meter is appended in appendix C.

2 .3.3 Automated Meters

Automated Meters make use of the existing technologies such as wireless networks to deliver a solution that can allow for time series data from a remote location without any human intervention (McNabb, 2011). This system uses smart meters, which are composed of a two-way communication between the meter and the power provider allowing the provider to obtain meter readings on demand and can even command the meter remotely. The smart meters normally contain components in the communication network which are also connected to the utility providing the billing system. The automated meter is shown in appendix C.

2.4 Automated Meter Reading

Automated Meter Reading (AMR) is an up to date technology for taking water, electric or gas readings automatically from a remote location without any human intervention (Bala and Babu, 2012). Cabioc et al., (2010) proposed an SMS-based automatic billing system for reading household meters. The system consists of a distant site and a base station as shown in Figure 2.1.

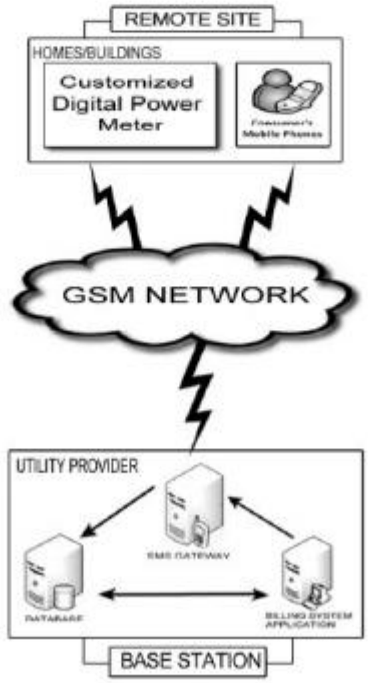

Figure 2.1 : A reproduction of the System Architecture (Cabioc et al.,2011)

Abdollahi et al., (2012), proposed a similar SMS-based system. The system contains additional security features and sends more complex messages to the base station. The remote site must first identify itself to the base station by sending an acknowledgment SMS before it is admitted as a legitimate remote site. The system thus rejects any SMS received from unidentified sources.

Sharef et al., (2013) on the other hand designed an AMR system, which uses short Radio Frequency (RF). It consists of an analogue meter connected to a radio frequency transmitter at the customer site and a receiver RF device, which can be able to receive readings from the transmitter. The system is however restricted to a 300 feet radius for successful operation. This means that such a system is only semi manual since the utility personnel would still have to go round with the receiver modules in order to pick the meter readings.

There is also another proposal to utilize a sensor network using ZigBee technology according to (Sun et al., 2009). ZigBee works like the Wi-Fi and Bluetooth but costs much less and has a low power consumption. This system architecture includes the meters connected to ZigBee wireless sensor network, which is in is turn connected to the centralized server using GPRS. The meter readings are then sent to the centralized server via GPRS.

All these AMR systems have a common feature in requiring additional devices to be installed in addition to changing some of the conventional meters. This would however be at a high a cost implication to the power providers and this may be a hindrance into investing on such technology. There is therefore need for an AMR system, which does not require the utility provider to make changes to the existing conventional meters. This study provides a solution that will not require the utility provider to change the meters. The only requirement however is in the provision of the necessary infrastructure to receive the data sent by a current sensor connected to a microchip on the meters. This translates to minimal costs incurred by the utility provider compared to the other methods. The following are some of the technologies that have come up with relative solutions to automated meter reading.

2.5 Remote Meter Reading via Analogue Connection

Remote Meter Reading through an analogue set up is a technique that allows remote data collection of electricity, gas, and water meters through analogue Telephone Landlines. Here the meter takes the consumption units used by the customer and stores the data in memory. The data that is already stored is then sent to the remote location using transparent data via different interfaces using the analogue telephone landlines (Di et al., 2013).

This technique eliminates the need for manual data collection and billing but fails in practicality in many places without landline telephone services, Kenya being a perfect example. Figure 2.2 illustrates this system.

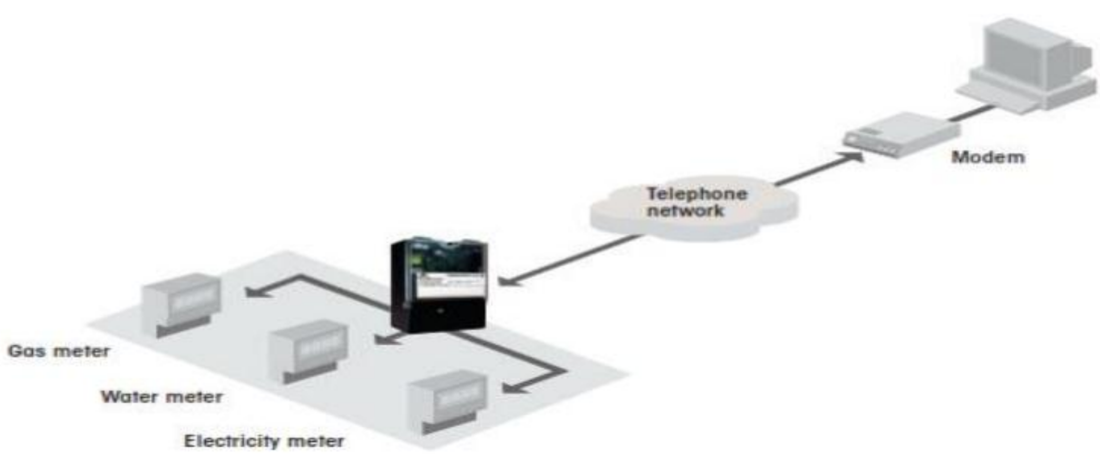

Figure 2.2 : Remote Meter Reading via Analogue Connection (Di et al., 2013)

2.6 Intelligent SMS based Remote Meter Reading

This is a technique for remotely reading Electricity meters via the Short Messaging Service (SMS). Existing Global Mobile for communications Systems (GSM) have been used for sending and receiving SMS (Mohammad et al., 2009).

This technique has been developed to read electricity meter readings from a remote server automatically using the existing GSM networks for cellular phones. This technique can be applied for gas or water meters as well. The meters send the meter readings like kilo-watt-hour (kWh), voltage, current, bill, etc. by SMS to a central server. The central server then stores the information in a database for analysis and sends the bill to the customer by e-mail. Prepaid scratch-card based billing scheme can also be implemented. The SMS based data collection can be done very quickly and efficiently. Data can be collected after any desired time interval such as hourly, daily, weekly, or monthly basis. As there is no human intervention in the entire process, there is no chance of human error and corruption. Figure 2.3 illustrates this technique.

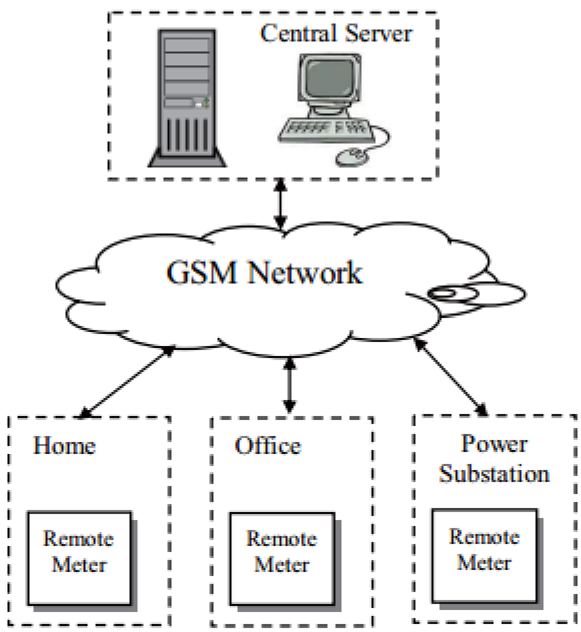

Figure 2.3 : SMS Based Remote Metering System (Mohammad et al., 2009)

The proposed remote metering system is composed of several remote meters and a central server as shown in the illustration. The remote meters which are placed in various premises, exchange information with the central server via SMS using GSM networks for cellular phones. Both post-paid and prepaid billing scheme can utilize this architecture.

2.7 Mobile Water Meter Metering System Based on Hall Effect Sensor

This prototype utilizes a Hall Effect sensor for automatic water metering and real time data upload to a server for storage and required analysis (Mwangi, 2016). He further alludes that the prototype can ensure that consumers stay informed and can actively participate in issues related to water through the available communication platform. This helps the utility firm in provision of relevant advice, which can assist in decision-making processes. This promotes effectiveness, transparency, and improves the consumers' capacity to ensure advocacy and responsiveness (Mwangi, 2016).

The Hall Effect Sensor works on a platform that is based on ATmega328 microcontroller. The controller has 14 digital pins that can be used as either input or output pins. The board has a USB connection that provides connection to a PC when uploading a control program and a power jack that gives a reliable connection (Banzi, 2012). Figure 2.4 shows the Arduino board.

Figure 2.4 : Arduino Board (Banzi, 2012)

Pluggable extension shields are used to extend the functionality of the Arduino board and control to other devices. GSM shields is one among the various pluggable boards that can be included in the sensor that supports HTTP and TCP protocols (Warren et al., 2011). By using the GSM shield it is possible to connect the Arduino board to the internet by use of wireless technology. The shield is plugged into the Arduino board and a sim card from an operator offering GPRS coverage is inserted to enable connection into the internet. This will facilitate communication between the sensor and remote location (Warren et al., 2011).

2.8 Automatic Meter Reading using Otsu Threshold Algorithm

This research uses the machine-to-machine learning technique. Under this study a computer checks the image using pattern recognition technology to obtain the numbers. Image processing techniques in this paper, include image pre-processing, image segmentation (Otsu threshold method), and number recognition are used. Then they finally utilize a graphical user interface that uses the visual C# program. This automatic meter reading consists of the mechanical rotary-type counter with its related technologies such as wireless digital communication, advanced control, sensor, embedded system, and database management system. This finally shows the consumption that has been used (F. Dabel, 2008)

The technology in this method revolves around the use of AMR. The study proposes a system that can let energy companies keep track of the consumption of an energy meter remotely without sending a utility employee to collect data, which helps save and cut costs for the firms. Here the customer knows the cost of the utility they consume and further lets them know how they can make better use of the energy and save money as well. It makes use of the image recognition technique. Image segmentation is the most basic yet the most important task in the image processing system. The results of image segmentation affect feature extraction and target recognition. A practical approach to image segmentation is threshold segmentation. Most threshold segmentation methods are based on the one-dimensional gray level histogram, which comes from a two-dimensional image.

The Otsu threshold is used to determine the threshold value of a histogram. It makes use of a method to search for the threshold that minimizes the weighted within-class variance, and the variance here represents the difference between the foreground and the background (Liao et al., 2001). The method is a global non-parametric, unsupervised, and automatic threshold selection algorithm. This method however suffers some shortcomings. The Otsu threshold method is very sensitive to noise and the size of the image. It gives better results when the graph of between-cluster variance is a single-peak graph. The double and single pick graphs are captured in Appendix C.

There is another disadvantage with this technique also. The system depends on the light intensity very often and its operation may be affected in areas that are not nicely lit.

2.9 Text Recognition System for Meter Reading

This solution also utilizes a pattern recognition technique to come up with a solution for automatic meter reading. A camera is used to take digital images of the meters and uses machine-learning techniques to automatically take meter readings. This paper uses the Adaboost Learning Algorithm, which is one of the machine learning techniques in pattern recognition. The Adaboost Learning Algorithm is a method of combining a set of weak classifiers to make a strong classifier (Chen et al., 2004). This algorithm has been used extensively in the area of detection of objects in images and videos. The algorithm takes as input a training set (x1, y1), ..., (xm, ym) where each xi belongs to some domain or instance space X, and each label yi is in some label set Y. We assume for this case that Y = {-1, +1} (Chen et al., 2004).

Adaboost calls a given weak learning algorithm repeatedly in a series of rounds t=1... T. The algorithm maintains a distribution or set of weights over the training set, denoted by D (ti) for a training example on round t. Initially all weights are set equally but on each round, the weights of incorrectly classified examples are increased so that the weak learner is forced to focus on the hard examples in the training set. The weak learner must find a weak hypothesis ht: X → {-1, +1} appropriate for the distribution Dt. The goodness of a weak hypothesis is measured by its error εt as per the formula illustrated below. Once the weak hypothesis ht has been received, Adaboost chooses a parameter αt, which measures the importance assigned to ht (Freund and Schapire, 1995).

From the pseudocode, it is clear αt gets larger as εt gets smaller. DT is then updated as shown in the rule in the pseudocode. This rule increases the weight of examples misclassified by ht and decreases the weights of correctly classified examples. The weight thus tends to concentrate on hard examples (Voila et al., 2004). The Pseudocode is illustrated in Appendix C.

A number of steps are involved in the text extraction process of digital images. The Adaboost Algorithm follows the four important steps for this process. The first step in this process is text detection which refers to the determination of the presence of text in a given image. The second step, text localization, is the process of determining the location of text in the image and generating bounding boxes around the text. There is an intermediate step known as text tracking, which is performed to reduce the processing time for text localization and to maintain the integrity of position across adjacent frames. The third step is text extraction and enhancement, which is used to segment the text from the background to facilitate its recognition. Finally, in the fourth step, the extracted text image is converted into a binary image and enhanced, before being fed into an OCR engine for transformation into plain text. Figure 2.5 illustrates the extraction architecture.

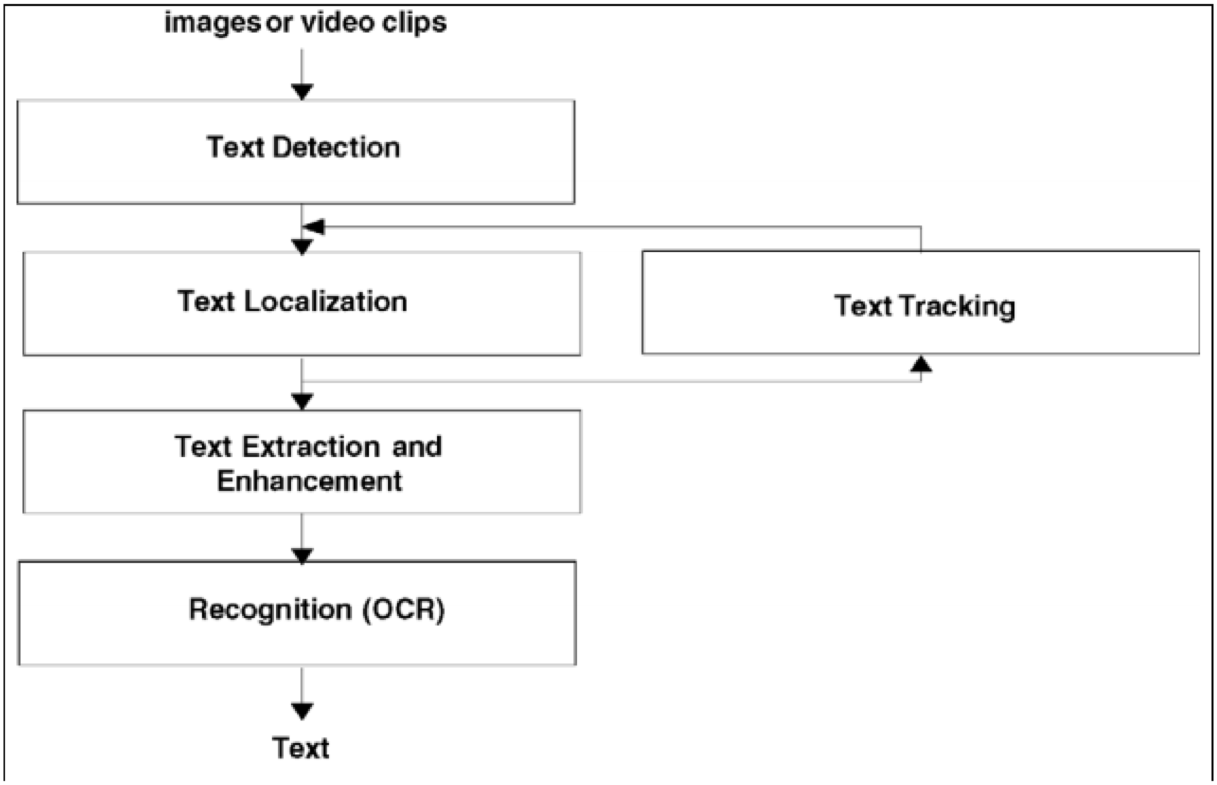

Figure 2.5 : Architecture of a Text Information Extraction System (Jung et al., 2004)

This study achieved only a 75.4% accuracy of the learning algorithm. The object detection techniques like face recognition have achieved much better results (Chen and Youlle, 2004). It is therefore important to seek ways of improving the algorithm. This is the drawback with this method in Automatic Meter Reading.

2.10 Google Cloud Messaging

This is an Android service offered by Google. It permits systems to send data from a cloud server to a registered Android enabled mobile phone. It also allows receive messages from the registered devices through the same connection. Different message queuing aspects and delivery to the intended device on free service terms can be handled by this service (Jamsa, 2013).

To make use of the service, the android enabled device first registers with the Google Cloud Messaging (GCM). The device then forwards the registration data to the cloud server. When the system sends a message to the mobile device, the message goes to the GSM server that then handles the pushing of the message to the target device say another mobile with the android enabled application. The advantage is that the service is free and easy to integrate with the cloud system server (Jamsa, 2013). Figure 2.6 illustrates.

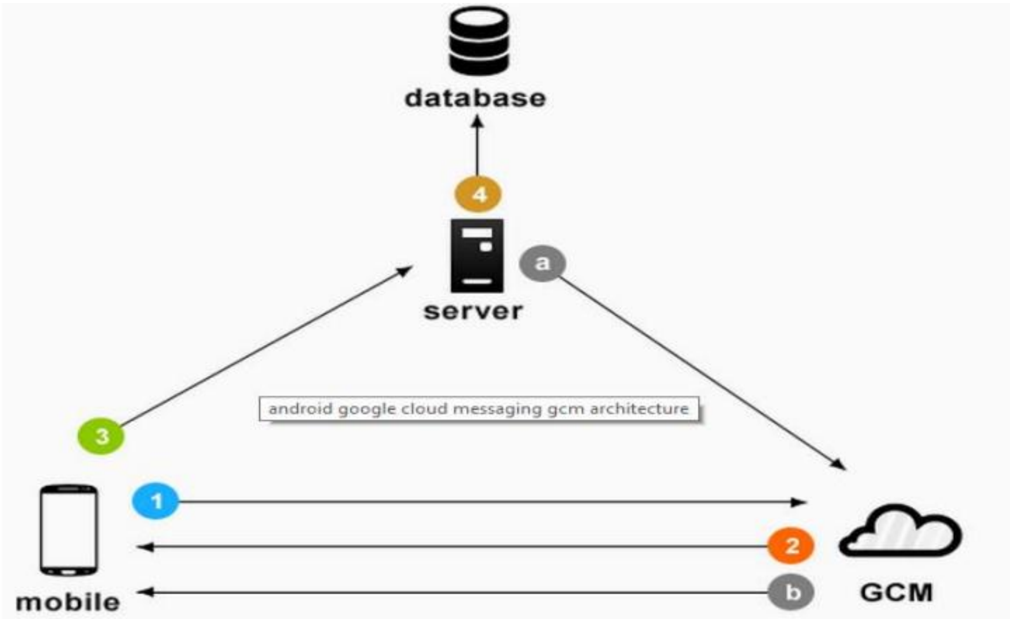

Figure 2.6 : Google Cloud Messaging Architecture (Jamsa, 2013)

2.11 Mobile Applications and Services built around the theme of Power

2.11.1 The Kenya Power E-Bill service and Mobile Application

This is a mobile SMS service that allows customers to check their power electricity account balance and the bill due date. Users are able to use a USSD mobile application to query their balances (KPLC, 2012). As compared to the hard copy bills that are sent through post office boxes, the E-bill service can enable customers to check their bills via the phone using the USSD service. The service is also available in e-mail service as E-bill where customers can enquire their bills through e-mail. There is also a mobile application that was built to enable android phone users access their monthly bills. This is however limited to only checking your bill balances and due dates as opposed to viewing your meter readings.

2.11.2 The Kenya Power Pre-paid metering and Billing

The Kenya Power Prepaid billing system is a system that allows for buying electricity prior to its use. It allows "meter to cash" revenue cycle management. A study conducted by Business Monitor International (2011) showed that the prepaid billing system aids in revenue management and debt reduction. The Kenya power has teamed up with the mobile service providers to create a platform for purchase of credit tokens via the mobile phone for its customers.

The prepaid system works like a prepaid mobile phone where the customer has the prepaid meter installed at the point where the houses are connected to the Kenya power supply line. The consumer purchases tokens and loads them into their prepaid meter, which records the amount of electricity used and deducts the tokens accordingly. When the unit tokens are exhausted, the customer gets automatically disconnected from the power supply until he recharges it again for automatic reconnection (Ronald, 2014). The recharge can be supported by the mobile service providers' applications.

2.12 The IR Arduino Sensor

The IR Arduino Sensor is an electronic instrument used to sense certain characteristics of its surroundings either by emitting or detecting Infrared radiation (Chilton, 2014). This sensor is hooked up to the meter and will sense the light from the meter LED that will in turn be translated to an energy consumption value through a data logger. All modern meters have an optical pulse output LED. In such cases, an optical sensor can be used to interface with the meter. The Arduino sensor image is Appended in C.

Pluggable extension shields are used to extend functionality for the Arduino and control other devices. GSM shield is one of the pluggable boards that can be added into the Arduino that supports TCP and HTTP protocols (Warren et al., 2011). Arduino board and a sim card from an operator offering GPRS coverage is inserted to enable connection into the internet. This will enable communication with the sensor from a remote location (Warren et al., 2011).

2.13 ATmega328P Microcontroller

The ATmega328P is a low power CMOS 8-bit microcontroller based on the AVR enhanced Reduced Instruction Set Computing (RISC) architecture. By executing powerful instructions in a single clock cycle, the ATmega328P achieves throughputs close to 1MIPS per MHZ. This empowers system designers to optimize the device for power consumption versus processing speed (LoRa Microchip, 2015). This MCU has an over the Arduino because of its low power usage and can be programed to achieve many functionalities. The ACS712 sensor is the one that picks the load from the meter and feeds to the Microcontroller AtMega328P. It is then coupled to a communication module RN2483 that send data via Wi-Fi to a remote LoRa gateway through a LPWAN transmission for upload to a cloud server. Detailed design is described in chapter 4.

2.14 Conceptual Design

Figure 2.7 represents the proposed framework.

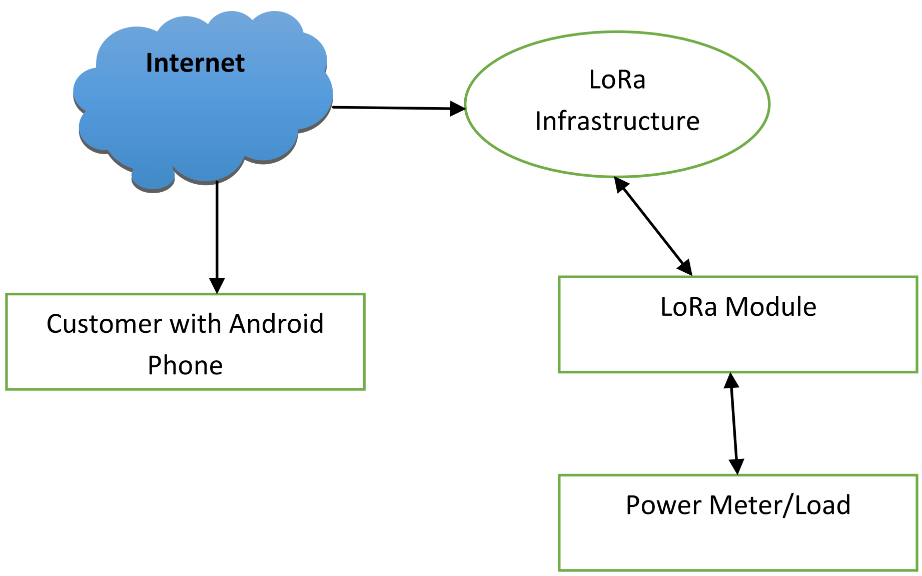

Figure 2.7 : Conceptual Framework

Power/Load

Contains embedded hardware that consists of the current that is to sense the load fron the meter in current and voltage.

LoRa Module

Consists of the communication hardware that has the Microcontroller-Unit Atmega 328p that is programmed to enable the machine to machine communication with the LoRa infrastructure

LoRa Infrastructure

Contains the Radio gateway that is meant to be the transceiver module. The LoRa infrastructure on the other hand has the Long Range Radio gateway that sits on a Raspberry Pi and sends data to the cloud server via internet.

Internet and Users

The cloud server can be then be accessed by users via the internet by the Android applications or Web applications designed for this function.

Chapter 3: Research Methodology

3.1 Introduction

This chapter contains the Research Methodology used and the challenges faced in Power supply management. It also contains the procedures used to design and develop the proposed solution. It also entails the methods used in the study, why the methods were used, and how they were used. This includes the research design used, target population of the study, the sample design, method of data collection and the data analysis and presentation.

3.2 Research Design

The focus of this research was to design, develop, and test a prototype that can be used in solving the problem of estimated readings through automated meter reading. Research design is a guide for research study defining the type of study, data collection, and analysis. This helps the researcher to obtain the relevant evidence by outlining the type of evidence needed to answer the research questions (Gall, 2010).

An applied research design was used in this study. The research design included identifying market need for the product, design a product with the potential to meet the need (s), build a prototype and test whether the prototype met desired functions with respect, cost, environmental consequences and profitability when it was brought to the market (Marder, 2011).

Moreover, the researcher reviewed literature to understand current metering infrastructure and power supply challenges. This study also sought to design an Automated Meter reading prototype for collecting data and transmitting it to a cloud server for storage and analysis. In particular, a cross-sectional study was conducted which involved a sample of elements from a population of interest at one point in time. The study was concerned with a sample of elements from the population. Such data was analyzed and conclusions were drawn.

We have also employed the use of quantitative research. Chen and Manion (2012) defines quantitative research as a type of research that explains phenomena by collecting quantitative data that are analyzed using statistical methods. We chose this type of research because it allowed the researcher to decide what to study, ask specific narrow questions collect quantifiable data, analyze the data using a statistical tool, and conduct the enquiry in an unbiased and objective manner.

3.3 Target Population and Location

A sample is a portion or a subgroup of a larger group called population and a target population is a sample taken as a representation of a target group (Gall, 2010). Gall (2010) further alludes that identifying the target population further depends on what the researcher wants to know. Consequently, based on the objectives of this study the research identified best-suited characteristics for the target population as; one being adult above 18 years of age and preferably a resident of Nairobi where the research was based.

The target population targeted both gender, looked at persons with a probability of owning a mobile phone, and had power supply. Justification of this population target was that they would have a mobile phone, have access to power in their homes and are adults. Nairobi County was the location of the study. Population Reference Bureau (2011) showed that there were about 1,710,000 adults in Nairobi. Moreover, there is an estimated 16.64% android phone users in Nairobi (Salim et al., 2014). This gives approximately 285,000 android-enabled phone users. Thus, using the two facts, people with android enabled phones and access to power connection gives an approximate value of 162,450 people. This is the target population used for this study.

3.4 Sample Size

The population of Nairobi County was estimated to be 3 million people as at 2013. About 50% of this population is estimated to have access to power supply. Others rely on alternative sources of energy like solar, wind and generators (United Nations Population Fund (UNPF), 2013). This puts the number of people with access to power at 1.5 million.

Using the target population derived above (162,450) from Nairobi, we used the sampling techniques available to calculate the sample size. Calculating the sample size at say 95% confidence, the result is as shown in table 3.1. This approach has been used owing to the fact that we are dealing with a large population and a probability sample technique is ideal.

Table 3.1: Sample Population at 95% Confidence level

Population	Confidence level of 95%			
Confidence Interval	3%	5%	7%	10%
162,450	1068	385	196	97

3.5 Data Collection

Data-collection techniques allow researchers to systematically collect information about the objects of study (people, objects, phenomena) and about settings in which they occur. The research made use of both primary and secondary data. Primary data was useful in getting first-hand and new information from the various stakeholders. The main strength of questionnaires is that a large number of questions were asked about a given topic and gave flexibility to the analysis. This method is also less expensive, permits anonymity, and may result in responses that are more honest. Additionally, it eliminates bias due to phrasing questions differently with different respondents.

Secondary data was used to compare various meter-reading techniques used in power meter reading. This data was also collected by reviewing literature. In addition, the secondary data was used to identify ways of developing future works such as improving the existing automated meter reading technologies.

Interviews were also used to collect data from mobile phone users and power supply personnel. This was used to help understand the challenges different users faced pertaining to power usage and their system expectations with an anticipation to a solution of their problem. This was achieved through having sessions with the respondents and asking them questions and noting their response.

Finally, prototyping was used to help refine the application by including missing identified functionality. It was carried out by issuing the mobile application to a number of participants who were requested to use it and give a feedback. Peer reviewers including my classmates were also used in getting alternative perspectives of the solution.

3.6 Data Analysis

Inferential Statistics analysis was used to analyze the gathered data. Mathematical models were applied to the data and provide a basis for the analysis. Moreover, Microsoft Excel and SPSS software was used for statistical analysis to analyze, tabulate and compare the primary qualitative data.

3.7 Data Presentation

Data was represented using tables and pie charts. This is because they are helpful in giving summaries in areas of the collected data (Odhiambo, 2009).

3.8 Validity

Validity is the degree to which an instrument measures what it is supposed to measure (Cohen et al., 2012). The methodology and the research design's validity is guaranteed by the sampling size selected, the research type, sampling strategies and research instruments that were used. Given the quality of the above named and the knowledge of the researcher, the research was to assure academic validity trust and usage of the developed solution by users in applicable areas or related areas of study in the future.

3.9 Reliability

The reliability of the sources of information from the sample size, location of study, research instruments, and other research aspects used was assured. This was of course based on the approval by the academic supervisor and information from other previous successful research studies that may have used the same methods. The sample size used for this thesis was 96 and was derived from a probability sample technic owing to the large number of the target population

$$n = \frac{NZ^2 \times 0.25}{[d^2 \times (N-1)] + (Z^2 \times 0.25)}$$

Where,

n = Sample size

N = Total Population size (known or estimated)

d= Precision level (usually 0.10 or 0.05)

Z = Z statistic for a level of confidence (e.g. 1.96 for 95% confidence level)

3.10 Ethical Measures

Prior to implementation of all research design and methodologies discussed in this research, a precondition of permissions and understanding was done before data collection to ensure no ethical issue would arise to ensure legality and validity of the research. The research made sure that the users' data would be maintained private and no personal data about power billing and payments would be accessible for other uses. This was achieved by only allowing legitimate users to access their data through log in.

Chapter 4: System Design and Architecture

4.1 Introduction

This chapter gives a detailed design structure of the proposed solution. The chapter will examine the functional and non-functional requirements that were obtained from the user requirements collected during the survey. The chapter further covers the design diagrams drawn using the Unified Modelling Language (UML). There are also corresponding explanations of the diagrams. The design diagrams include the use case diagram with a detailed explanation of each use case, System Sequence diagram, Context diagram, Data flow diagram, Partial domain model, class diagram, and Entity Relationship Diagram (ERD).

4.2 Requirements Analysis

A research to determine the power meter reading challenges in Kenya was carried out with a view to finding out a viable solution. This is based on the study's research objectives. Out of the targeted 96 respondents, 70 participants responded and the rest failed to respond. Attached to appendix I was the questionnaire used to collect data and the results here below.

4.2.1 Mobile Use and Ownership

The use of mobile phones and its ownership was key to the success of this research. The focus was on the users of Android enabled phones. From the research on the participants, 91% had Android enabled phones, 6% Windows phones and the remaining used others. Results as shown in figure 4.1.

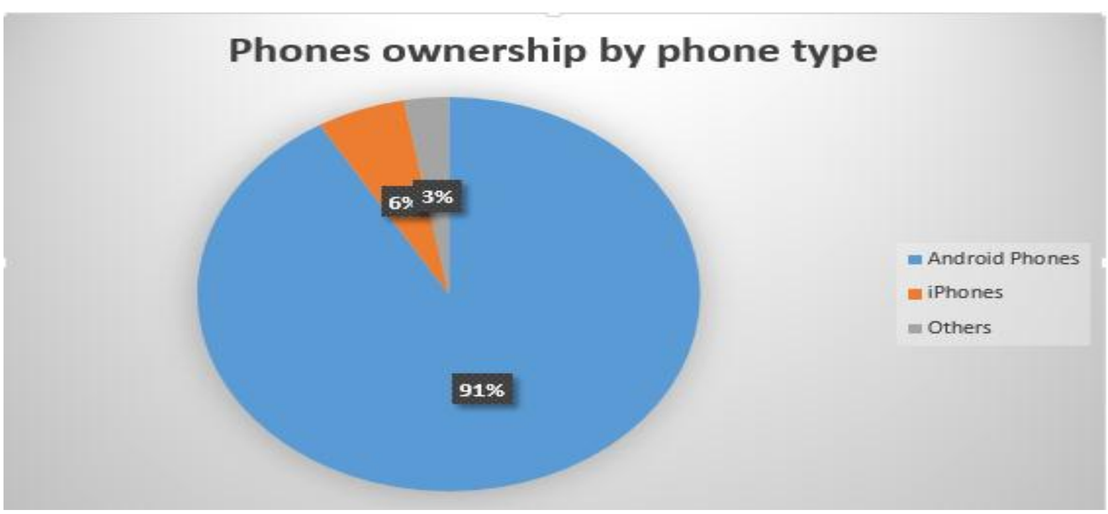

Figure 4.1 : Phone ownership and Type of Mobile (Adopted from Research results)

The research also considered home ownership, and power connection. Results obtained are as shown below. The results from the 70 respondents showed that about 59 owned their own houses and with power connections, 9 owned houses without houses whilst 2 did not own houses nor had power connections. Figure 4.2 illustrates the outcome.

4.2.2 House Ownership and Power Connection

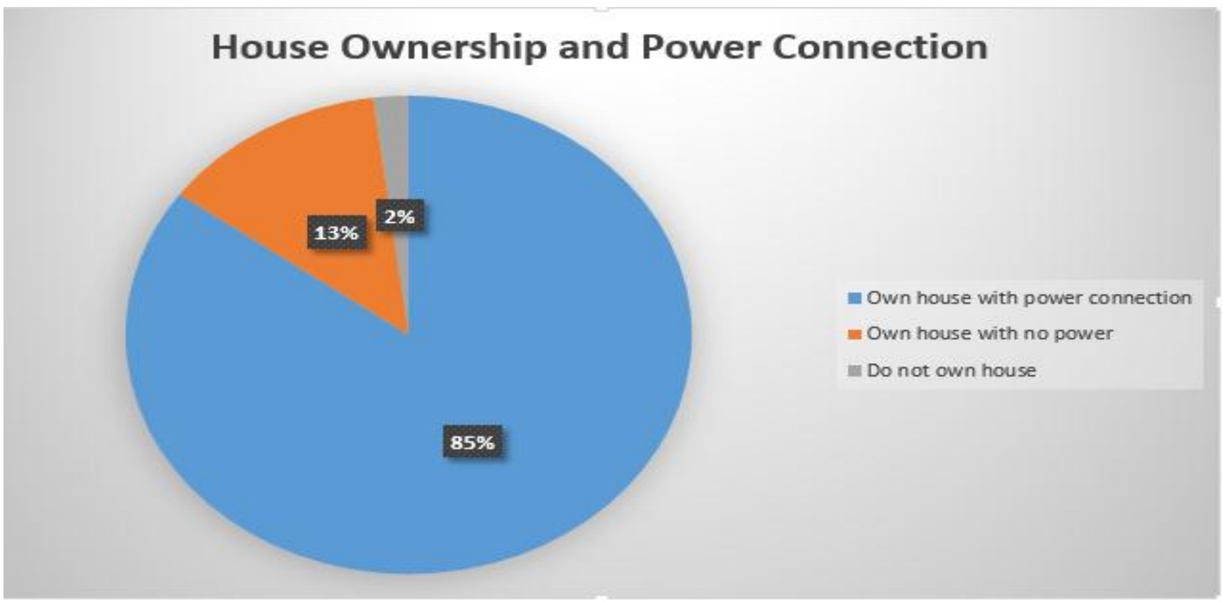

Figure 4.2 : House Ownership and Power Connection

From the interviewed respondents, there was need to establish how and which challenges affected power consumers. It was found out that 21 respondents had challenges to do with power rationing, 3 were ignorant of their power bills. 14 complained of inefficient payment methods, another 14 did not know who to complain to, 7 had high bill complaints, about 5 lack of power, 5 inconvenient complaint channels whilst 3 complained of lack of channels to launch their complaints. Figure 4.3 illustrates the scenario.

4.2.3 Consumer Power Challenges

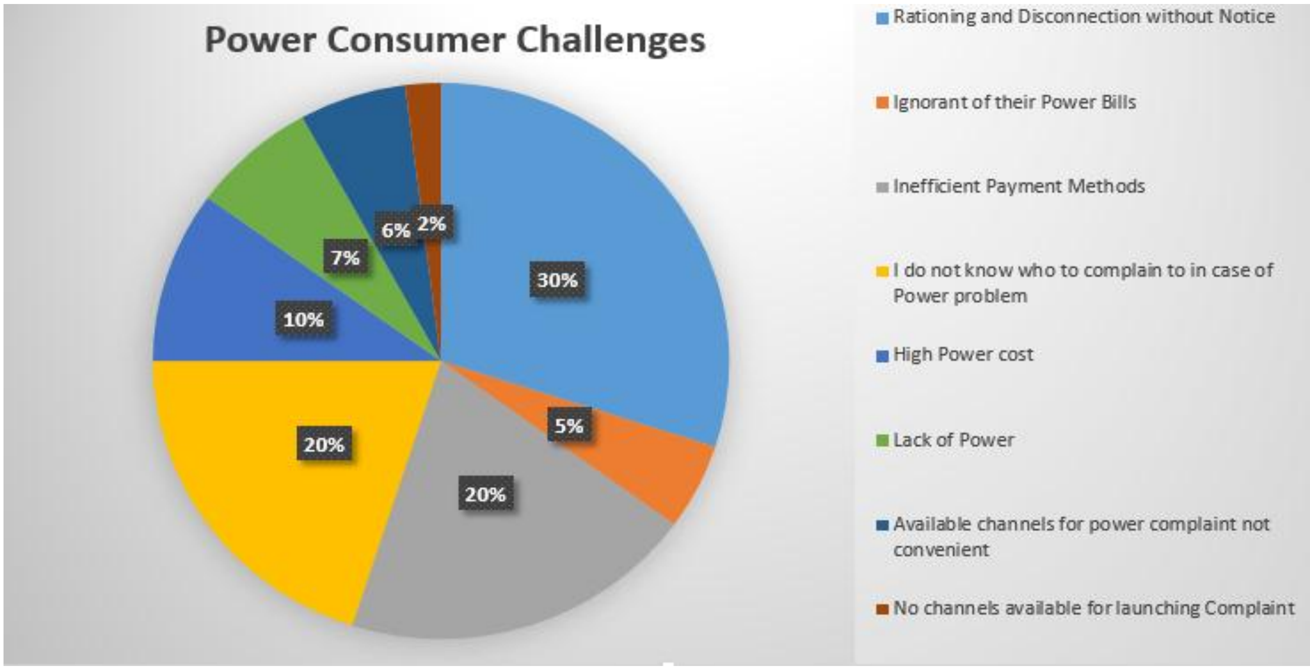

Figure 4.3 : Power Consumer Challenges (From Research Results)

The research also did Survey on the challenges to do with the already metered power supplies. Figure 4.4 shows the results from the research carried out on the respondents.

4.2.4 Metered Power Supply Challenges

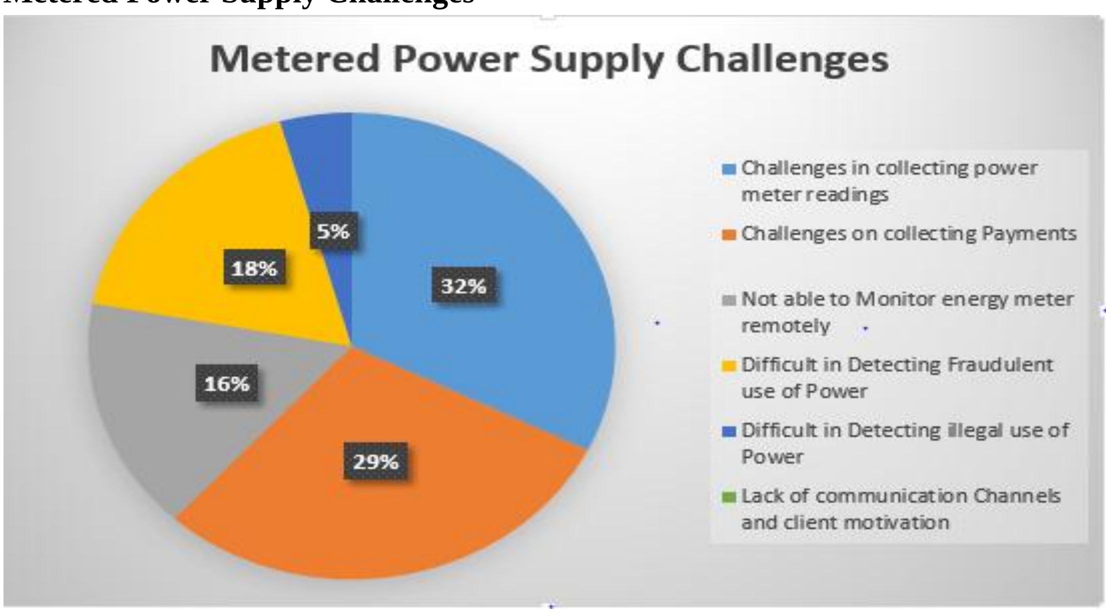

Figure 4.4 : Metered Power Supply Challenges

The following are the functional and non-functional power requirements that were carefully derived from the initial study objectives.

4.2.5 Functional Requirements

This define the various functions that the implemented system will be able to perform (Rubin and Chisnell, 2013). These include all the processes and capabilities in line with the objectives of the study. The functional requirements hereunder this study include:

i. User Registration-Entails the first process any power consumer will undertake before using the mobile/web application.

ii. Login/Logout-Enables Web/Mobile application users log in and out of their respective application before and after using them.

iii. Monitor Power Meter-Allows the Power supply manager to check on the power meter remotely.

iv. Sending Messages-Allows power supply consumers to send messages to the Power supply managers.

v. Send Notification-Allows Power supply authorities to send messages to its consumers.

vi. View Power Bill-Allows consumers to view their power bills and the power supply managers to view consumer's bills from the web/mobile application.

4.2.6 Non-Functional Requirements

These include requirements that are used to evaluate the operation of the system (Rubin and Chisnell, 2013). The non-functional requirements in this study include:

i. User Credentials-For both the Administrator and the user to access the system

ii. Availability and Accessibility-Internet connection required for both the web and mobile application.

iii. Feedback-Mobile/Web application ends require Feedback to give knowledge on working of the application.

iv. Performance and Reliability-Requires that the application works throughout to ensure efficient power metering.

4.3 System Design

This involves the design and development of an Automatic Meter Reading prototype and its description. The prototype presents an intelligent meter reader that uses a designed hardware infrastructure that connects to the cloud using a long range low power wide area network (LPWAN) miniature device through a Long Range Wide Area Network gateway. The development of this system involves a physical connection between the meters and the embedded hardware infrastructure and an unlicensed radio spectrum in conjunction with Wi-Fi between the embedded hardware infrastructure and the cloud. An end user application subscribed to the cloud is developed as the interface that visualises the power consumed in a given duration at any given time and the amount of money that the end user is to be charged based on this consumption. The overall block diagram design is as shown in the figure 4.5:

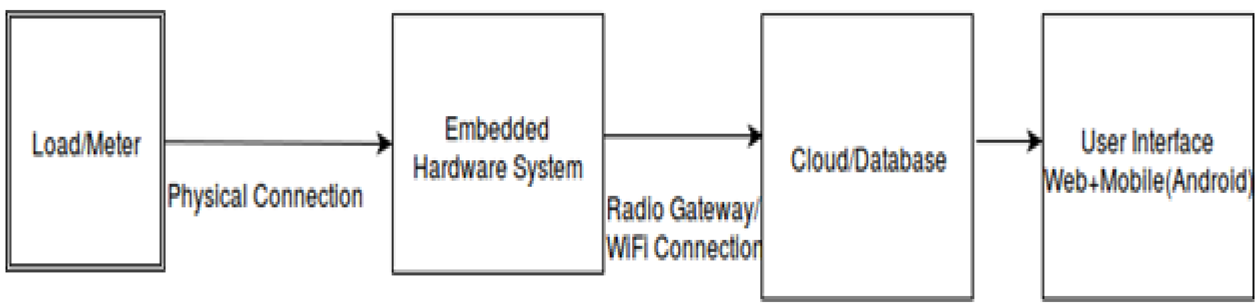

Figure. 4.5 : Design of Block Diagram of the Automated Meter Reading System

Figure 4.6 illustrates the system architecture that comprises of the Embedded hardware, the radio Gateway for transmission and the data base that is accessed by the users via the internet. The users may use the web application or the mobile phone. The Embedded hardware is put in the Customer premises where the power meter has been installed. The communication module sends data through a machine-to-machine communication to the radio gateway which in turn is configured to send the data to a cloud server for subsequent access by the users via the mobile/Web application.

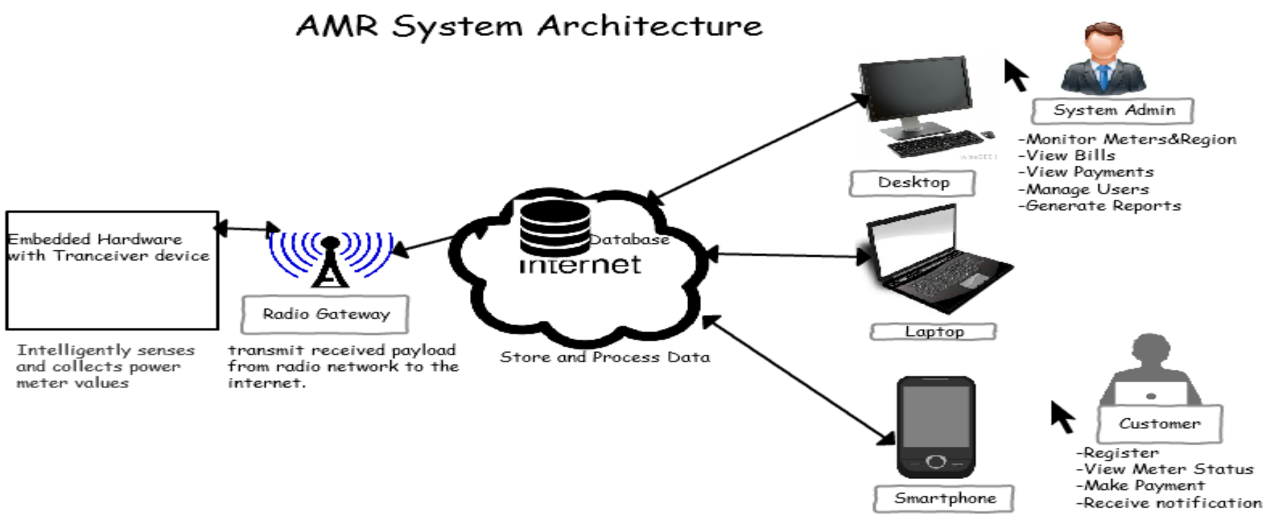

Figure. 4.6 : System Architecture

The following design diagrams and corresponding information were used to give an understanding into the actual implementation of the application.

4.3.1 Use Case Diagram

In order to identify and partition the system into actors and use cases, the study adopted the use of the use case diagrams where actors represent the system user while the uses cases represent the behavior of the system. The main actors of the system included the power utility staff, the power consumer, and the automated power meter system. Diagram 4.7 illustrates.

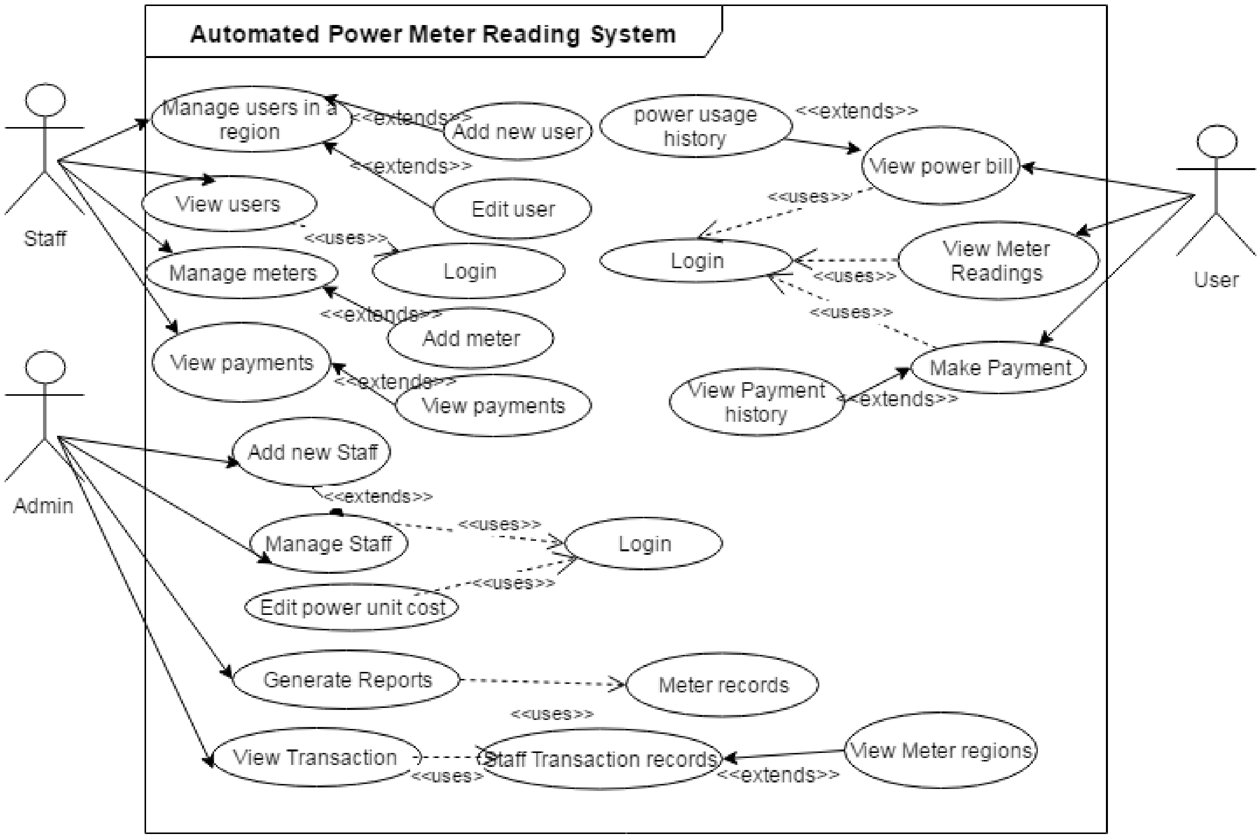

Figure 4.7 : Use Case diagram of the Automated Meter Reading System

Table 4.1: Make Payment Use Case Description

Use case Name	Make Payment	Identifier: 1
Brief Description	User makes payments of power bill	
Type	External	
Major Inputs **Mpesa Transaction code**	**Source** User	**Major Outputs** Payments confirmation
Preconditions	User has sent payments to power supply company and receives transaction code	
Post conditions	Payment is made	
Flow of Events	1.User starts the mobile application 2.The application presents different options to user to select make payment option 3.The application presents the user with the input field to fill the transaction code 4.Types the Mpesa transaction code and submits 5.The payment is updated in the database and user is issued with a payment confirmation notification	

4.3.2 Use Case Descriptions

Make Payment

This use case gives details on the process of making payments by the user. Table 4.1 shows the illustration of the use case.

View Power Bill Use case

This use case helps the consumer in checking the power bill. The step by step scenario of the process is shown in Appendix C.

View Payments Use Case

This use case gives the process of the power supply manager viewing the power supply payments of the consumers. Appendix C captures the process.

Add New User Use Case

This use case describes the process undertaken by the power supply managers/administrators in adding a new user to the system. The scenario is as illustrated in Appendix C.

4.3.3 Context Diagram

This gives an overall view of the main components of the system and how information flows between various entities. For the Automated Power Meter Reading system, the context diagram is as shown figure 4.8.

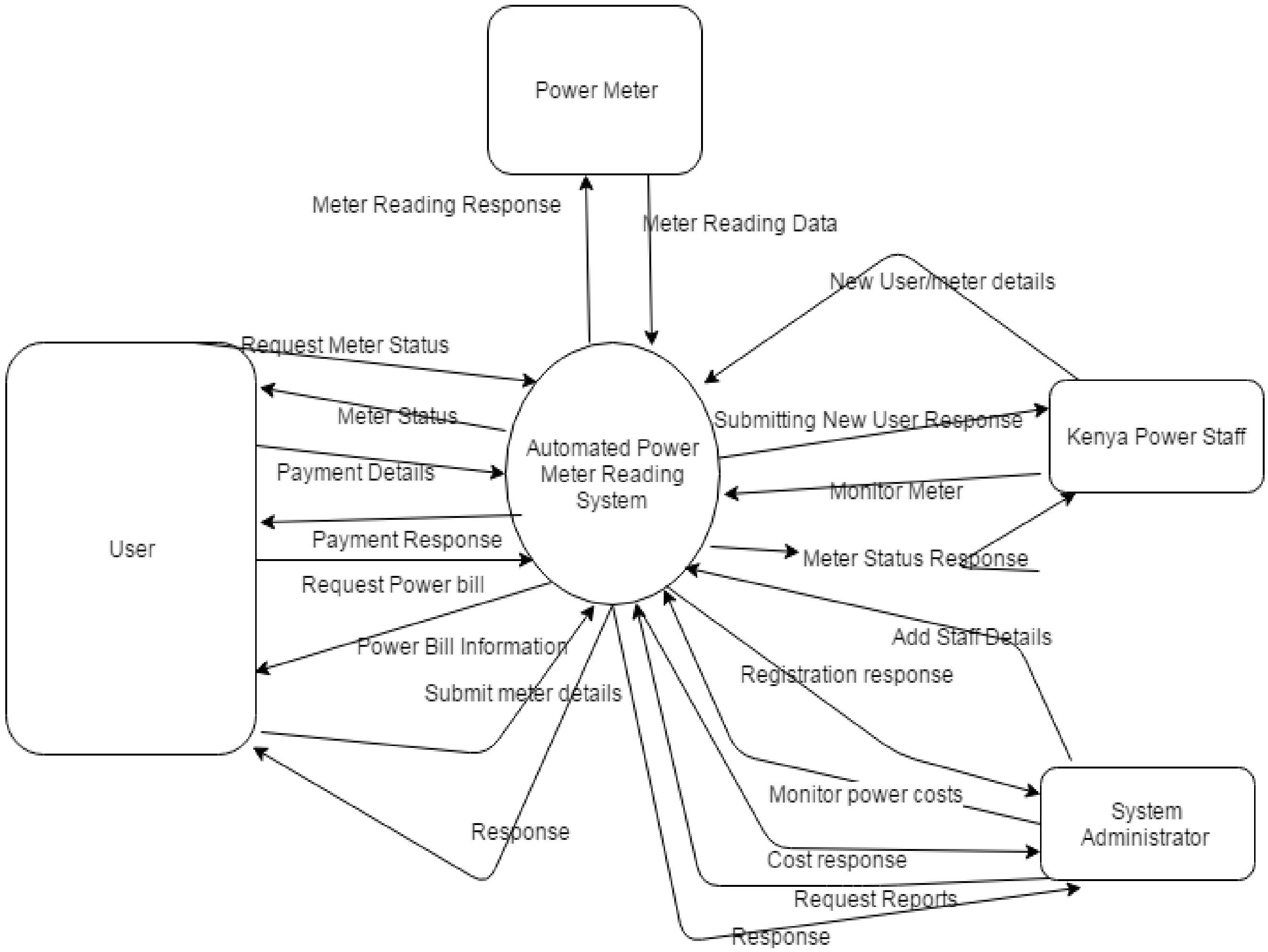

Figure 4.8 : Context Diagram of the Automated Meter Reading System

4.3.4 Data Flow Diagram

To help illustrate the information flow between various components of the system, a data flow diagram is as shown in figure 4.9.

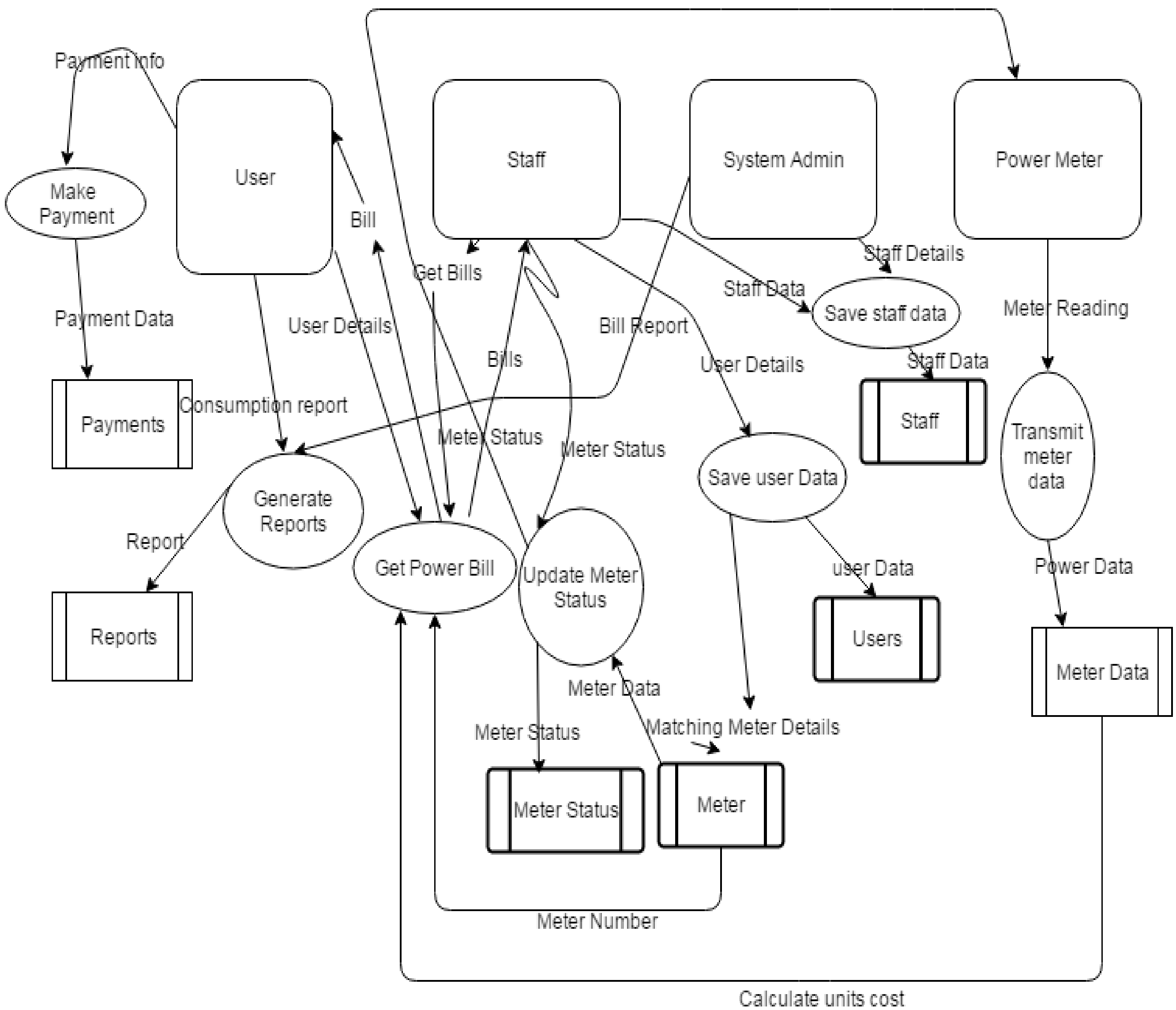

Figure 4.9 : Data Flow Diagram of the Automated Meter Reading System

4.3.5 Partial Domain Model

Figure 4.10 represents the partial domain model of the system. This consists of the system classes showing the names, attributes, entity relationships and multiplicity (Kruchten, 2010). Shown in figure 4.10.

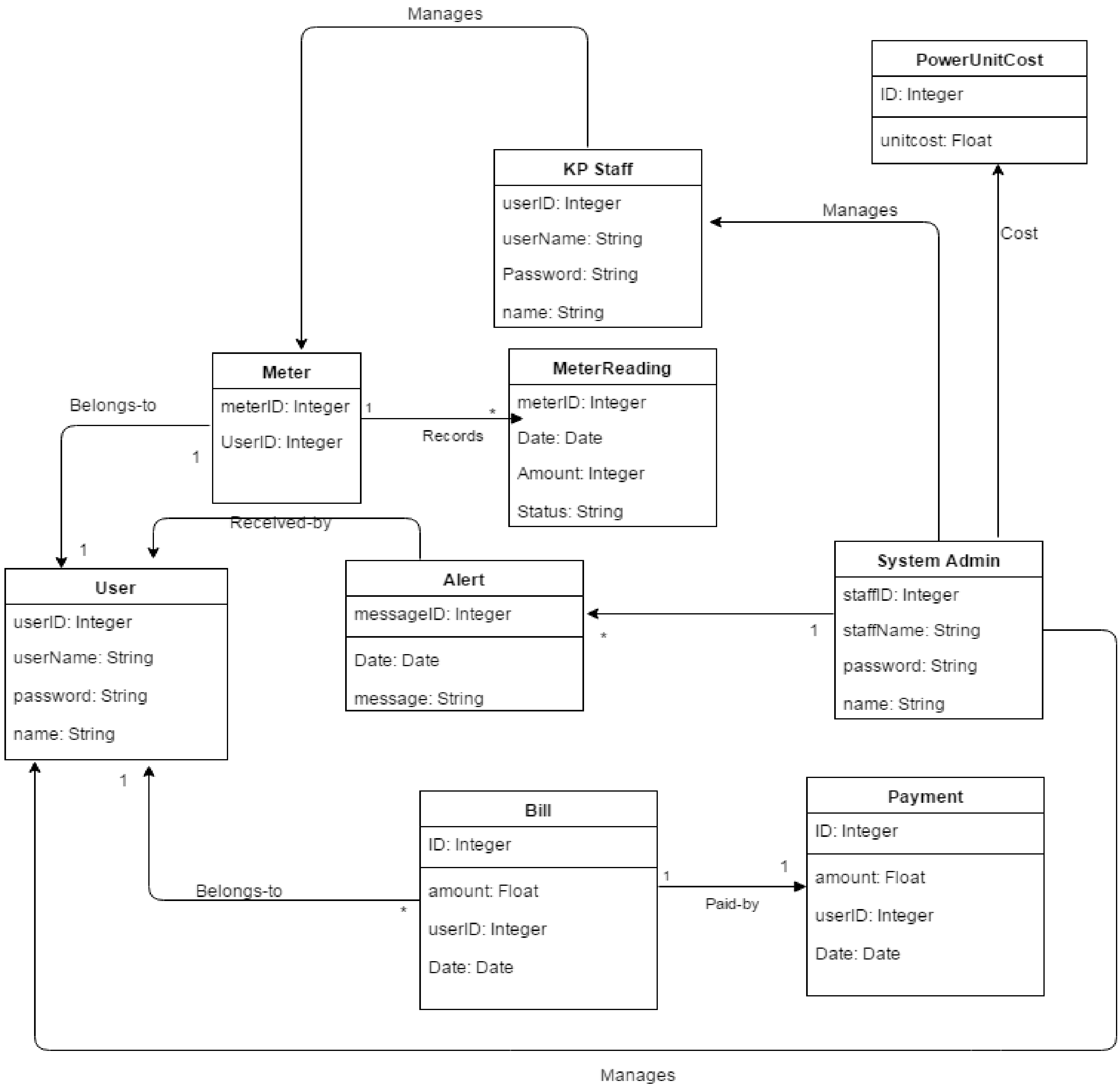

Figure 4.10 : Partial Domain Model

4.3.6 System Sequence Diagram

System Sequence diagram displays the sequential flow of information between an actor and the system (Kruchten, 2010). Figure 4.11 shows the System Sequence diagram for three actors: the user, Kenya power staff, and the system administrator interacting with the Automated Meter Reading system.

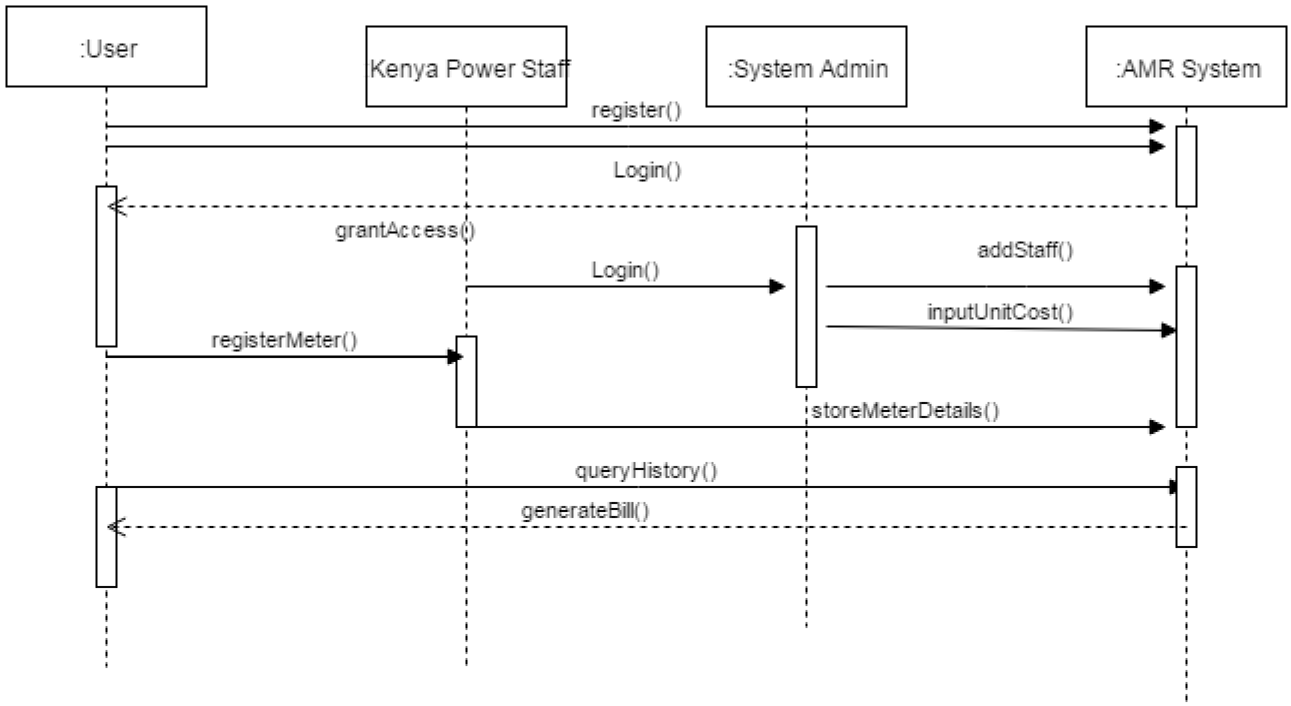

Figure 4.11 : System Sequence Diagram

4.3.7 Entity Relationship Diagram

The system is designed with both SQL and NoSQL approach handling data for almost all entities and components in the entire system. The SQL approach covers the transactions, which include the following details: consumer information, Kenya power staff details and the payment details. The NoSQL approach has the meter id and the units consumed as well as the meter status.This is as shown in figure 4.12.

4.4 Hardware Architecture

The hardware system of the prototype has a number of components including a voltage and a current sensor, a LM358 filter, an ATmega328P microcontroller, an RN2483 LoRa module, and an IC880A concentrator. Figure 4.13 illustrates the overall hardware architecture.

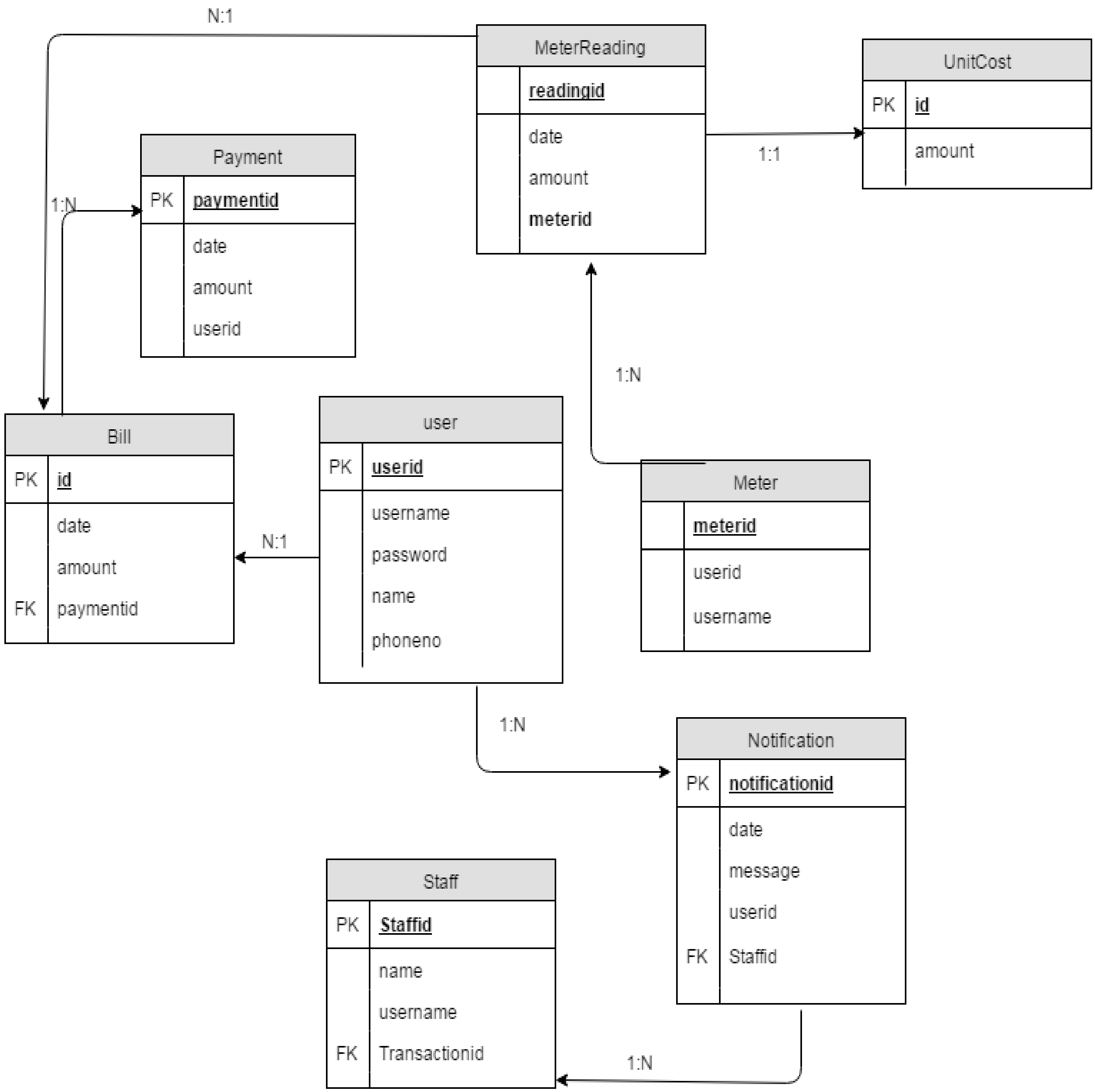

Figure 4.12 : Entity Relationship Diagram

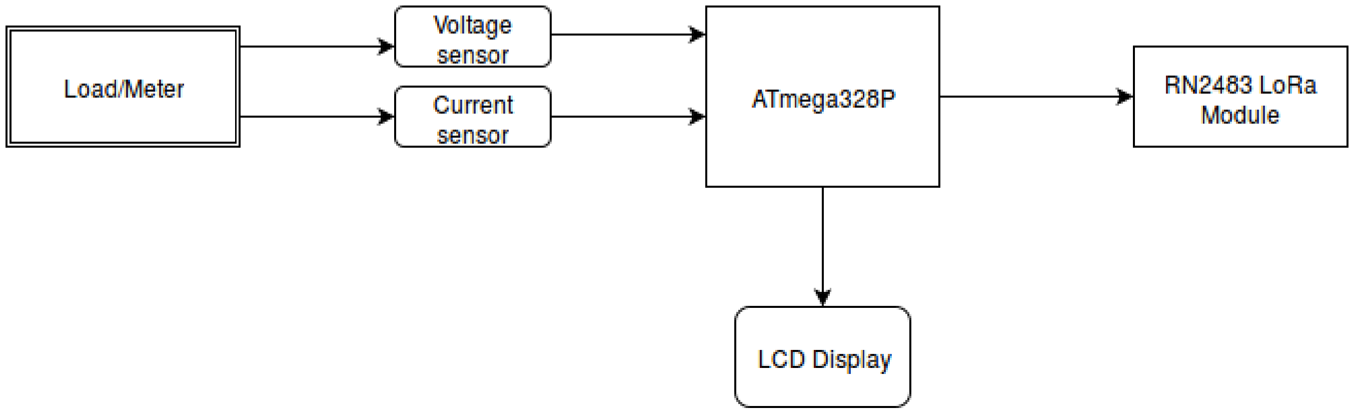

Figure 4.13 : Hardware Architecture

The hardware infrastructure encompasses the use of an ACS712 – 20A current sensor that is adopted as a simulator of an intelligent power meter installed at the customers’ premises by the power utility company. The ACS712 implements the Hall Effect mechanism in detecting changes in current. The Hall Effect is the production of a voltage difference (the Hall voltage) across an electrical conductor, transverse to an electric current in the conductor and a magnetic field perpendicular to the current. This detection combined with a sampling technique of calculating real and apparent power as well as the units using root mean square capability algorithm incoporated in the code libraries enables us to obtain this parameters for transmission to the cloud. This is as outlined in the overall code in the Appendix C.

The current sensor’s detected values are then processed by the ATmega328P, which is an 8-bit AVR RISC-based microcontroller that combines 32KB ISP flash memory with read-while-write capabilities. It hence reads the values of changes in current detected by the ACS712 through its analog interface. The values obtained are translated to digital float values and transmitted by the RN2483 through the ATmega328P UART interface.

The RN2483 is a Low-Power Long Range technology from Micro chip. It is a transceiver module that provides an easy to use, low-power solution for long range wireless data transmission. It runs on LoRa which is a physical layer modulation scheme and complies with the Lora WAN Class A protocol specifications. It integrates RF, a baseband controller, command Application Programming Interface (API) processor, making it a complete long range solution. This capability allows it to transmit data upto 15km in sub-urban environments and 10km in dense cities. In this architecture, this module transmits the float values processed from the ACS712 by the ATmega328P through the UART interface of the microcontroller.

4.4.1 ACS712 Current Sensor

In this design, an ACS712 is used as it provides economical and precise solutions for AC or DC current sensing in industrial, commercial and communications systems. Typical applications include motor control, load detection and management, switched-mode power supplies and over current fault protection. The device consists of a precise, low-offset, linear Hall sensor circuit with a copper conduction path located near the surface of the die. Current measured by this sensor is up to 20A. Similarly, the voltage is measured by this device. The image below shows the ACS712 current sensor. The two terminals on the left are connected to a load or meter and the three terminals on the right are connected to the microcontroller (ATmega328P). Figure 4.14 illustrates the connection of the ACS712 current sensor (LoRa Microchip, 2015).

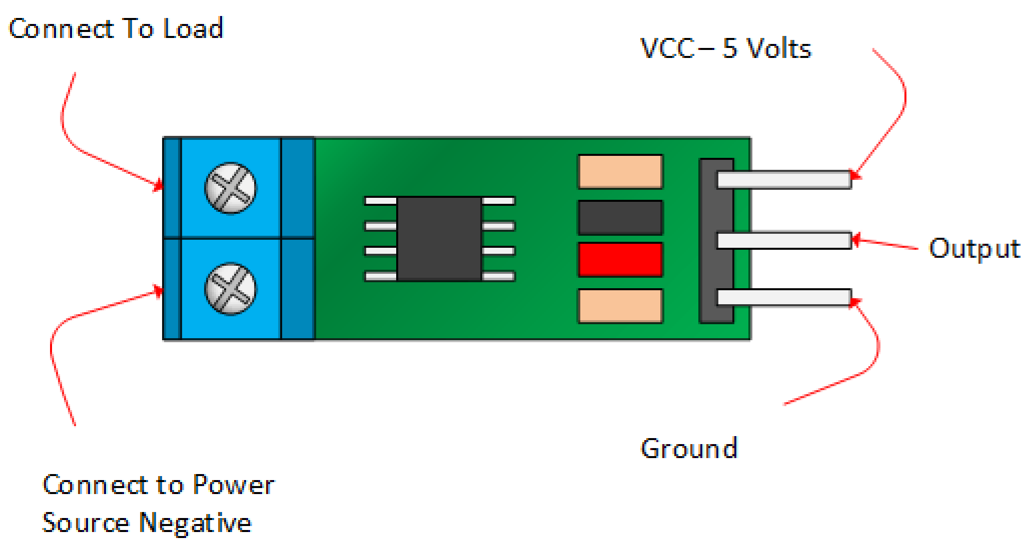

Figure 4.14 : Connection of ACS712 Sensor (LoRa Microchip, 2015)

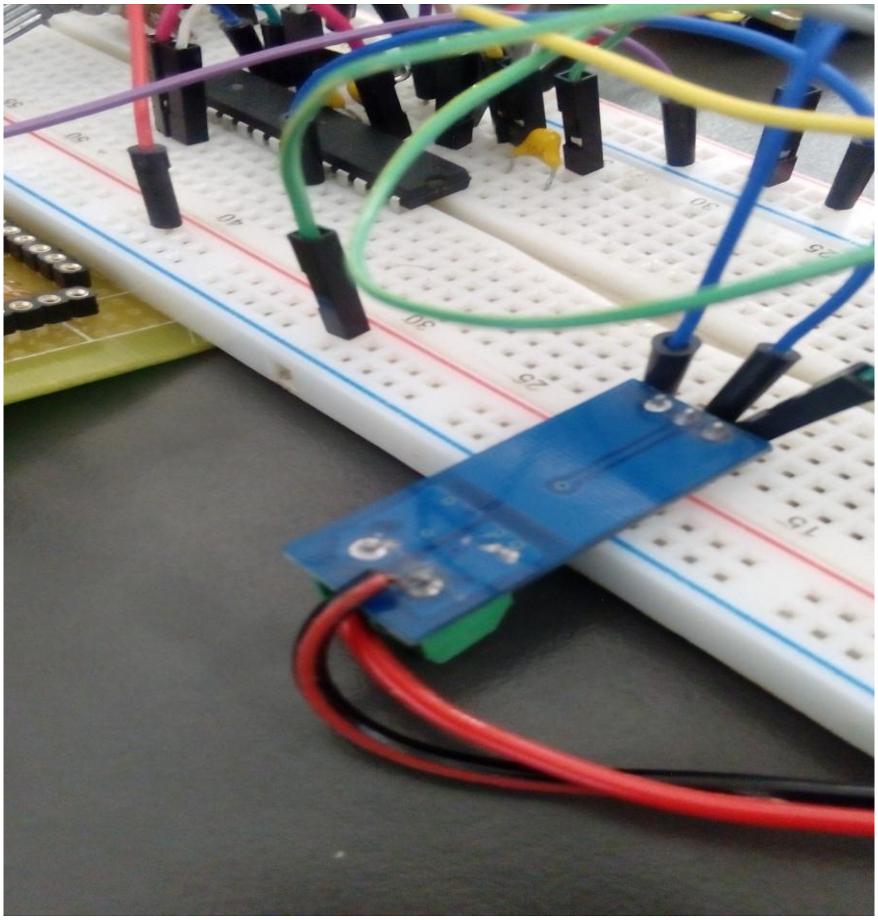

Figure 4.15 : Connection of ACS712 Sensor on breadboard

4.4.2 ATmega328P Microcontroller

The ATmega328P is a low power CMOS 8-bit microcontroller based on the AVR enhanced Reduced Instruction Set Computing (RISC) architecture. By executing powerful instructions in a single clock cycle, the ATmega328P achieves throughputs close to 1 MIPS per MHZ. This empowers system designers to optimize the device for power consumption versus processing speed (LoRa Microchip, 2015).

The ATmega328P provides the following features: 32KB of In-System Programmable Flash with Read-Write capabilities, 1KB of EEPROM, 2KB SRAM, 23 general purpose input/output lines, 32 general purpose working registers, Real Time Counter (RTC), Three flexible Timer/Counters with compare modes and PWM, 1 serial programmable USARTs, 1 byteoriented 2-wire Serial Interface, A 6 channel 10-bit ADC An SPI serial port and an interrupt system to continue functioning.

The ATmega328P pin configuration is as captured in Appendix C.

In the implementation of this prototype, this device packages the interface to the ACS712 -20A current sensor and the communication module (RN2483). The intelligence of the automated power meter reading is executed by the internal capability designed on this microcontroller through the pinouts that are programmed for this prototype. The image in appendix C shows how this device connects on the breadboard.

The image below is a snippet of a C++ code syntax that has been used to program the ATmega328P. It illustrates the initialization of various header files and a call of the sensor connection to execute the detection of the current changes.

```
//intelligent power metering cpp code

//Samuel Ondieki
//12th May 2017


//initialisation of the header files/libraries

#include <TheThingsNetwork.h>
#include <SoftwareSerial.h>
#include "Arduino.h"
#include "ACS712.h"
#include <LiquidCrystal.h>
#include <Wire.h>
#include <stdio.h>

//current sensor
ACS712 sensor(ACS712_05B, A1);
```

The full code is shown in Appendix C.

4.4.3 RN2483

The RN2483 is a low-power long-range low-power transceiver module based on wireless LoRa Technology. It utilizes unique spread spectrum modulation within the sub-GHz band to enable long range, low power and high network capacity. The low power performance capability of the RN2483 provides a longer battery life enhancing the ability of this small device to connect millions of wireless sensor nodes to Lora gateways and IoT-connected Cloud Servers.

This module complies with the LoRaWAN Class A protocol specifications. It integrates RF, a baseband controller, command Application Programming Interface (API) processor that is easy to configure via simple ASCII commands through the UART, making it a complete long range Solution. (LoRa Microchip, 2015).

LoRaWAN networks are laid out in a star topology in which gateways relay messages between end-devices and a central network server at the backend. Gateways are connected to the network server via standard IP connections while end-devices use single-hop LoRa communication to one or many gateways. All communication is generally bi-directional, although uplink communication from an end-device to the network server is expected to have predominant traffic.

All LoRaWAN devices implement at least the Class A functionality. Devices implementing more than Class A are described as "higher Class end-devices." End-devices of Class A allow for bi-directional communications whereby each end-device's uplink transmission is followed by two short downlink receive windows. Class A operation is the lowest power end-device system for applications that only require downlink communication from the server shortly after the end-device has sent an uplink transmission. RN248 handles this protocol between the configured end-devices where a host MCU reads a sensor and commands this module to transmit the sensor reading over the LoRa network (LoRa Microchip, 2015).

The RN2483 is described as having such features as: Long range: greater than 15km, Low power consumption for 10+ year battery life, Operates in 433MHz and 868MHz bands, Embedded Lora WAN Class A protocol, Easy to use ASCII command interface over UART, Supply voltage: 2.1-3.6V, Temperature range: -40°C to 85°C, Adjustable output power up to +14 dBm, High receiver sensitivity down to -148 dBm , Device Firmware Upgrade (DFU) over UART, 14 GPIO for control, status and ADC, Excellent interference immunity and Secure AES-128 encryption

This module transmits the meter values processed on the ATmega328P in the development of this prototype to the Low power LoRa gateway interfacing on Raspberry Pi that then connects to the internet/cloud.

The RN2483 operates at 3.3V with a temperature range of -40°C to +85°C. The chip has an integrated MCU, crystal, EUI-64 Node Identity Serial EEPROM, Radio Transceiver with Analog front end, matching circuitry. This module provides an easy to use, low-power solution for long-range wireless data transmission. The following are the areas of applications for this module:

i. Automated meter reading

ii. Home and Building Automation

iii. Wireless Alarm and Security Systems

iv. Industrial Monitoring and Control

v. Machine to Machine learning

The code snippet below illustrates how this module is called by the microcontroller to transmit data using the LoRaWAN protocol. The module has been registered to an open platform called thethingsnetwork using a network key, an address key and an app key to interface with the LoRa gateway to enable it transmit real-time data to the internet and the cloud. The interface the module uses on the microcontroller is UART. In this case, it uses a software serial.

```
// Set your DevAddr, NwkSKey, AppSKey and the frequency plan
const char *devAddr = "26011B17";
const char *nwkSKey = "862290584505E41ADD244A15584038B3";
const char *appSKey = "7303E5E5E9A279B1A218861165C48647";
```

```
SoftwareSerial loraSerial = SoftwareSerial(8, 7);
#define debugSerial Serial

// Replace REPLACE_ME with TTN_FP_EU868 or TTN_FP_US915
#define freqPlan TTN_FP_EU868

TheThingsNetwork ttn(loraSerial, debugSerial, freqPlan);
```

```
{
  loraSerial.begin(57600);
  debugSerial.begin(9600);
    lcd.begin(16,2);


  // Wait a maximum of 10s for Serial Monitor
  while (!debugSerial && millis() < 10000)
    ;

  debugSerial.println("-- PERSONALIZE");
  ttn.personalize(devAddr, nwkSKey, appSKey);

  debugSerial.println("-- STATUS");
  ttn.showStatus();
  blinkLED(13,2,500);
}

void loop()
{
  char dataToSend[12];
  char buffer[7];
```

The RN2483 is a shown in Appendix C

4.4.4 LCD Display

LCD (Liquid Crystal Display) screen is an electronic display module and find a wide range of applications. A 16x2 LCD display is very basic module and is very commonly used in various devices and circuits. These modules are preferred over seven segments and other multi segment LEDs. The reasons being: LCDs are economical; easily programmable; have no limitation of displaying special and even custom characters (unlike in seven segments), animations and so on.

A 16x2 LCD means it can display 16 characters per line and there are 2 such lines. In this LCD each character is displayed in 5x7 pixel matrix. This LCD has two registers, namely, Command and Data.

The command register stores the command instructions given to the LCD. A command is an instruction given to LCD to do a predefined task like initializing it, clearing its screen, setting the cursor position, controlling display etc. The data register stores the data to be displayed on the LCD. The data is the ASCII value of the character to be displayed on the LCD. The 16x2 LCD display is used in the development of this prototype to mimic the display the power meter comes with. The image below shows the 16x2 LCD screen and the connections interfaced to the ATmega328P microcontroller.

The LCD panel uses an Inter-intergrated circuit (I2C) interface on the microcontroller that is called by the following C++ code snippet on the hardware:

```
//LCD Initialization
LiquidCrystal lcd(12,11,5,4,3,2);
```

```
//print to lcd
  lcd.setCursor(0,0);
  lcd.print("Power:  ");
  lcd.print(realPower);
  lcd.setCursor(0,1);
  lcd.print("units:  ");
  lcd.print(units);
```

The LCD display is shown in Appendix C.

4.5 Network and Software Block Diagram

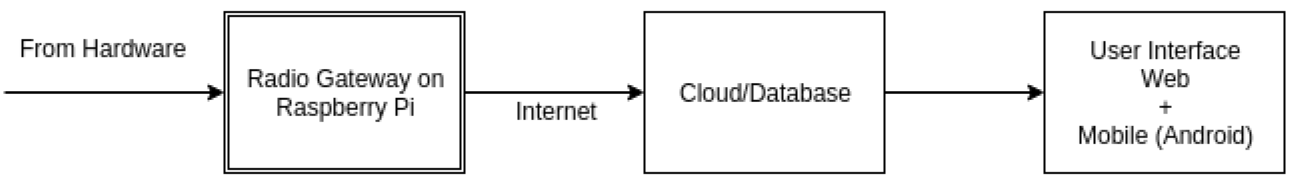

Figure 4.16 : Design of the Software Architecture

4.5.1 IC880A LoRa Gateway

The concentrator module iC880A is targeted for a huge variety of applications like Smart Metering, IoT and M2M applications. It is a multi-channel high performance

Transmitter/receiver module designed to receive several LoRa packets simultaneously using different spreading factors on multiple channels. The concentrator module iC880A can be integrated into a gateway as a complete RF front end of this gateway. It provides the possibility to enable robust communication between a LoRa gateway and a huge amount of LoRa end-nodes spread over a wide range of distance (LoRa Microchip, 2015).

The iC880A needs a host system for proper operation. This host system can be a PC or MCU that will be connected toiC880A via USB or SPI. IC880A is able to receive up to 8 LoRa packets simultaneously sent with different spreading factors on different channels. This unique capability allows implementing innovative network architectures advantageous over other short-range systems as follows:

i. End-point nodes (e.g. sensor nodes) can change frequency with each transmission in a random pattern. This provides vast improvement of the system robustness in terms of interferer immunity and radio channel diversity.
ii. End-point nodes can dynamically perform link rate adaptation based (by adapting their spreading factors) on their link margin without adding complexity to the protocol. There is no need to maintain a table of which end point uses which data rate, because all data is demodulated in parallel.
iii. The capacity of the air interface can be increased due to orthogonal spreading factors.
iv. Due to the high range a star topology can be used. These results in simple implementation avoiding complex network layers, wireless routers and additional network protocol traffic.

The major features of this device include compact size 79.8 * 67.3 mm, Frequency band 868MHz, Orthogonal spreading factors, Sensitivity down to -138dBm, SX1301 base band processor, Supply voltage 5v, Status LEDs and Range up to 15km (Line of Sight).

In the development of an AMR system described herein this device is connected to a raspberry Pi, receives all traffic from the RN2483 module on the ATmega328P and channels the data to the cloud database. The connection of the Raspberry Pi to the IC880A is shown in Appendix C.

Due to the fact that the combination of spreading factors and signal bandwidths results in different data rates, the use of “Dynamic Data-Rate Adaption” becomes possible. That means that LoRa nodes with high distances from the concentrator must use higher spreading factors and therefore have a lower data rate. LoRa nodes which are closer to the concentrator can use lower spreading factors and therefore can increase their data rate. This allows to build easy to handle star or multiple networks without the need of routers or repeaters (LoRa Microchip, 2015).

The following code snippet illustrates the telecommunication parameters the iC880a concentrator uses to receive data from the ACS712 current sensor through the RN2483. These parameters include: frequency, bandwidth, power, spreading factor and coding rate.

```
{
    "SX1301_conf": {
        "lorawan_public": true,
        "clksrc": 1, /* radio_1 provides clock to concentrator */
        "radio_0": {
            "enable": true,
            "type": "SX1257",
            "freq": 867500000,
            "rssi_offset": -166.0,
            "tx_enable": true
        },
        "radio_1": {
            "enable": true,
            "type": "SX1257",
            "freq": 868500000,
            "rssi_offset": -166.0,
            "tx_enable": false
        },
        "chan_multiSF_0": {
            /* Lora MAC channel, 125kHz, all SF, 868.1 MHz */
            "enable": true,
            "radio": 1,
            "if": -400000
        },
        "chan_multiSF_1": {
            /* Lora MAC channel, 125kHz, all SF, 868.3 MHz */
            "enable": true,
            "radio": 1,
            "if": -200000
        },
        "chan_multiSF_2": {
            /* Lora MAC channel, 125kHz, all SF, 868.5 MHz */
            "enable": true,
            "radio": 1,
            "if": 0
        },
        "chan_multiSF_3": {
            /* Lora MAC channel, 125kHz, all SF, 867.1 MHz */
            "enable": true,
            "radio": 0,
            "if": -400000
```

Figure 4.17 Telecommunications code snippet

4.5.2 Raspberry Pi

A Raspberry Pi is described as a system on a chip (SoC) which is a single microchip or integrated circuit (IC) that contains all the components for a system. SoCs are typically found on cell phones and embedded devices. For the Raspberry Pi, the SoC contains both an ARM processor for application processing and a Graphics Processing Unit (GPU) for video processing.

Three models of the Pi currently exist. While the three models are similar, the major differences are as listed in the table 4.2.

Table 4.2: Difference in Raspberry Pi models

Model A	**Model B**	**Model C**
256MB RAM	512MB RAM	1GB RAM
One USB Port	Two USB ports	4 USB Ports
No Ethernet port	One Ethernet Port	Ethernet Port
700MHz single core CPU	900MHz quad core CPU	1,200MHz quad core CPU
No built-in WiFi	No built-in WiFi	802.11n and Bluetooth
ARM1176JZF-S based CPU	ARM Cortex-A7 CPU	ARM Cortex-A53 CPU

In the development of the AMR prototype, the Raspberry Pi has been used here to construct a gateway together with the IC880A LoRa device to receive data from the RN2483 ATmega nodes attached to the meter. The Raspberry Pi model three is the one used here as a translator of long-range radio signals to the cloud transmitting the data received from the meter nodes to the web interface and eventually to the mobile application. This construction uses the SPI interface of the Raspberry Pi.

The code snippet below illustrates the C code that is packaged in a description file of the gateway of the iC880A on the raspberry Pi.

```
{
  "gateway_conf": {
    "gateway_ID": "B827EBFFFECBEAA6",
    "servers": [
      {
        "server_address": "router.eu.thethings.network",
        "serv_port_up": 1700,
        "serv_port_down": 1700,
        "serv_enabled": true
      }
    ],
    "fake_gps": true,
    "ref_latitude": -1.310146,
    "ref_longitude": 36.812234,
    "ref_altitude": 124,
    "contact_email": "leonardmabele91@gmail.com",
    "description": "iC880a + Rpi3"
  }
}
```

Figure 4.18 Code snippet for gateway file description

4.6 Conclusion

To implement the proposed system, this section of the system design is aimed at collecting the user requirements in relation to the research objectives that had been set for the study. This was attained through the enlisting of the user requirements followed by the system architecture and design diagrams that brought out the picture of the expected system. Details of each of the diagrams were also important as they were used to explain the various designs achieved in the literature in this chapter.

Chapter 5: Implementation and Testing

5.1 Introduction

In this chapter, we cover both the implementation and testing of the prototype. The chapter looks at the implementation in terms of the required functionalities for mobile and web application as well as the automated power meter. It first begins by a discussion on the implementation of the automated power meter and then the implementation of the web application then integrated into a mobile application. Testing of the prototype then follows the same order.

5.2 Automated Power meter Implementation

In realizing the implementation of the automated power meter, an assembly of an energy load, a microcontroller unit (MCU), and a radio gateway were put together. A control program to read power data and send it to the system server was written and uploaded into the board. The implementation set up is as shown in Figure 5.1.

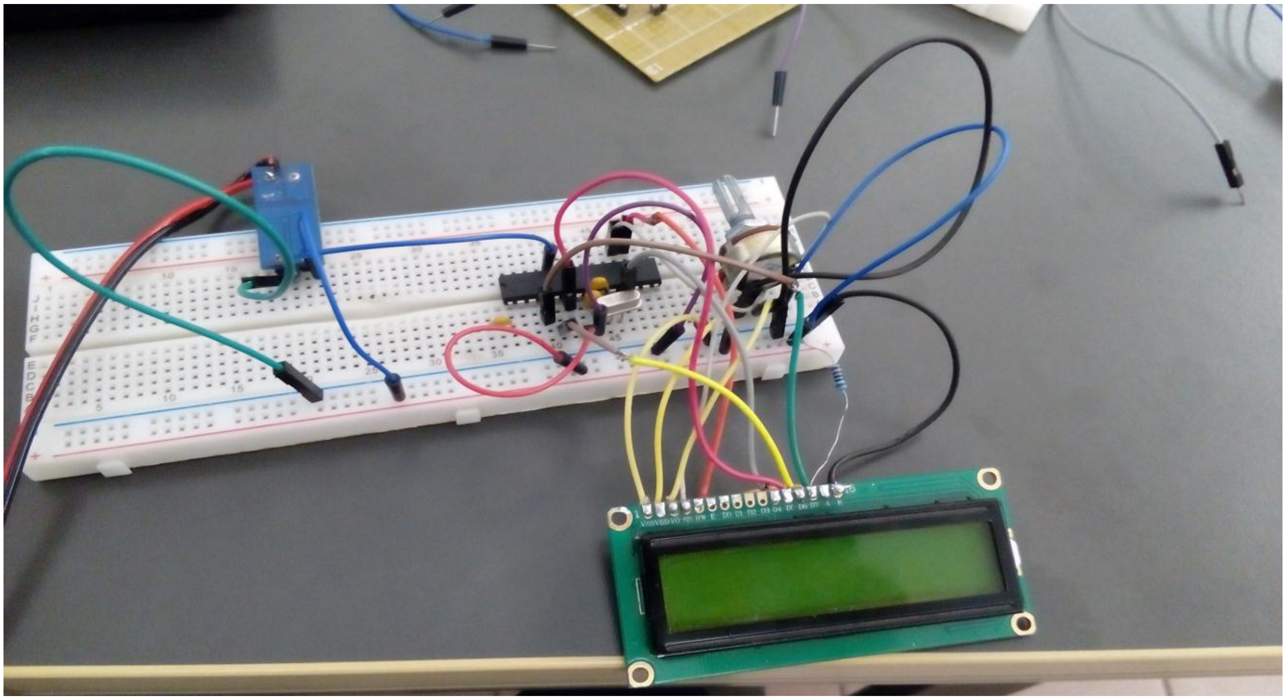

Figure 5.1 : Implementation of the Automated Power System

5.2.1 Web Application Implementation

This section gives the web application implementation in detail. Some screen shots were taken and named based on the task being undertaken at a given time.

Login

The user of the web application is required to login in order to get access to the system. To be able to login the user must be registered and have the login credentials which include the username and password. The login screen is as shown in Figure 5.2.

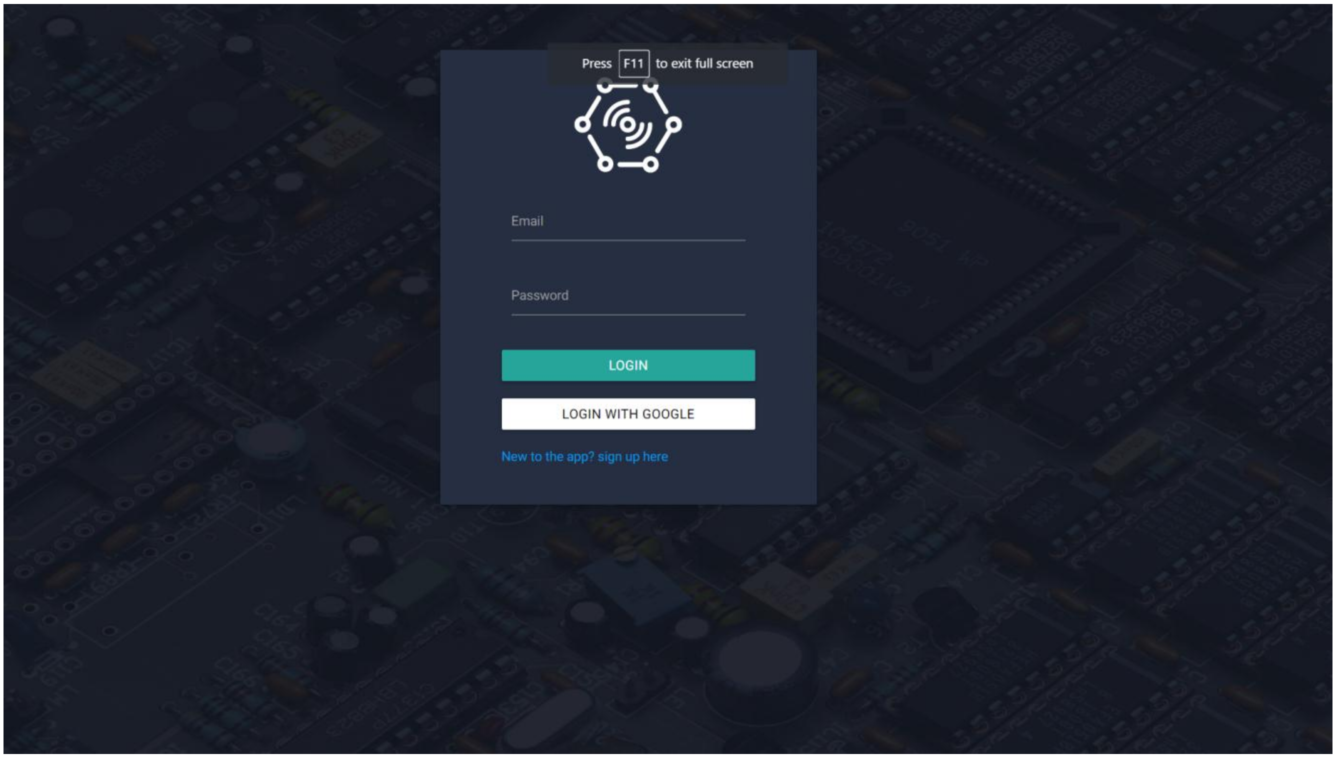

Figure 5.2 : Log in interface

Checking Power Bills

The system allows for checking of the power bills. There are different menu options available on the web application. This allows the user/admin to navigate around in performing different actions. A screen shot for checking the power bill for the customer is as shown in Appendix C.

Adding a new Customer

For new customers who may want to use their mobile phones to access the automated power meter reading system, their information is required by the power supply managers first. This may include the names and meter numbers. The meter number is vital for power meter readings data recordings and subsequent billing. These users are added from the backend dashboard to match their meter numbers. The back-end adopted in this development is Firebase. Appendix C shows an image for adding a new customer.

Control of the Power meter

This option would help the customer and the power supply managers remotely monitor and control the power meter. The figure 5.3 depicts the implementation.

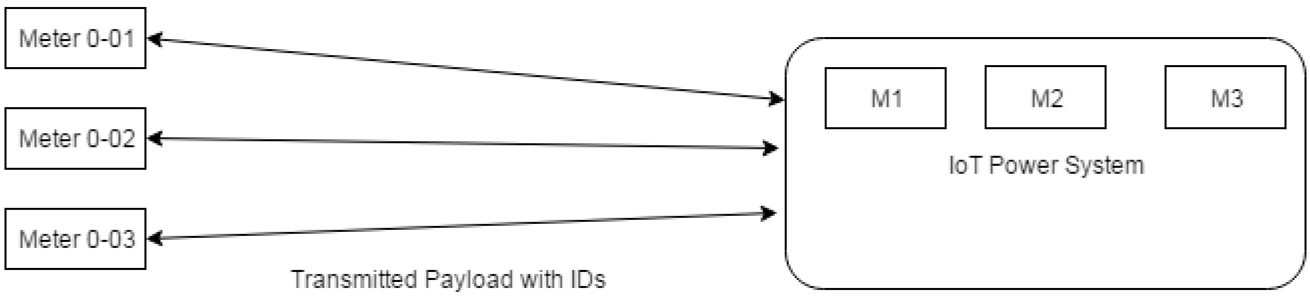

Figure 5.3 : Control of the power meter

Power Usage Graph

This enables the users to see their power consumption graph. The data will present the cumulative power usage per day for a duration of one month. In order for the power managers to visualize the power demand and help them in future, forecasts and planning can use such data from various users valuably. The user can be able to see their power usage monthly from a drop-down option by clicking ok as shown in Appendix C.

5.2.2 Mobile Application Implementation

The mobile application is similar to the web application as it has the login function. Once logged in the user accesses the mobile application home page as shown in Appendix C.

Sending a Message

This functionality enables the power consumers report on any issues to do with power to the service provider. This will appear as an alert on a mobile application.

5.3 Prototype Testing

The functionality of the different components of the system was checked while testing the prototype. This was done systematically and with different combinations of inputs to ensure that any anticipated system behavior was dealt with precisely.

5.3.1 Automated Power Meter Testing

This test was carried out to ensure that the automated power meter was sending the power data to the prototype server. The test results are as shown in table 5.1.

Table 5.1: Power data upload to server

Test Case Number	1		
Test Case Name	Upload Power data		
Description	Upload to system server		
Preconditions	Load connected to meter		
Step No.	**Action point**	**Anticipated Response**	**Outcome**
1	Load turned on	Power data initialized	Pass
Post conditions	Power data sent to server		

5.3.2 Web Application Testing

This phase involved the testing of the web application that was used to receive power consumer messages and energy meter readings for upward data processing. Tests were carried to ensure that all functionalities worked devoid of errors. Viewing of the power bills was the first process tested. This was done to ensure that the readings captured by the energy meters were retrievable and could be viewed by the power supply managers. Table 5.2 summarizes the test case.

Table 5.2: Checking consumer power bills test case

Test Case Number	2		
Test Case Name	Check power bill		
Description	Supply manager/consumer checks bill		
Preconditions	Consumer/manager logged into system		
Step No.	**Action point**	**Anticipated Response**	**Outcome**
1	User selects view bill option	A number of power bills pop up	Pass
Post conditions	User receives all the Power bills data		

Another test case for adding the user was carried out and the results are as shown in the table in Appendix C. This was purposely for checking the add user functionality and how it responded.

5.3.3 Mobile Application Testing

Just like in the web application testing, some tests were also carried out to check the various functionalities of the mobile application. Making payment use case, sending message test case and checking the power bill test case are all shown in Appendix C.

Chapter 6: Discussion of Test Results

6.1 Introduction

This chapter encompasses a discussion of the various tests performed to evaluate the prototype performance and its relevance and practicability. The chapter also includes a discussion that shows how the results obtained help meet the research objectives. There are a number of tests conducted and among them included the prototype testing and usability testing. Prototype testing was done with the aim of confirming the quality of the developed system. Usability testing was done by use of users by testing it to determine how they responded. Key among the comparisons based on this thesis compared to other solutions are highlighted in table 6.1

Table 6.2 Test Results for Functional Requirements

Module Name	**Test Description**	**Expected Behaviour**	**Observed Behavoiur**
Log in and out	To Test log in and out of system	Successful logging in and out of the system	Successful log in and out
Send and Receive Message	To test the sending and receiving messages	To successfully send and receive message	Successful send and receive message
View Power Bills	Test retrieval of power bill data	Able to retrieve power bill information from data base	Power bill data successfully retrieved from database
Add New user	Test adding new user into the data base	Successful insertion of new user into database	Successfully added new user into system

Table 6.1 Comparison of Results

KeyDiscussion Factors/	AMR based on LoRa Infrastructure	Other solutions
Initial cost	Approximately KES25,000 to cover up to 40 installations	Example of one smart meter would cost up to KES 70,000 per a meter and that is one installation
Operation cost	Low operating costs as the only thing needed is software and firmware upgrade.Runs on low power (3.3v-5v) Can reliably run on DC power – only detecting the mains.	Other solutions for example GSM use high power (12v-18v) and and needs operational costs ranging from the Telephone service provider to software
Scalability	The ease of one gateway serving a huge community makes the solution an easy one to scale due to the low cost of the infrastructure, replicating the development in any given environment is easy and less costly	Most of the other solutions are for single installation set ups
Efficiency	Highly efficient due to the use of spread spectrum mechanism unlike GSM infrastructure (accuracy of up to 90%).Due to the low power requirement of the entire system, the infrastructure can be installed to perform sufficiently in remote places as well as towns and cities.Data logged from the hardware to the mobile application matches. This guarantees accuracy of power reading, transmission and visualisation on the application.	Lower efficiency (80-85%) due to GSM dependancy Can not operate well in remote places due to its dependacy on GSM networks that are normally in uptown set-ups locking out the rural remote areas.Data may vary especially on solutions using text recognition patterns and cameras.
Reliabilty	Logs data to the cloud and application in real-time.Can be programmed to communicate status of power (i.e. can be used to detect blackouts) Customers can tell of the cost of their power and available units on the go.	Data for most of the other solutions is not real-time and may Have delays especially on the SMS based applications.Some functionalities can not be achieved with the other solutions
Performance	Due to the low power requirements of the entire solution, the system can run on a low-power DC system for longer	Lower perfomance due to their high power dependancy
Robustness	The entire solution can be developed on a PCB that can withstand temperature, pressure and other thermal changes. The gateway can be installed in noisy places as long as the best line of site is selected.	Most of the other solutions can be affected by noise and light intensity for example the ones utilizing text recognition techniques
Intergration to existing infrastructure	The infrastructure can be incorporated on any class of power meters as the application has generically been developed to interface with the infrastructure.It can be implemented in the industrial power systems as well	Most of the applications given by the other solutions define the type of meters they can work with for example those that can only be used on analogue meters.

6.2 Prototype Testing

Entails the various tests carried out on the mobile and web applications

6.2.1 Testing Environment

70 participants were used to test the application. The application developer tested the application before distributing it for external testing.

6.2.2 Functional and Compatibility Testing

Functional testing was carried out to determine how satisfactorily the mobile and web applications met the set functional requirements. The results are as shown in table 6.1.

The complete system testing passed the system specification requirements. The results showed that the implemented system was operational and met the research objective of developing an automated power meter-reading prototype.

The compatibility test was also done for both the web and mobile applications. This was in a bid to ensure that a maximum number of devices was compatible with the developed system. The results are as shown in table 6.3. Web application compatibility table is shown in table 6.4

.

Table 6.3: Android Model Compatibility with mobile Application

Android Model	Compatibility
Android 8 (2.2)	Yes
Android 9 (2.3.1)	Yes
Android 10 (2.3.3)	Yes
Android 11 (3.0)	Yes
Android 12 (3.1)	Yes
Android 13 (3.2)	Yes
Android 14 (3.3)	Yes
Android 15 (4.0.3)	Yes
Android 16 (4.1.2)	Yes
Android 17 (4.2)	Yes
Android 18 (4.3)	Yes
Android 19 (4.4)	Yes

Table 6.4: Web Application Compatibility with Browser

Browser types	Compatible
Firefox (version 8.0 and above)	Yes
Chrome (All versions)	Yes
Internet Explorer (versions 4 and above)	Yes

From the test results, it was evident that the developed applications are compatible with the target users' devices. This further went a long way in meeting the researches' study objective.

6.3 Usability Testing

Since the developed system was intended to solve the users' problems, testing of the system was important since the users were required to interact with the developed system. The Usability test involved aspects to do with functionality, aesthetics, user friendliness, and acceptability. The results of the corresponding tests and their discussions are represented in figure 6.1.

6.3.1 User Interface Aesthetic Value

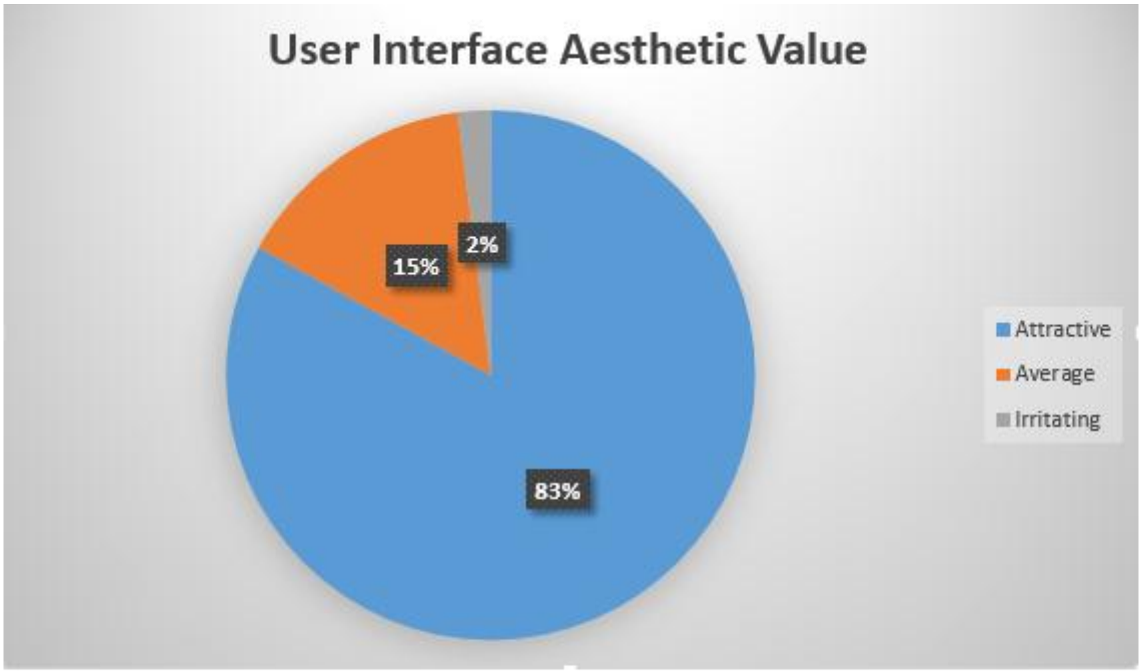

Figure 6.1 : User Friendliness Aesthetic Value

70 respondents were used for the above test. The information gathering about the applications aesthetic value based on users was carried out. With the options to choose from of Attractive, Average and Irritating, 59 of the respondents chose Attractive, 10 selected Average and 2 gave their feedback as Irritating. The chart illustrates the survey in percentage.

6.3.2 User Friendliness

The options floated for this test were Easy, Average, and Difficult. Out of the available 70 respondents, 57 selected Easy 7 chose Average while 6 chose Difficult. Figure 6.2 shows the chart that represents the test results in percentage.

6.3.3 Functionality Test

Functionality of the proposed system is paramount as the user requirements are expected to be met by the proposed solution. The users were asked to state the functionality satisfaction level while using the developed application. The choices that were floated to the respondents were Below Average, Average, and Good. Out of the 70 respondents, 50 gave a feedback of Good, 17 Average while 3 rated the functionality as Below Average. Results shown in the figure 6.3.

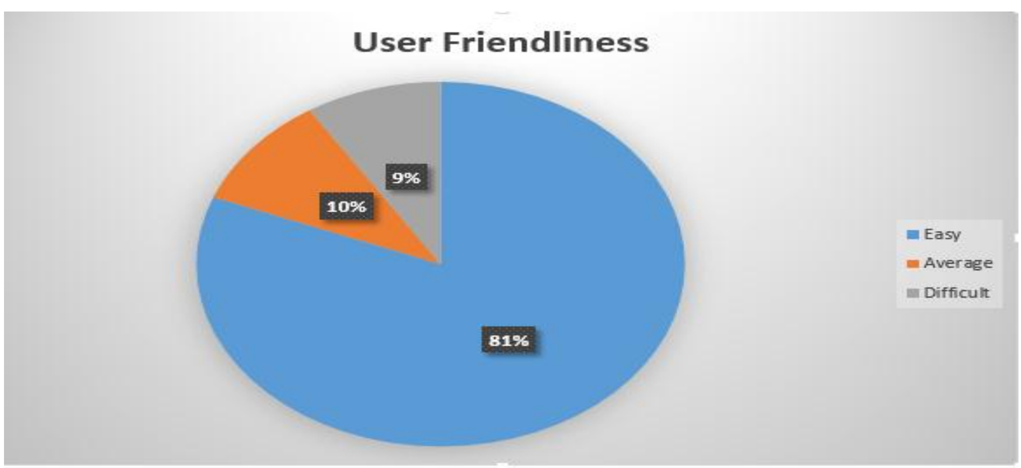

Figure 6.2 : User Friendliness Test Results

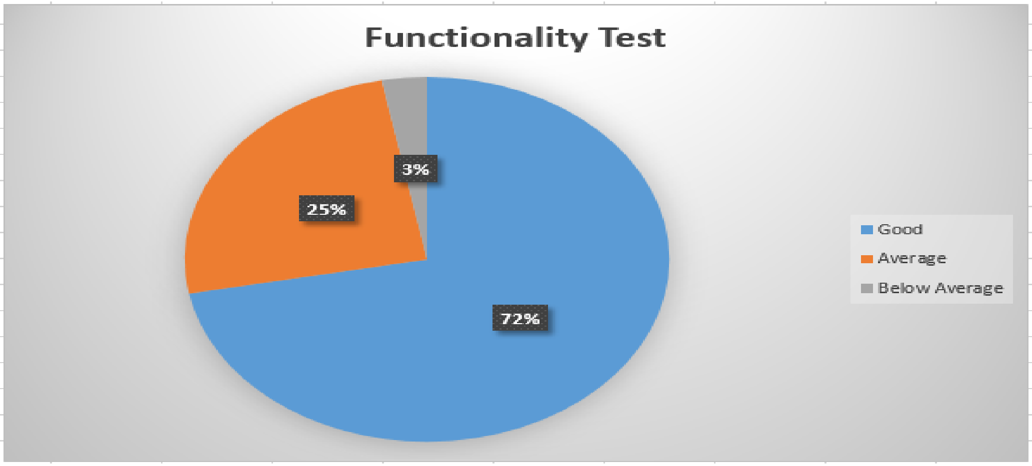

Figure 6.3 : Functionality Test Results

6.3.4 Acceptability Test

This was solely carried out to determine how users would accept and adopt the developed application. Out of the 70 respondents 60 said they would accept the application, 6 were not sure and 4 would reject the application. The results are as shown in figure 6.4.

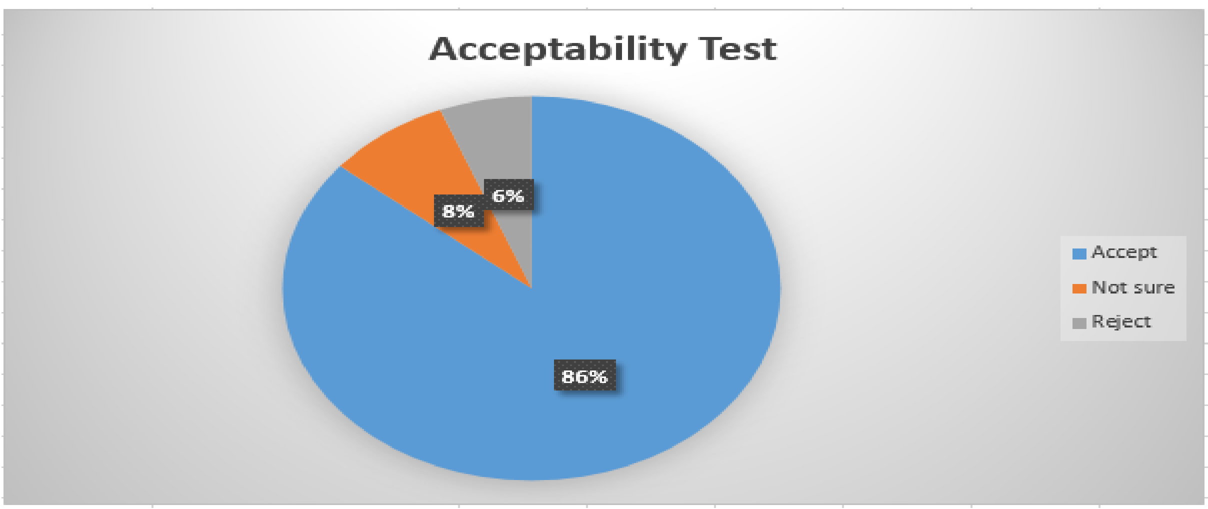

Figure 6.4 : Acceptability Test Results

6.4 Feedback from Users

A survey from the users who used the mobile and web application showed that the applications were easier to use and visually appealing from the feedback gotten. There were recommendations that were however raised concerning the users feedback.

i. Visual icons to be used in the menus for the application to be better

ii. Feedback to be enhance especially for users who have posted a report

6.4.1 Sample Feedback from Users

A sample survey to get feedback from users on whether the developed system would gain support or not was carried out. The results of the respondents response is as shown in figure 6.5.

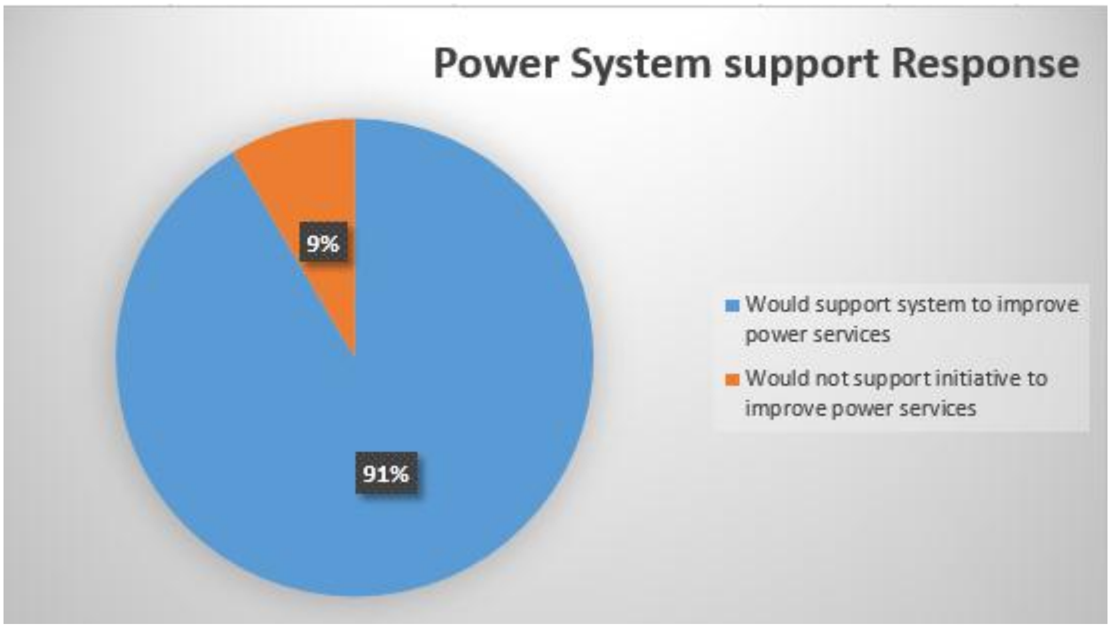

Figure 6.5 : User system Response support

Chapter 7: Conclusions and Recommendations

7.1 Conclusions

The main aim of this study was to develop a prototype that would automatically read power meters as a way of offering alternative solutions to the problem of estimated readings. This aim has been achieved. Considering the existing methods used for billing customers, this study has proved that it can help improve efficiency at a cost-effective price. Further, it has been shown that the prototype developed will not replace the existing post-paid meters making it easy to implement and in a short time.

Generally, this study has proven to have more merits compared to the other solutions already discussed in this thesis. Key among the merits are contained in the lower costs both initial and operating costs. Performance and efficiency have also been proven an edge over the existing solutions. One iC880a gateway can serve upto 40 installed meters all transmitting through the same gateway at different frequencies, spreading factors, codeing rate, power and bandwidth. This can only compare with for example smart meters which have part of these merits but not all especially in scalabilty.

7.2 Recommendations

This study has shown that it is possible to have an automated power meter reading system, which would help improve on efficiency, accountability, transparency and leverage on the capacity to demand responsiveness in provision of power supply.

The research recommends that in bid to make the solution more commercial and look into mass production there will be need to have changes on the solution in order to achieve scalability. Since the industry deals for example with a big number of meters the solution required would use an architecture that can easily be scaled especially on the gateway controller to be able to offer solution to a bigger number of meters.

There is still room for improvement in this research of automated power meter reading systems. With the advent of mobile technology which keeps changing due to varied user demands, emerging innovations can be utilized towards improvement of automated meter reading systems. This research would recommend further works with regard to power supply and automation of the meter reading services.

i. The inclusion of artificial intelligence for example to help in data analytics with the expected volumes of big data. This is considering that the data can be gotten real time leading to a possibility of time series data and its analytics.

ii. We would also recommend that possible inclusion of some intelligent agents to look into issues of power losses especially through fraudulent use of power. Since automation would mean no regular physical visits by the Kenya power employees, such expert systems would try send reports in cases where for example some customers may resort to power theft.

7.3 Future Works

i. Focus has been on post-paid mode of meters. Future works can also look at a way to monitor consumption and readings of pre-paid type of consumers.

ii. I would also recommend that future works could focus on a bigger geographical terrain and consider putting in more time to cover more locations. This is in a bid to reach out to more population for requirement analysis.

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APPENDIX A

Letter of Introduction
Dear Respondent,

I am a graduate student at Strathmore University undertaking a Master's Degree in Information Technology. The following questionnaire is part of a study conducted to design an Automated Power Meter reading prototype for billing and accuracy for Kenya Power and its customers. The focus of the study is for residents in Nairobi County and tries to find out the challenges they face in power supply systems. Your response will be treated confidentially and used for academic purposes only.

Choose the answer which best explains your preference and circle the letter(s) next to it. Leave blank any question that does not apply.

PART A

1. **What is your age?**

   A. Between 20-30 years
   B. Between 30-40 years
   C. 40 and above years

2. **Do you own a mobile Phone?**

   A. No
   B. Yes

3. **What type of operating system does your phone use?**

   A. Windows

   B. Android

   C. IOS

   D. Others

3. **Do you own your own house in Nairobi or you rent?**

A. Yes

B. No

4. **If Yes in 3 above, what is your main source of Power?**

A. Solar

B. Wind

C. Kenya Power grid

D. No power

E. Other

PART B

Please rate the following power supply issues between 1-5 where 1 denotes least challenging and 5 most challenging

6. **I do not know who to complain to in case of a water problem**

○ 1 ○ 2 ○ 3 ○ 4 ○ 5

7. **Power Rationing and disconnections happens without notice**

○ 1 ○ 2 ○ 3 ○ 4 ○ 5

8**. I do not know how much I use for power bills**

○ 1 ○ 2 ○ 3 ○ 4 ○ 5

9. **There are no clear channels to complain about power problems**

○ 1 ○ 2 ○ 3 ○ 4 ○ 5

10. **Inconvenient available channels for reporting on power related issues**

○ 1 ○ 2 ○ 3 ○ 4 ○ 5

11. **Lack of power availability**

○ 1 ○ 2 ○ 3 ○ 4 ○ 5

12. **High cost of power**

○ 1 ○ 2 ○ 3 ○ 4 ○ 5

13. **Inaccurate power payment payments**

○ 1 ○ 2 ○ 3 ○ 4 ○ 5

14. **What are the other functionalities you could wish added in the system/application?**

○ 1 ○ 2 ○ 3 ○ 4 ○ 5

15. **Would support the initiative to have this system for communication between consumer and power supplier?**

○ 1 ○ 2 ○ 3 ○ 4 ○ 5

Submit

APPENDIX B:

Feedback Questionnaire

Dear respondent,

I am a graduate student at Strathmore University undertaking a Master's degree in Information Technology. I am conducting a research study on the use of Automated Power meter reading and supply management. Your participation and response will be highly appreciated. I further assure you that your response will be treated confidentially and strictly used for purposes of this academic research only.

1. **Is the application compatible with your device?**

A. Yes

B. No

2. **Is the application satisfactory and of use?**

A. Yes

B. No

3. **Is the application visually appealing?**

A. Attractive

B. Average

C. Irritating

4. **Is it easy to navigate through the application and get information?**

A. Yes

B. No

5. **How user friendly is the application?**

A. Easy

B. Average

C. Difficult

6. **How well did the application execute different operations?**

A. Good

B. Average

C. Below average

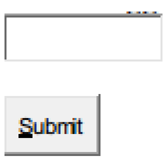
7. **Did you find the application useful and would you willingly accept to use it?**

A. Accept

B. Not sure

C. Reject

8. **Give your view of any improvement**



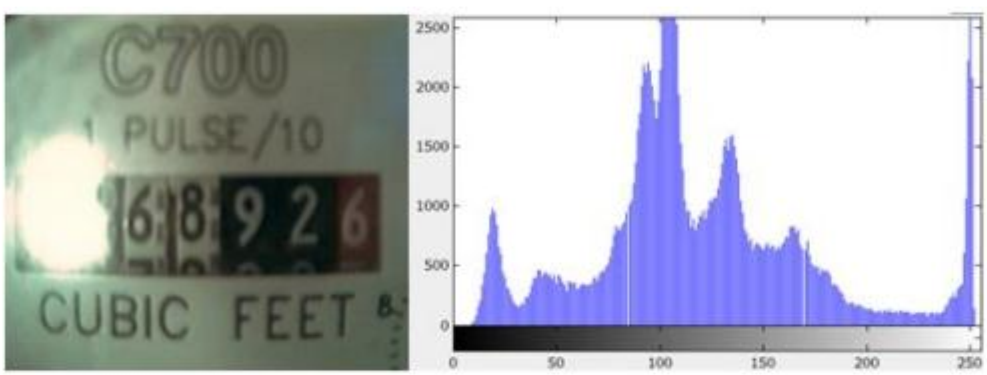
APPENDIX C

Analogue Meter: Measures the amount of electrical energy via the voltage and current coil.

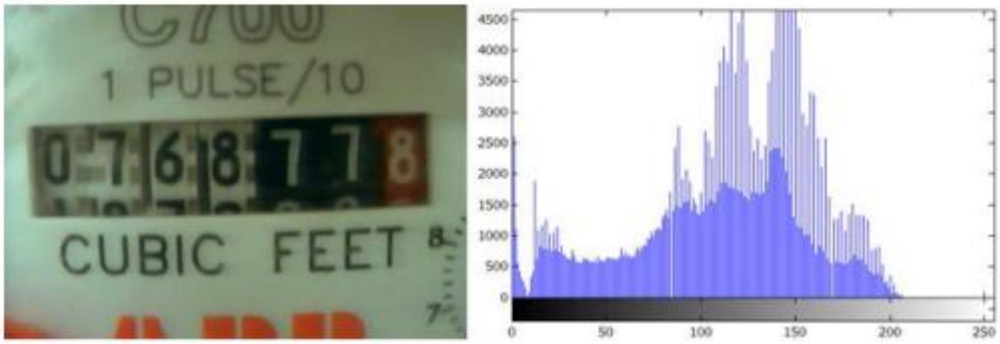
The readings are displayed on an analogue kind of display.It has mechanical gears

Prepaid Meter:Has the customer buying a token and uploading the units before having power on

Automated Meter:Can send data to the service provider via GSM automatically



Double peak Graph:Recognition of text from a picture to a pattern recgnition method by Adaboost Learning in a double peak graph



Single peak Graph: Recognition of text from a picture to a pattern recgnition method by Adaboost Learning in a single peak graphy

Given: $(x_1, y_1), \ldots, (x_m, y_m)$ **where** $x_i \in X, y_i \in Y = \{-1, +1\}$
Initialize $D_1(i) = 1/m$.
For $t = 1, \ldots, T$:

- **Train weak learner using distribution** D_t.
- **Get weak hypothesis** $h_t : X \to \{-1, +1\}$ **with error**

$$\epsilon_t = \Pr_{i \sim D_t}\left[h_t(x_i) \neq y_i\right].$$

- **Choose** $\alpha_t = \frac{1}{2} \ln\left(\frac{1 - \epsilon_t}{\epsilon_t}\right)$.
- **Update:**

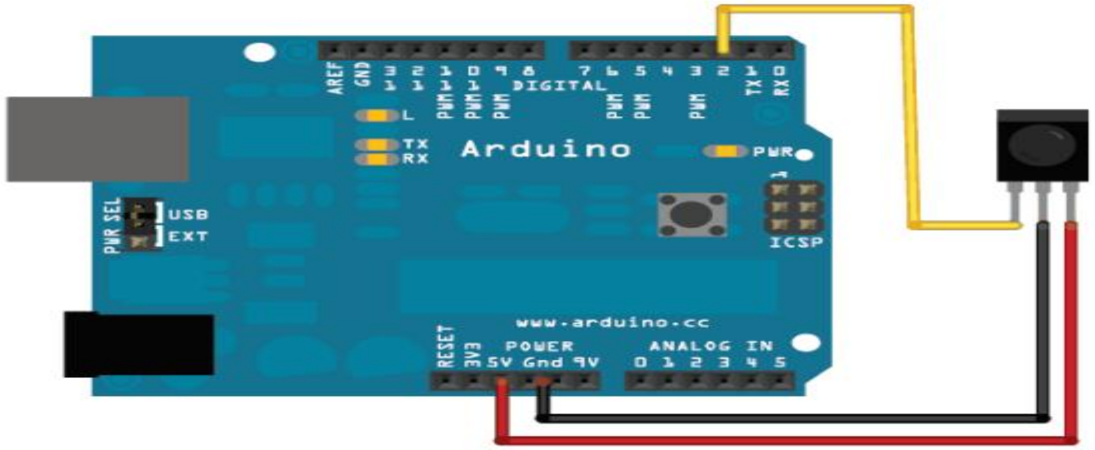
$$\begin{aligned} D_{t+1}(i) &= \frac{D_t(i)}{Z_t} \times \begin{cases} e^{-\alpha_t} & \textbf{if } h_t(x_i) = y_i \\ e^{\alpha_t} & \textbf{if } h_t(x_i) \neq y_i \end{cases} \\ &= \frac{D_t(i) \exp(-\alpha_t y_i h_t(x_i))}{Z_t} \end{aligned}$$

where Z_t **is a normalization factor (chosen so that** D_{t+1} **will be a distribution).**

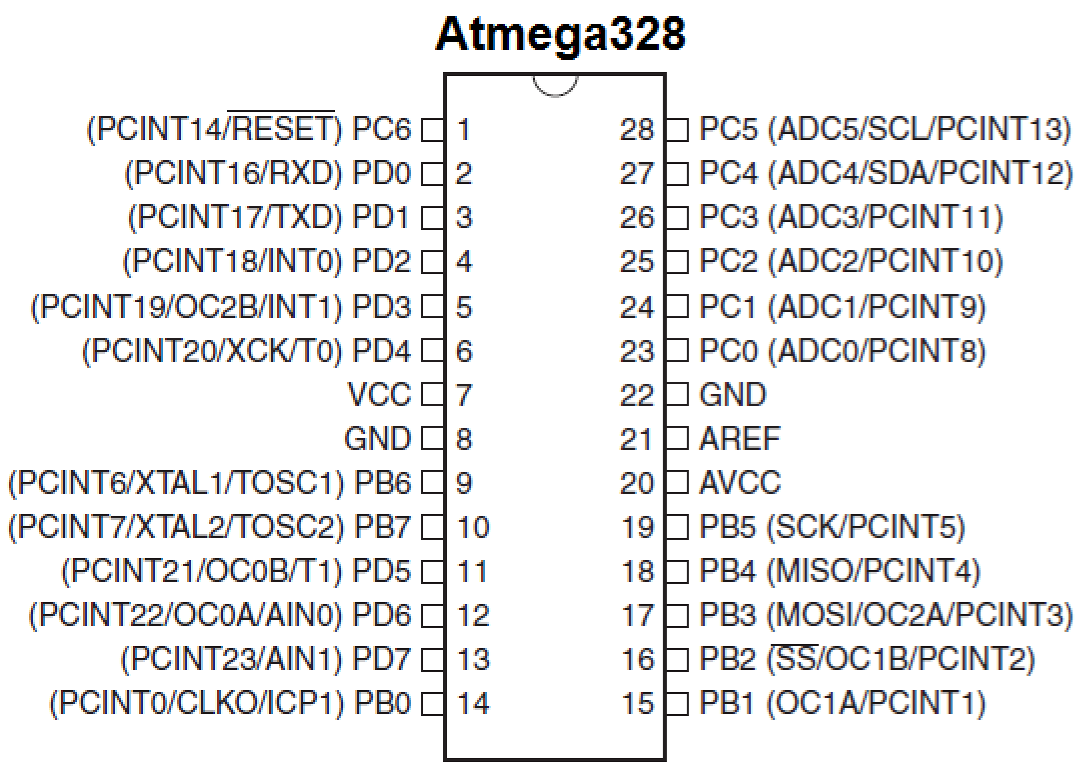
Output the final hypothesis:

$$H(x) = \text{sign}\left(\sum_{t=1}^{T} \alpha_t h_t(x)\right).$$

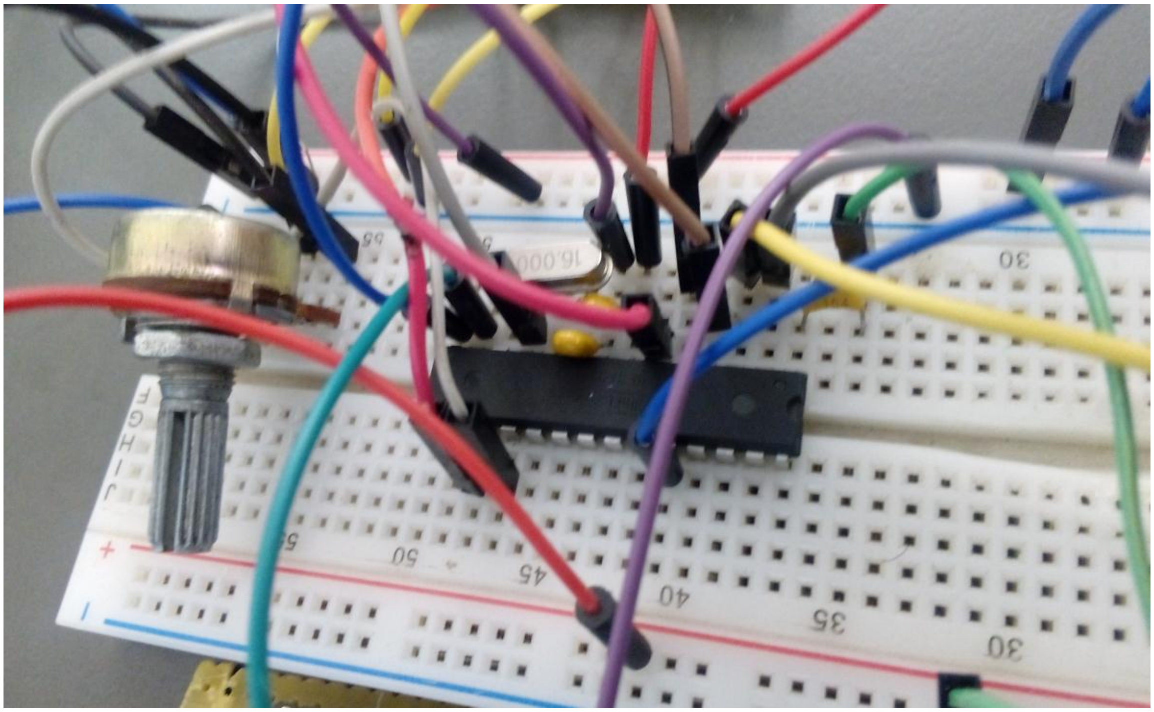
Pseudocode for Text Recognition in Adaboost Learning method. Essentially for pattern recognition



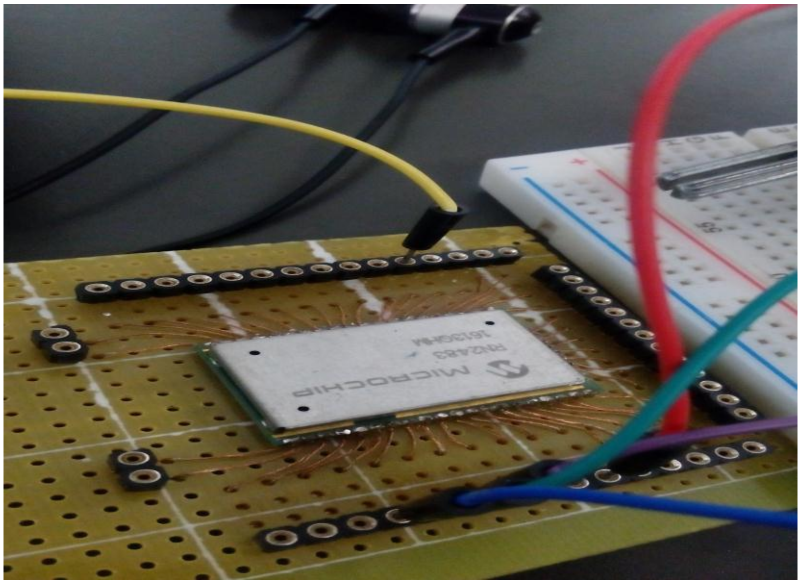
Arduino Sensor: For sensing envirnmental characteristics say temperature, smoke,frequency



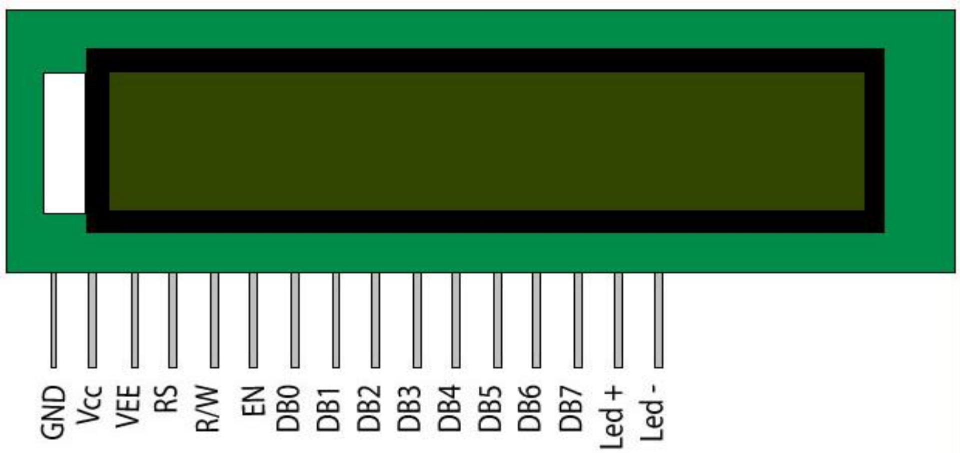
AtMega 328 Pin : Shows the configuration of various pins contained in the programmable Module



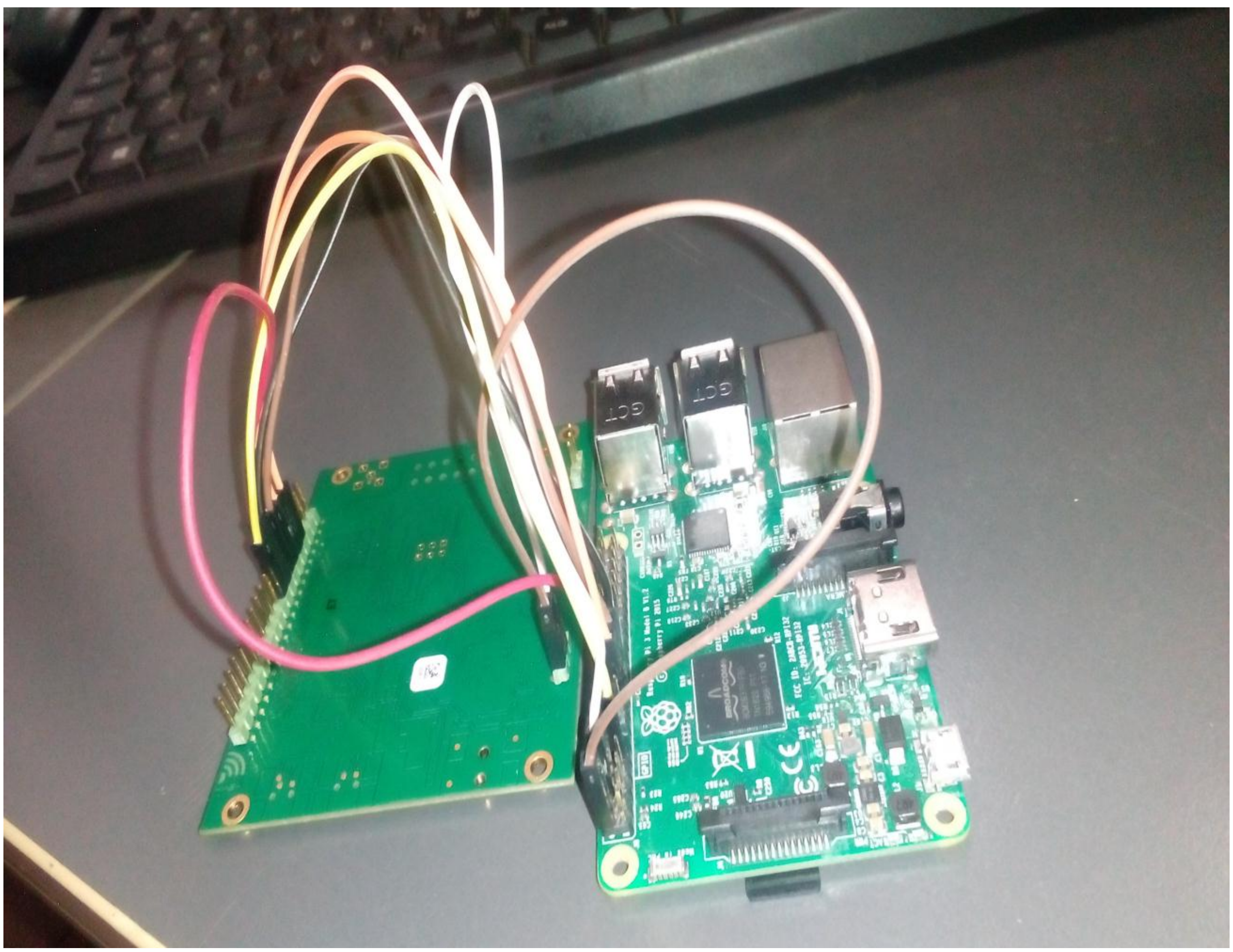
Connection of Atmega28 to the Breadboard:Depicts the connection of the embedded hardware on the breadboard



RN2483 Connection: Depicts the connection of the LoRa communication module to the embedded hardware



LCD: Shows the display that gives the load values at given times connected to the meter and the embedded hardware



Respberry Pi :Shows Connection of the Lora infrastructure to the Raspbery Pi-IC880A

Use case Name	View Power bill	Identifier: 2
Brief Description	User views power bill	
Type	External	
Major Inputs Power bill request	**Source** Power consumer	**Major Outputs** User receives power bill
Preconditions	User having to launch the mobile application	
Post conditions	User receives power bill	
Flow of Events	1.User selects view power bill option 2.The application presents the current power bill from the server to the user	

View power bill Use case: The use case enables the view power bill option by the customer

Use case Name	View Payments	Identifier: 3
Brief Description	Manager views power bill payments	
Type	External	
Major Inputs Power bill payments request	**Source** Power supply manager	**Major Outputs** User receives power bill
Preconditions	Manager must be logged into the application	
Post conditions	Power bills Payments report	
Flow of Events	1.Prototype presents the manager with options to choose from 2.Manager selects view power bill payments 3.Prototype presents power bill payments to the manager	

View Payments Use case: Enables the viewing of payments made by the customer

Use case Name	Add New User	Identifier: 4
Brief Description	Manager new power user into the system	
Type	External	
Major Inputs Power user details	**Source** Power supply manager	**Major Outputs** New user added into system
Preconditions	Manager must be logged into the application New power user wants to be registered and connected to power supply	
Post conditions	New power consumer added into system	
Flow of Events	1.Prototype presents the manager with options to choose from 2.Manager chooses the Add new user option 3.Power consumer represents the registration details 4.Manager enters the details into the system 5.Manager submits the details into the system 6.New member is added to the database 7.Manager receives the feedback on the registration process-success/fail	

Add New User Use Case: Enables the Admin/power utility managers add new users who may want to use the system

Test Case Number	3		
Test Case Name	Add user		
Description	Supply manager/Administrator add new user		
Preconditions	Administrator/manager logged into the system		
Step No.	**Action point**	**Anticipated Response**	**Outcome**
1	Admin/Manager selects add new user option	Option of adding new user pops up	Pass
2	Admin inputs details and submits	Add new user created to the database	pass
Post conditions	New user is added to the database		

Add User Test case: Basically shows the pre/post conditions for adding a new user

Test case Number	4		
Test case Name	Making Payment		
Description	Testing Functionality of making payment of bills on mobile app		
Preconditions	User must start the installed mobile app		
Step Number	**Action point**	**Anticipated response**	**Outcome**
1	User choses payment option from menu presented	Option of making payment presented to the user to input payment transaction code	Pass
2	User types the payment transaction code and submits	Dialogue of the process informing user to wait for completion	Pass
3	User receives server response	User presented with message: payment successful/failed	pass
Post conditions	Payment information saved in the database		

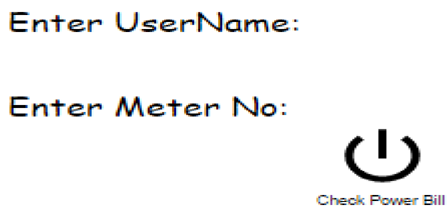
Making Payment Test case: Showing the steps that are followed in making of power bill payments by a user

Test case Number	5		
Test case Name	Sending message		
Description	Testing Functionality of user sending message to power company		
Preconditions	User must start the installed mobile app		
Step Number	**Action point**	**Anticipated response**	**Outcome**
1	User choses send message option from menu presented	Option of sending message presented to the user on the input fields	Pass
2	User types the send message and submits	Dialogue of the process informing user to wait for completion	Pass
3	User receives server response	User presented with feedback: message successful/failed	pass
Post conditions	Message is saved in the database		

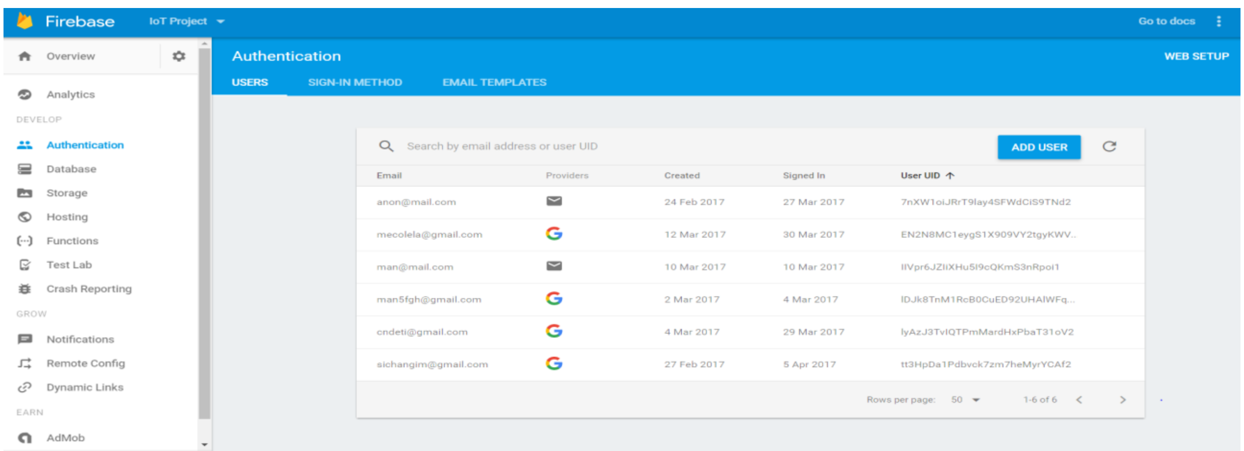
Sending Message Test case: Depicts the process of sending the message until it is saved in the database/cloudserver

Test Case Number	6		
Test Case Name	Checking power bill		
Description	Testing functionality of user checking power bills		
Preconditions	User starts mobile application		
Step No.	Action	Response	outcome
1	User selects check power bill	Process pops but tells user to wait	pass
2	App receives data from server	App presents power bill	pass
Post conditions	User receives power bill		

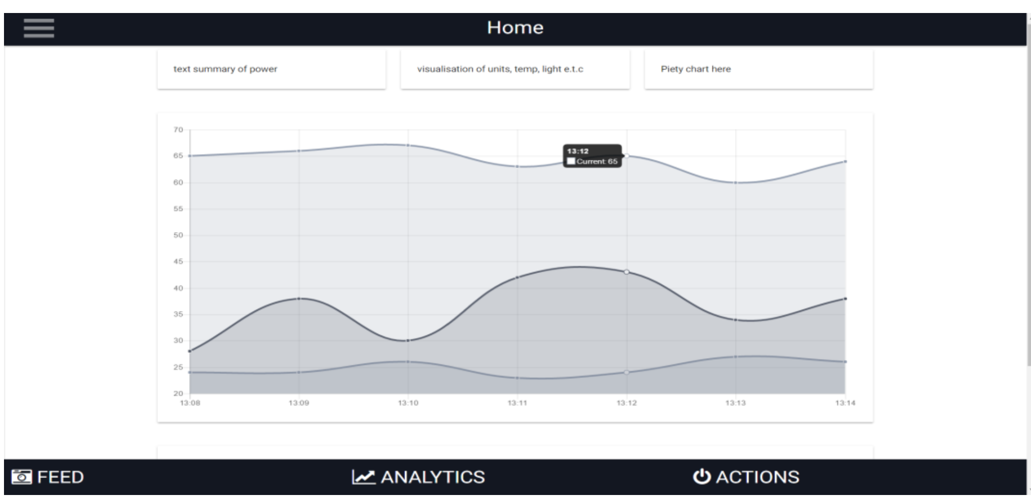
Checking Power bill Test case: Shows the process of a user checking his/her power bill



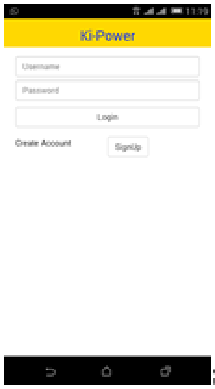
Checking Power bill: Web application Screen Shot



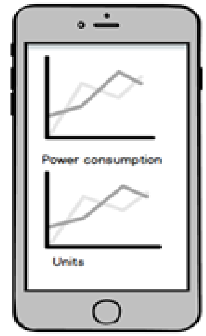
Adding New Customer on Web Application



Power Usage Graph: Shows the average power consumption graphically



Sign Up and Login Check Bill



Consumption

Mobile Application home page: How the mobile App looks like on the home page

Full Hardware and Communication code

```
//intelligent AMR cpp code

//Samuel Ondieki
//12th May 2017


//initialisation of the header files/libraries

#include <TheThingsNetwork.h>
#include <SoftwareSerial.h>
#include "Arduino.h"
#include "ACS712.h"
#include <LiquidCrystal.h>
#include <Wire.h>
#include <stdio.h>

//current sensor
ACS712 sensor(ACS712_05B, A1);


double vRMS = 0;
float voltageV, voltageC;
float instVoltage, instCurrent;
int sampleV, sampleC;
float sumI, sumV, sumP;

const int numberofSamples = 3000;

float realPower, apparentPower, ReactivePower;
float powerFactor, Voltage, Current;
unsigned long KWhTime, last_KWhTime;
float units = 12.45;
//float units;



//LED_BUILTIN
#define LED13  13
```

```
//LCD Initialization
LiquidCrystal lcd(12,11,5,4,3,2);

// Set your DevAddr, NwkSKey, AppSKey and the frequency plan
const char *devAddr = "26011B17";
const char *nwkSKey = "862290584505E41ADD244A15584038B3";
const char *appSKey = "7303E5E5E9A279B1A218861165C48647";

SoftwareSerial loraSerial = SoftwareSerial(8, 7);
#define debugSerial Serial

// Replace REPLACE_ME with TTN_FP_EU868 or TTN_FP_US915
#define freqPlan TTN_FP_EU868

TheThingsNetwork ttn(loraSerial, debugSerial, freqPlan);

float calculatePower(){
    for(int i = 0; i<numberofSamples; i++)
    {
        sampleV= 240;
        //sampleC = analogRead(A1);
    sampleC = sensor.getCurrentDC();
        // || sensor.getCurrentAC();

        voltageC = sampleC*5.0/1023.0;
        voltageV = sampleV*5.0/1023.0;

        instCurrent = (voltageC-2.5)/0.66;
        instVoltage = (voltageV-2.46)*7.8;

        sumV += instVoltage*instVoltage;
        sumI += instCurrent*instCurrent;

        sumP += abs(instVoltage * instCurrent);
```

```
}

  Voltage = sqrt(sumV/numberofSamples);
  Current = sqrt(sumI/numberofSamples);

  realPower = sumP / numberofSamples;
  apparentPower = Voltage * Current;
  powerFactor = realPower/apparentPower;
  ReactivePower=sqrt(apparentPower*apparentPower - realPower*realPower);

  last_KWhTime = KWhTime;
  KWhTime = millis();

  units += (realPower/1000)*((KWhTime - last_KWhTime)/3600000.0);

  sumV = 0;
  sumI = 0;
  sumP = 0;

  Serial.print(Voltage);
  Serial.println(" V");
  Serial.print(Current);
  Serial.println(" A");
  Serial.print(realPower);
  Serial.println(" KW");
  Serial.print(units);
  Serial.println(" KWH");

  return realPower;


oid blinkLED(int ledID, int repeat, int wait) {
 if (repeat == 999) {
   digitalWrite(ledID, HIGH);
   return;
 }
 if (repeat == 0) {
   digitalWrite(ledID, LOW);
   return;
```

```
  }
  for (int i = 0; i < repeat; i++) {
    digitalWrite(ledID, HIGH);
    delay(wait);
    digitalWrite(ledID, LOW);
    delay(wait);
  }
  delay(1000);
}

void setup()
{
  loraSerial.begin(57600);
  debugSerial.begin(9600);
    lcd.begin(16,2);


  // Wait a maximum of 10s for Serial Monitor
  while (!debugSerial && millis() < 10000)
    ;

  debugSerial.println("-- PERSONALIZE");
  ttn.personalize(devAddr, nwkSKey, appSKey);

  debugSerial.println("-- STATUS");
  ttn.showStatus();
  blinkLED(13,2,500);
}

void loop()
{
  char dataToSend[12];
  char buffer[7];


  calculatePower();

  //print to lcd
   lcd.setCursor(0,0);
   lcd.print("Power: ");
```

```
    lcd.print(realPower);
    lcd.setCursor(0,1);
    lcd.print("units: ");
    lcd.print(units);

  debugSerial.println("-- LOOP");

  // Prepare payload of 1 byte to indicate LED status
  byte payload[20];
  //payload[0] = (digitalRead(LED_BUILTIN) == HIGH) ? 1 : 0;

  dtostrf(calculatePower(), 2, 2, buffer);
  strcpy(dataToSend, buffer);
  strcat(dataToSend, ", ");
  dtostrf(units, 2, 2, buffer);
  strcat(dataToSend, buffer);

  debugSerial.println(dataToSend);
  // Send it off
  ttn.sendBytes(dataToSend, sizeof(dataToSend));

  delay(10000);
}
```

This full code has the embedded hardware code for integration of both the current and voltage in coming up with real power in KW. Also contains the code for communication of the between the LoRa module and the radio gateway

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