COLLEGE OF SCIENCE AND TECHNOLOGY

IoT based Monitoring System for Authorized retail freezer contents for beverage Companies

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College of Science and Technology

Master of Science in Internet of Things – Embedded Computing Systems

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A dissertation submitted in partial fulfilment of the requirements for the degree of

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Supervised by: Dr Ndashimye Emmanuel

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Student declaration

I declare that this Dissertation contains my own work except where specifically acknowledged.

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Signature: .....  .....

Date: ……14.6.2021…….....

BONAFIDE CERTIFICATE

This is to certify that the project entitled “IoT based Monitoring System for Authorized retail freezer contents for beverage Companies” is a record of original work done by Nawoya Sarah with registration number 219013752 in partial fulfilment of the requirement for the award of masters of sciences in Internet of Things in College of Science and Technology, University of Rwanda, Academic year 2019/2020

This work has been submitted under the guidance of Dr Ndashimye Emmanuel and Dr Masabo Emmanuel

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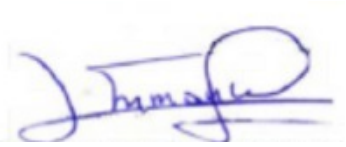
Signature:  Signature: 

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ABSTRACT

The market growth for beverage products has come with increasing expenditure in marketing, and companies issue out refrigerators to retailers and other resellers of their products. To ensure proper usage of the fridges, supervisors are employed. This system enables remote monitoring of the fridges by detecting illegal products and violation of the fridges. The products have standard weights and they are labelled with RFID tags. They are recognized by the RFID reader and weight sensor inside the fridge when inserted in the fridge. GPRS enables the company to remotely monitor the fridges while generating data about products added, violations of the fridge and general usage of the fridge to maximize efficiency. Data from these fridges enables the company generate valuable business insights. This enables significant reduction in cost incurred in monitoring the fridges.

Key words: RFID, IoT, load cell/weight sensor, GSM/GPRS, Arduino Uno, Smart fridge

List of Acronyms

RFID- Radio Frequency Identifier

GSM- Global System for Mobile Communications

UHF- Ultra High Frequency

HF- High Frequency

LF- Low Frequency

IC- Integrated Circuit

GPRS- General Packet Radio Service

IoT – Internet of Things

GPIO- General Purpose Input Output

LED- Light Emitting Diode

EEPROM- Electrically Erasable Programmable Read-Only Memory

LIST OF FIGURES

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1.0 INTRODUCTION

The idea behind the IoT is to use sensors, RFID tags and actuators in order to sense the events, to interact with each other, to send sensed data to a gateway for monitoring, evaluating, analysing and making a decision about such data [1]. With the emerging of IoT, industries have been impacted positively through aspects like easy monitoring and control, cost-cutting/increased profits, improved efficiency and effectiveness, easy generating and accessing of data and information, among others. Similarly, IoT in the beverage industry is used in monitoring and generating real-time sales data, and monitoring and controlling the refrigerators issued out to retailers. People put food, fruits and drinks in it, to keep the items cold or good (unspoiled) for a longer time [2]

Beverage companies produce ready to drink products. Some of the beverage companies in Uganda include Century bottling company (Coca Cola Company), Crown Beverages (PepsiCo Inc), Uganda Breweries Limited, and many others. There's no question that the brewing industry was one of the first to realize the significant benefits that refrigeration offered. German lager beer came to America with the German immigrants in the 1840s, tasting a lot better than American ale. Refrigeration enabled the breweries to make a uniform product all year round [3]. The beverages supply chain flows from the Syrup producer, to the bottler, to the distributor, to the Merchant and finally to the Consumer [4]. In order to boost sales and market presence, beverage companies issue out freezers and coolers to these sales points. These freezers are donned with company colours and only meant to accommodate specific company products. The company carries out routine maintenance and supervision of these fridges to ensure that they serve the required purpose. Coolers are a key component in terms of customer perception and customer satisfaction with Coca-Cola products. Which is why keeping them in good working order is vital for convenience to retailers [5].

The supervision of these fridges incurs great expenditures to the company since most of these freezers are distributed across the country, with example of Mbarara Municipality with over 300 coca cola fridges. The supervisors often look out to see

if the authorized products are the only ones being inserted in the fridges. In case a wrong product is found to be inserted in the fridge, the fridge is confiscated and withdrawn from the retailer. This alone is not an effective method since their movement patterns are always predictable by the retailers. This is also costly to the company in terms of facilitating the fridge supervisors. Currently, companies identify their products using barcodes which are on every bottle produced. These suffer from problems [6] like misorientation, obstruction by dirt, mist, protrusions and damage all cause failed reads or misreads and they have to be read at line of sight, usually at distances below one meter. Due to the current trend in IoT and ubiquitous computing, there is a sudden need to monitor things and people remotely. Remote monitoring is done in industries, homes, Agriculture, health and other fields to obtain data anytime, anywhere from anything. Pervasive computing [7]is an emerging trend associated with embedding microprocessors in day-to-day objects, allowing them to communicate information. It is also known as ubiquitous computing. The terms ubiquitous and pervasive signify "existing everywhere." Pervasive computing systems are totally connected and consistently available. The concept of ubiquitous applies to smart fridge through use of technologies like RFID and GPRS. Using RFID, refrigerators can be designed to be content aware.

The intelligent fridge according to [8] should be able to sense the context and to communicate the user context variations. In this way context is not only position and identity. The concept of context also incorporates knowledge about time, people's interactions and habits, as well as many other pieces of information often available in our environment. The context is minimally well defined by the "five W's": Who, What, Where, When and Why. A content aware fridge [9] based on RFID provides several content-aware services for patients to adjust their eating habits. The fridge is able to inform them to take certain food which good for their health. RFID (Radio Frequency Identifier) technology uses RFID reader and tags to identify products and it is proposed to be used in this system. RFID tags attached on each bottle are used to uniquely identify the product using the system placed inside the refrigerator. Cooperating partners in [10] can use the technology to provide fine-grained product traceability and quality assurances across the whole

supply chain by leaving RFID tags on the objects being produced as they move through the supply chain. This may translate into significant and tangible competitive advantages.

Though RFID tags are not currently placed on products by manufacturers, the continually declining costs of RFID tags along with Walmart's expressed desire for such tags to be placed on individual products suggest that the added convenience of RFID tags will eventually outweigh the costs [11]. Stores like Walmart benefit from RFID tags through both the per-item tracking and further automation of point-of-sale procedures that become possible should RFID tags replace UPC barcodes, which is becoming more and more likely as RFID tags become cheaper and easier to produce. The weight sensor placed below the fridge complements the RFID reader in identifying the authorized and unauthorized products. This uses a GPRS communication to report any abuse of the asset in terms of inserting unacceptable products (refrigerator), exceeding the allowed maximum weight for the fridge to the company control centre. The necessary action will be taken. This will give the company control over their fridges issued to the retailers. The information technology phenomenon of ubiquitous computing according to [12] provides easy and convenient access to relevant information through intelligent appliances that monitor, collect and transmit data. This directly relates to the smart fridge suitable to collect and transmit data for beverage companies by monitoring the fridges remotely.

1.1 PROBLEM STATEMENT

A large percentage of a company's budget is comprised of a marketing plan. A lot is spent in the process of getting the product to the target customer. For beverage companies like Coca-Cola, PepsiCo among others, this involves issuing out free brand display refrigerators to the merchants like supermarkets, retail shops, restaurants, bars, and many others. This is for brand visibility among the customers and also ensuring sales maximization in the very competitive industry. The merchants often misuse these assets by inserting drinks that do not belong to the company, or from rival companies and sometimes the freezers are received but are

not put to use. This puts the beverage companies in a position to employ fridge supervisors to do the job of supervision and monitoring while keeping records of ownership and location. This a very tedious expensive process for the companies since it makes the company incur a lot of expense in ensuring proper usage of these assets and good return on investment. These supervisors are liable to giving inaccurate data and can be bribed by the merchants. Compiling data collected from the field and making sense of it is also a long and expensive process.

This resulted in designing an IoT system to monitor authorized refrigerator contents for the beverage companies. Using RFID technology, the system can recognize authorized and unauthorized products as well as give an alert in case unauthorized products are inserted in the refrigerator and give details like the location of the refrigerator. The company will also be able to recognize if its asset is under-utilized or not.

1.2 STUDY OBJECTIVES

1.2.1 General Objective

To design a system that monitors the contents inside the company refrigerator using IoT and generates a notification in case the product inserted is wrong and if the fridge is on/off.

1.2.2 Specific Objectives

i. To investigate the misuse and enable the monitoring of beverage company fridges.
ii. To review existing related literature about smart fridges, RFID and weight sensor in relation to retail beverage company refrigerators.
iii. To design/simulate an algorithm to recognize authorized and unauthorized products and generate notification in case of unauthorized product.
iv. To setup a communication link from the deployed refrigerators to the company database
v. To provide a design means to facilitate real-time monitoring of refrigerators as company assets.

1.3 Hypotheses

How can beverage companies use IoT instead of the human supervisors to remotely monitor the contents inside the refrigerators to allow only authorized company products?

1.4 Study Scope

The one-year study focused on beverage company refrigerators issued out to retailers. This specifically looks at identifying and differentiating authorized company products from the unauthorized items. This will enable the fridge abuse data to be sent out to the beverage company and which keeps all records of the fridges while monitoring the maximum weight per fridge.

2.0 LITERATURE REVIEW

This section discusses related literature in aspects of smart fridge, RFID technology, GSM/GPRS and weight sensor. The concept of a Smart Fridge is not entirely new. Discussion about the potential of a fridge that is aware of its contents has being occurring for the past decade. Smart refrigerators range from domestic use to commercial use and some of these include the Samsung's Wi-Fi Smart Fridge, LG Smart Fridge for 2012, and Cool Media Fridge Freezer. These are costly and not user friendly for commercial purposes.

Radio Frequency Identification (RFID) also known as "electronic tag", has the capability to track and identify the products using radio waves. According to [13] RFID is a passive technology; i.e., it doesn't transmit the radio waves by its own but these ID can only be read by an RFID reader and have every object identified. RFID and related sensor technologies in [10] have the potential to change the way we control business processes in a fundamental manner. RFID allows us to track objects throughout their production and subsequent life cycle, spanning enterprise boundaries as well as spatial and temporal limits. Authors in [14, 15] designed an intelligent fridge "ifridge" to manage and locate items stored inside it. Every item is tagged with an RFID tag when the user places it in the fridge, the RFID reader will be able to identify the product's unique RFID tag, and register it as either in or out of stock in the database to allow the user to manage the items in the fridge. It focuses on effective management and accurate location of foods inside the fridge using a smart application and obtains the users' eating habits using the collected data. The ifridge uses Wi-Fi which is not readily available in most locations. Smart refrigerators [16, 17] based on RFID to identify the items inserted in the fridge and monitor the stock, and inform the user about the remaining quantities while monitoring the expiry dates of the items. The details about the product are stored in a database server which is frequently updated when items are removed or inserted in the fridge. The system in [18] consists of three main parts which are a sensing module, control module, and transmission module. The sensing module consists of load cell and odour sensor while control module consists of Arduino UNO and power supply unit and last but not least, the transmission module consists of LCD

module and Wi-Fi module. These modules work together to determine the content status inside the refrigerator and notify the user about the condition and quantity of the food via an SMS or an email. The ZmartFRI in [8] has a RFID antenna and a reader inside to read the goods stored in it. Each product has got a smart label attached to it. This uses zigbee communication while anyone can send a message to the online server which makes the system unreliable.

The types of load cells are -Shear beam - the shear beam load cell is fixed rigidly at one end with the force being applied to the other end. These can be used singly or in groups e.g., a platform scale using one cell in each corner. [19]Double ended - shear beam type cells are of different construction and are fixed rigidly at each end with the force being applied to the centre of the beam. [19] Single point - load cells are of similar design but are intended for use in single cell applications only. [19] A load cell/weight sensor [20] is inserted under a tray of the fridge to track the weight change of each foodstuff and thus the amount consumed. The weight sensor module automatically measures the weight of the foodstuffs put in the fridge, and outputs the value of the total weight as a digital signal. However, this system uses voice recognition to identify the type of items inserted which limits the number of users to the system. RFID and Load cell/ weight sensor are used in [21] to manage a toll gate. RFID is used to read information which are stored in the tag and the load cell is used to measure the weight of the vehicles. The system is designed for security where the vehicle and driver are classified as authenticated or unauthenticated depending on the information stored on the RFID tags and the load cell reading. The advantage of the system is that it also uses a web camera to increase on authentication measures. Another similar load cell application in [22] rectifies the corruption in fuel filling process through fuel level measurement using a load cell. Though there are numerous methods to measure the fuel level including those like mechanical float, optical sensors, ultrasonic etc., the accuracy in measurement is met by the use of load cell involving Arduino Uno microcontroller. [22]Here the precision in measurement is made even in a millilitre of added fuel. The measured output is sent via the global system for mobile communication (GSM) technology to the user mobile so that verifiable record can be created. The

GSM technology enables monitoring anytime and anywhere due to its wide coverage and it is used in this project as well.

To ensure minimum costs are incurred in smart fridge design, [23, 24] enhanced on the existing fridge design by basing on adaptive high frequency RFID combined with the traditional smart fridge features. This helps to monitor the freshness of the items in the fridge as well as automating the purchase of the items using the integrated sensing technology. The challenge is that it uses LDR for item recognition which isn't feasible for some items. The proposed system in [25] uses RFID tag to identify the goods to avoid misplacement and Weight sensor is used to avoid the overloads of goods in vehicle. The GPS and GSM are used to track the vehicle and also send the details of goods to source periodically. This system is based on GPS since it deals with mobile systems which is not necessary in this application. Papers in [26, 27] present a new fridge connected to GSM network. This allows the user to gain information about the product quantities and cooler temperatures inside, whenever the user requires by sending a text message or a phone call. The system in [27] particularly uses the object sensors and if not found any object in front of them, they produce NO Object signal which is fed to Object Detector Unit for further processing. In addition to allowing users to control the home appliance from remote places, it notifies them about any electricity faults in the system with an instant text message.

Communication is necessary to enable the user to have full remote control over the fridge. [17] uses GSM network combined with ethernet to send SMS to the user and automatically order for the products online. It uses infrared sensor to get the remaining quantities of the items which is not an effective method.

The invention in [27] relates to a system for controlling and monitoring a food refrigerator and its content of the type intended to be given in rental or in free loan from a manufacturer to a vendor of cold products. It comprises of a control unit for checking and storing a plurality of functioning parameters of said food refrigerator. More particularly, the present invention relates to a system of the type described above comprising communication units for interconnecting external devices or to

the internet, in order to allow a technician to check and modify, locally or remotely, the functioning parameters of the food refrigerator. The system uses RFID for identification and GPRS for communication and it monitors compressor condition and refrigerator temperatures. This is similar to the proposed system which monitors the authorized contents in the fridge but uses load cell and RFID hence more accuracy.

In the beverage industry business world, Coca-Cola Beverages Africa-Kenya (CCBA) [28] has partnered with Safaricom to connect its coolers with sensors that collect vital data that will enable the company to enhance its offering to retailers and outlets of its beverage products in the country. The connected coolers are wired with sensors which leverage on the Internet of things (IoT), the inter-networking of "smart" devices that collect and exchange data. The devices enable CCBA to monitor the temperature and how often the fridge doors are opened to give real-time data. The company is also be able to tell how many fridges are operational at any given time; taking note of declining or fluctuating units and schedule them for maintenance.

Safaricom [29], has partnered with Kenya Breweries Limited (KBL) to connect and enhance their refrigerators and coolers in the country. The new coolers and fridges will be provided to vendors and distributors for free. They are equipped with sensors that then gather and exchange critical data for helping KBL access gainful insights to drive and address consumer demands in the market. [29]This solution will transmit various data to a platform that generates business insights that will assist KBL to optimize the coolers," added Ruth Okuthe, Safaricom Chief Enterprise Business Officer. Distributors can pinpoint the location of their assets using the technology. They can tell if those assets are in use or otherwise, whether drinks are stored under optimal temperature and if a cooler's door has been opened, among other many features. The KBL coolers allow the distributors to pinpoint the location, see if the assets are in use or otherwise, and monitor the temperature inside the coolers.

The literature discussed explores using RFID, load cell for recognition of items inside the fridge but do not monitor the abuse of the asset or differentiate authorized from unauthorized products. The System proposed here is to monitor authorized retail freezer contents, allow pinpointing location of refrigerator, see if the assets are in use or otherwise for beverage Companies.

3.0 RESEARCH METHODOLOGY

The project is comprised of 4 parts; sensing, communication, control and remote monitoring platform. In sensing we have Load cell/ weight sensor and RFID. In communication we use a GPRS module to send the message obtained from the sensors to the remote database.

3.1 System Design methods

In this research, I used qualitative and quantitative research. The goal is to investigate existing systems and to find its merits and weakness that can applied to focus my research and to build a suitable and valuable system.

A qualitative approach has been used to do the evaluation of how existing system are working, what they weakness and which something to improve in the performance of the existing system or making the new application while quantitative approach was used to collect data, analyze data and to test prototype.

The system was designed in simulation and prototype. The simulation was done in proteus but it could not make it possible to simulate RFID. With this I could only have the GSM, Arduino board and a load cell. This did not give good results, hence I opted to do prototype.

The code is written in Arduino IDE, with the database using PHP. The different libraries were downloaded and added to Arduino to simulate the components of the project. The diagram is the block diagram of the project

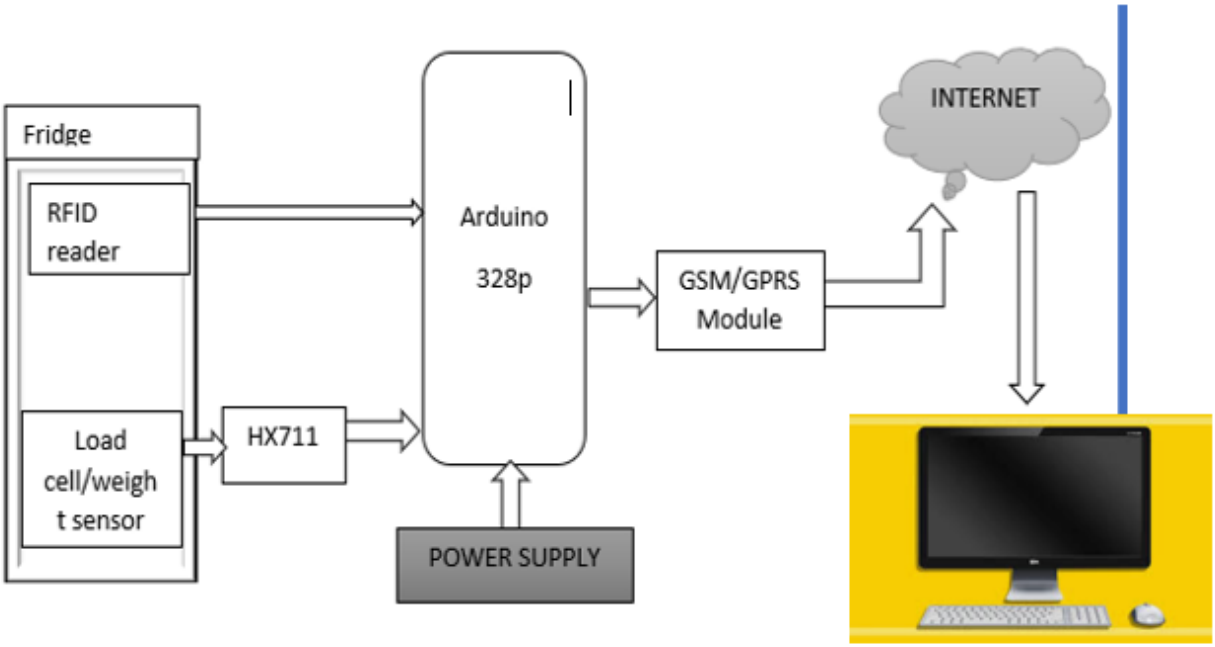


Figure 1: System Block diagram

The load cell is placed at the base of the fridge to measure all the weight changes inside the fridge. The RFID reader is placed in the upper section of the fridge to read the RFID tags which will be inserted on the top of each bottle. The RFID reader has an antenna which produces electromagnetic waves to be recognized by the passive readers. The GSM modem antenna is put on the top of the fridge to allow to read the network well. This is illustrated in the diagram below.

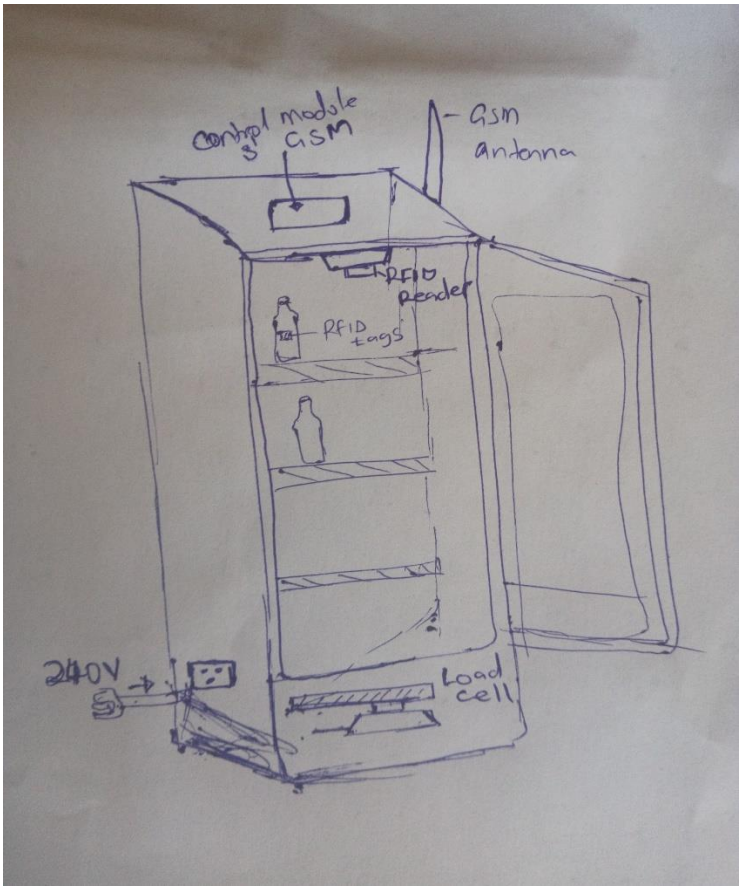


Figure 2: System physical design

3. 1 Sensing module:

To achieve the objective of detecting the unauthorized items inserted in the fridge, the following sensors are used to detect changes in the fridge and capture the magnitude of the change and detect accepted items.

3.1.1 Weight sensor module

The module to capture the weight changes consists of a loadcell and an HX711 module.

A Load cell: Is a transducer that measures force, and outputs this force as an electrical signal. This is used to measure the weight of the refrigerator contents. Load cell primarily consists of a spring material and strain gauge. Spring material [22]causes a strain due to the applied force and strain gauge changes its resistance in accordance with the change in strain. Strain gauge utilizes the principle of change

in resistance of many metals when they are elongated or contracted. It is shown in Fig 3. Since resistance depends upon the resistivity, length and cross-sectional area of the material.

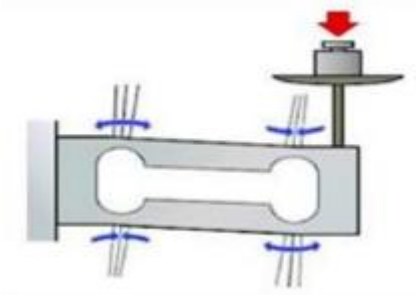


Figure 3: Strain Gauge

The same metallic wire will have different electrical resistance depending on whether it is elongated or contracted. The longer the metallic string becomes, [22]the larger the resistance. The strain gauge utilizes this principle and is defined as a device whose electrical resistance varies in proportion to the amount of strain in the device.

This is able to detect any given number of bottles added to the fridge. The figure 3 below shows the load cell. This was used in the prototype. It is a 20kg load cell, meaning it measures a maximum of 20kgs. It measures weight change in Analog form and uses the HX711 module to convert the Analog signal to Digital.

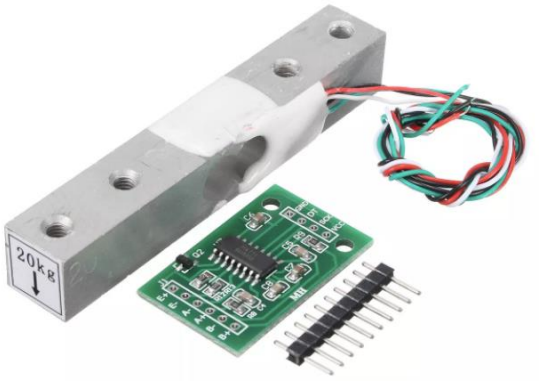


Figure 4: Load cell with HX711 module: Picture courtesy of handsontec.com

HX711; The HX711 IC allows us to easily read load cells to measure weight. The purpose of a load cell amplifier is to easily read the changes of the resistance of the

load cell. This particular Load Amplifier is a 24-bit Analog-to-Digital converter designed for weight scales. By using a 24-bit ADC, we can achieve higher resolution for weight. That is, we can more easily detect small changes in weight. It will take in a power supply of 2.7-5.5V. The HX711 uses clock and data pins, so we should be able to connect it with the GPIO pins of our microcontroller. The HX711 Load Cell Amplifier accepts 5 wires from our load sensor. Four of the wires are hooked up in a Wheatstone Bridge Formation. How a Wheatstone bridge works is that it is a configuration of four resistors with a known applied voltage.

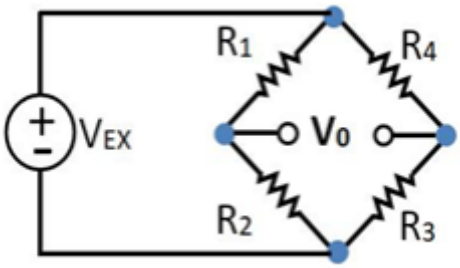


Figure 5: Wheatstone bridge

The output voltage is calculated by using Equation 1:

$$Vout = \left(\frac{R3}{R3 + R4} - \frac{R2}{R1 + R2}\right) Vex$$

3.1.2 RFID module

This module consists of the passive RFID tags which are attached to each bottle belonging to a specific company to uniquely identify each item and RFID reader which scans and recognizes the items.

RFID reader: This is meant to scan items that are inserted inside the fridge and identify the items. This is powered by 3.3Vwhich is obtained from the Arduino controller. The reader uses serial peripheral interface to communicate with the controller. For accurate readings, there must be an antenna attached to it. The RFID reading is used to make comparison with the load cell reading in identifying the illegal items and fridge misuse.

The RC522 RFID reader is used in this project. This reads one tag at a time and its pinout is shown in the figure below

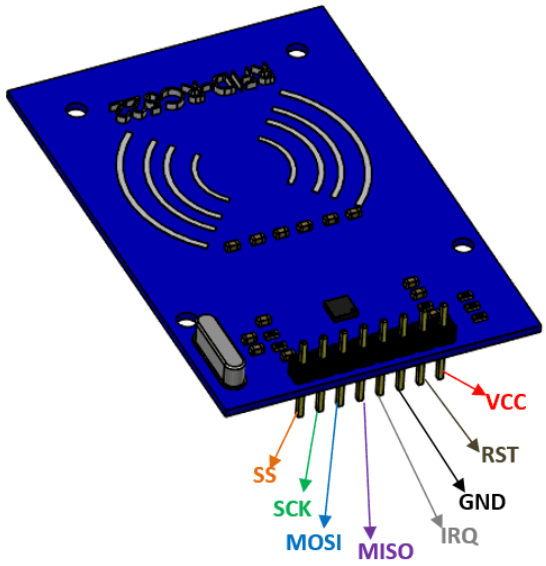


Figure 6: RFID reader pinout

RFID tags: Bottles contain LF passive RFID tags which have the benefit of being able to be read at a fast rate. They are [30] extremely thin (allowing them to be placed between layers of paper) and are extremely cheap (less than $0.05 in 10,000+pcs volumes). Every RFID tag has a unique identifier which helps in unique identification of each product.

Tags without batteries are referred to as passive tags [10]. These tags harvest energy from the communication signal sent by the RFID reader to run their operations. By contrast, active tags use a battery for energy supply. RFID tags can have diverse storage capabilities starting at a few bits and going up to several megabytes.

Regarding the communication frequency [10], RFID tags are usually categorized into low-frequency (LF), high-frequency (HF) or ultra-high frequency (UHF) transponders. RFID solutions that use LF have low read ranges that are usually about 0.5 m. The communication with the reader is facilitated via inductive coupling in the near field of the reader antenna. The available tag to be used in this

project is the LF tag, but the most ideal tag for the project implementation is the HF tag.

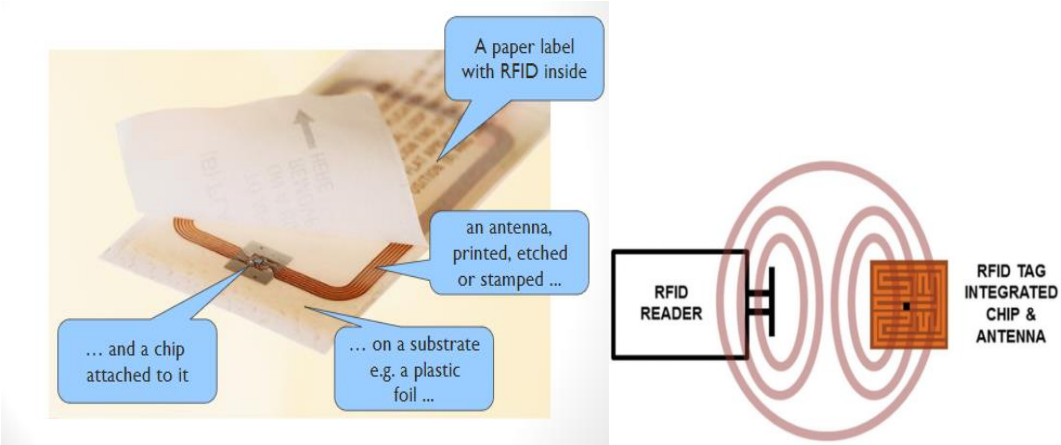


Figure 7:On the right; paper RFID tag and on Left; RFID reader and tag operation

UHF reader with frequency of 433 MHz, 860-920 MHz is used which has a reading range of about 100meters, and can read multiple tags at a time.

3.2 Communication.

To enable the module inserted in the fridge to communicate with the end user who is the beverage company, a SIM800L modem is used to achieve this. This enables data to be sent from the sensing module to the remote database and finally get accessible by the company for monitoring.

GSM is a wireless modem that works with a GSM wireless network. Dial up modem send & receives data through radio waves. In order to operate, GSM modem requires a SIM card from a wireless carrier [31]. In this project we use the SIM800L module to remotely update the changes inside the fridge.

It uses the 5V power and hence a buck converter can be used in actual implementation to step down from 12V to 5V for all components of the system.

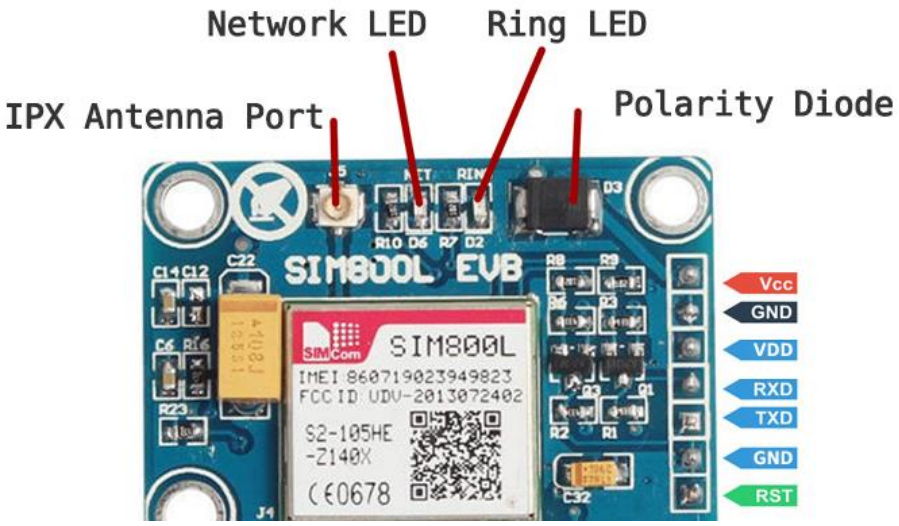


Figure 8: SIM800 GSM/GPRS modem

The onboard LED indicator will blink once every two to three seconds when it has completely registered the SIM to a network. When the LED indicator is blinking every second, this means that the SIM800L is still searching for a network to register onto. [32] If the LED indicator does not blink, recheck the power supply to ensure that it provides plentiful current and precise output voltage. The SIM800L module requires voltage in range of 3.4 to 4.4 V. If proper voltage is not provided, the module will give under- and overvoltage warnings.

For the protype, I used the IPEX antenna to capture the GPRS network. This is shown in figure 6 below.

Figure 9: SIM800L circuit board antenna

3.3 Remote monitoring platform

This enables the company to remotely obtain the information about the fridges issued out. Every fridge is registered in the system on the monitoring platform. The web system is hosted on 000webhost which is a free web hosting platform. Data about the violation of the fridge is stored in a remote database. The database consists of 3 tables; table one contains details of each individual fridge i.e. Fridge ID, Location, Ownership, and maximum load. Tracking the maximum load helps to avoid overloading the fridge. This is shown in the image below;

fridges

Column	Type	Null	Default
FRIDGEID *(Primary)*	varchar(255)	No	
Owner	text	No	
Location	text	No	
MAXLOAD	int(11)	No	
PREVIOUSLOAD	int(11)	No	

Figure 10: Fridges database table

Table 2 contains updates of each item inserted in the fridge i.e. Item type, location. This enables the company to generate timely data about the demand of each of their products. This is shown in the figure below.

productsAdded

Column	Type	Null	Default
ID *(Primary)*	int(11)	No	
FRIDGEID	varchar(255)	No	
KEYID	varchar(255)	No	
NAME	varchar(255)	No	
MASS	int(11)	No	

Figure 11: products added table

Table 3 consists of violation reports, which include the fridge Id, the type of violation and time of incidence. This enables the company to view timely data about violations of the fridges. This is also shown in the image below.

violations

Column	Type	Null	Default
ID *(Primary)*	int(11)	No	
FRIDGEID	varchar(255)	No	
SMSCODE	varchar(255)	No	
TIME	varchar(255)	No	current_timestamp()

Figure 12: the fridge violations table

3.4 Control module

The entire system is controlled using an Arduino uno microcontroller. This a microcontroller that takes in and executes all commands in the system. It is a microcontroller board based on the ATmega328P. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator (CSTCE16M0V53-R0), a USB connection, a power jack, an ICSP header and a reset button.

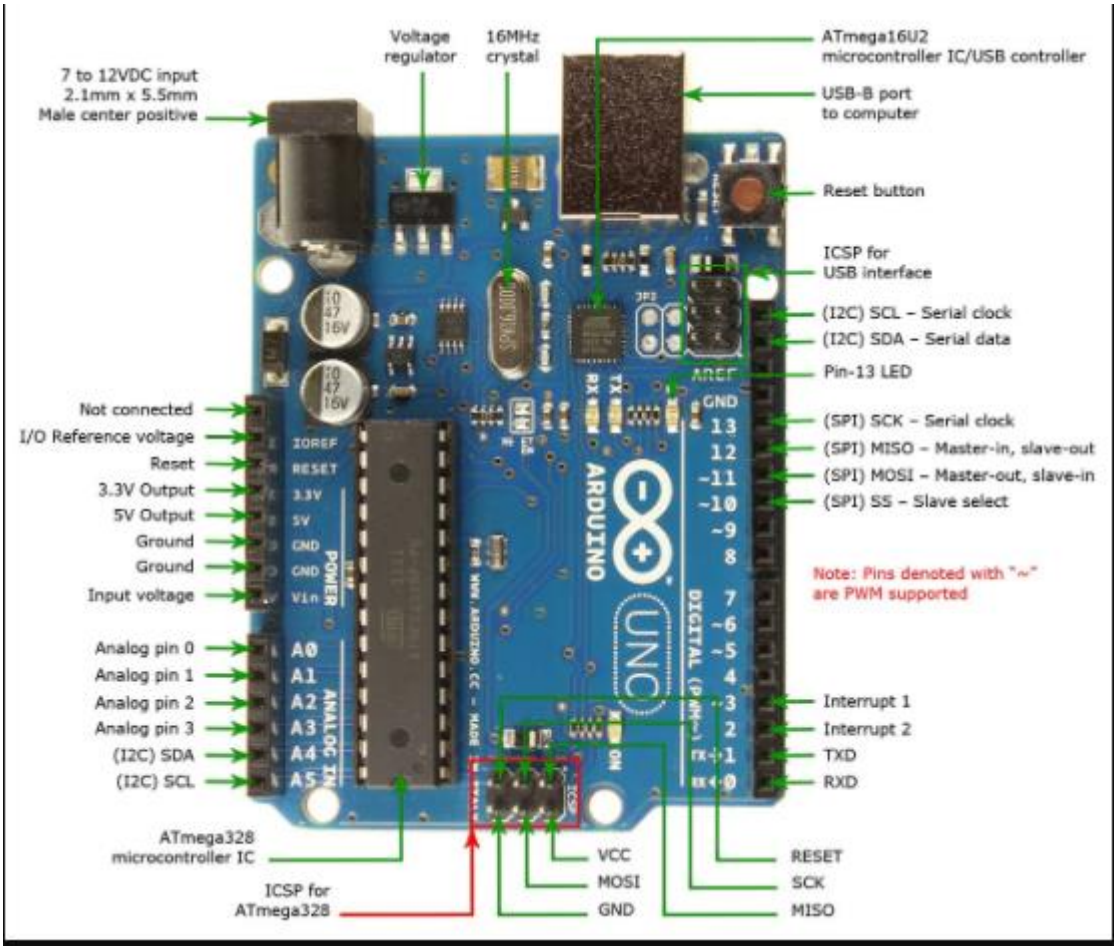
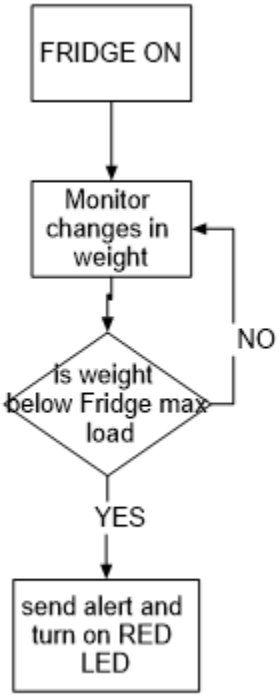


Figure 13: Arduino Uno

3.2 Flow chart of the system

The figure below shows the system flow chart



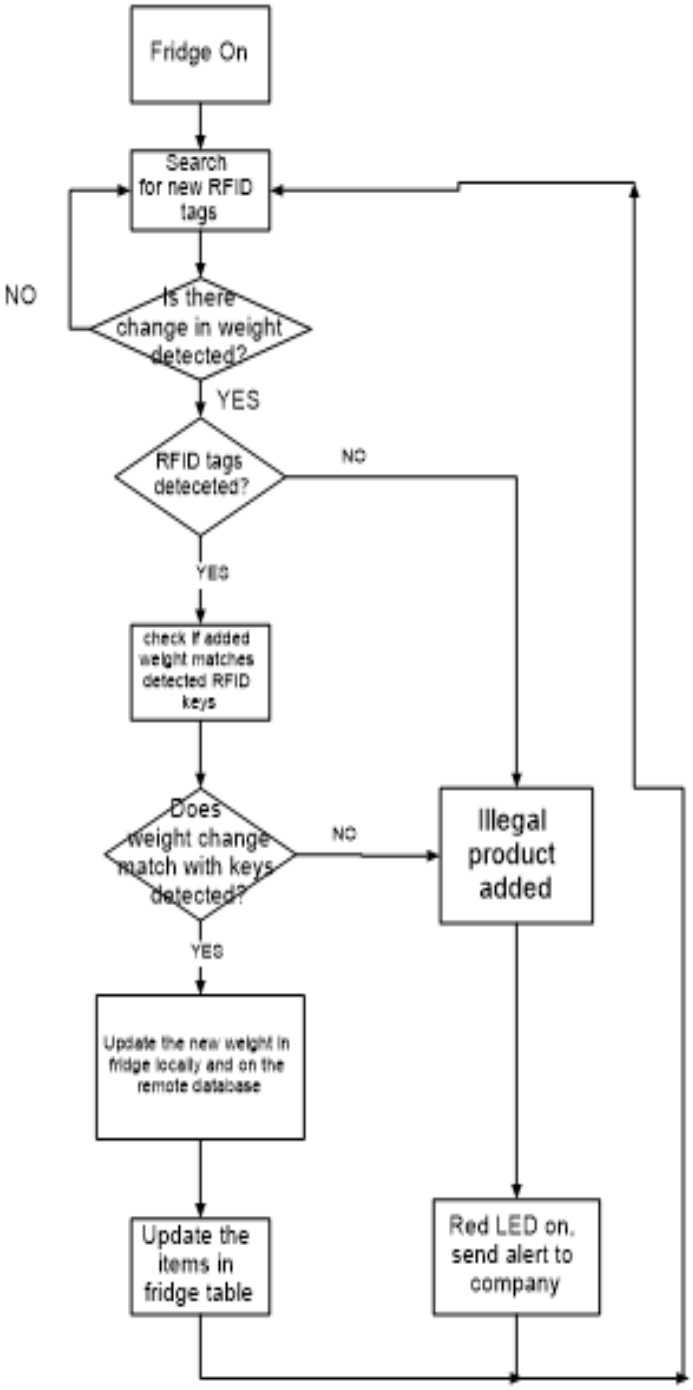


Figure 14: System Flow chart

Figure 15: Flow chart for Max load monitoring loop

4.0 SYSTEM AND RESULT ANALYSIS

The system is designed and simulated in proteus as shown below.

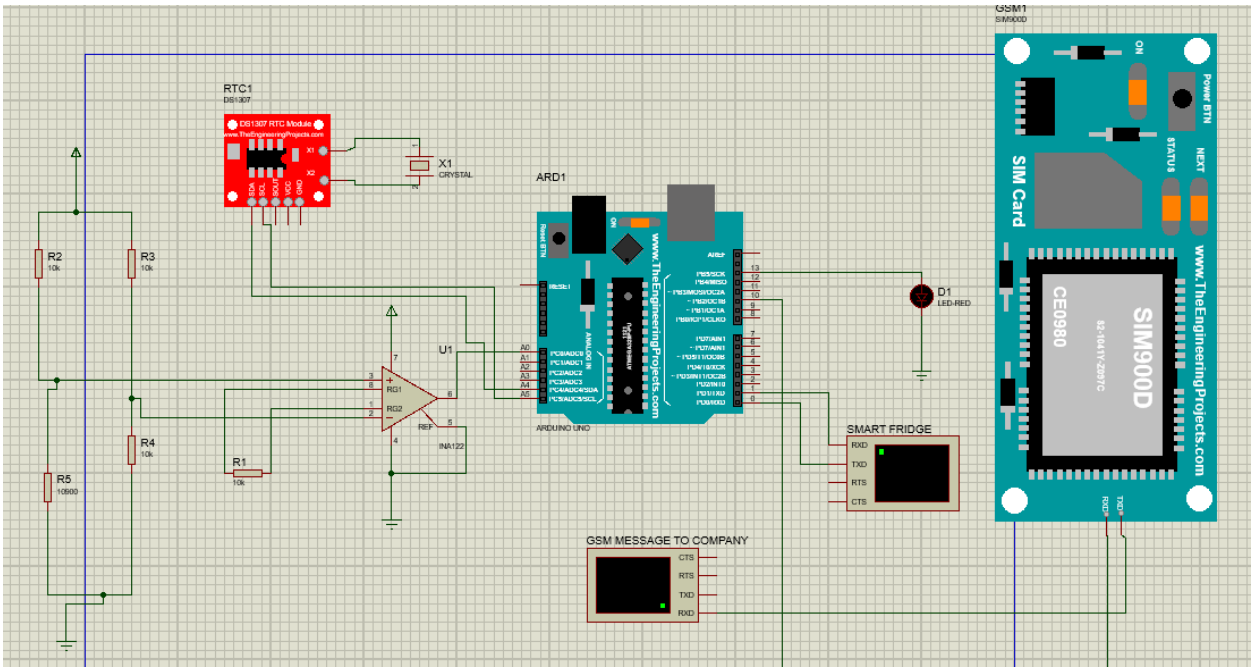


Figure 16: System Simulation

The system is to be installed in a refrigerator to detect unauthorized items and issue notification in case of asset/fridge violation. Upon reception of this information, the company can take the necessary action and also use this data for business insight and analysis.

During simulation, some components like RFID could not be simulated, and this resulted into designing a system prototype which is shown below. This enabled me to get actual results from the system.

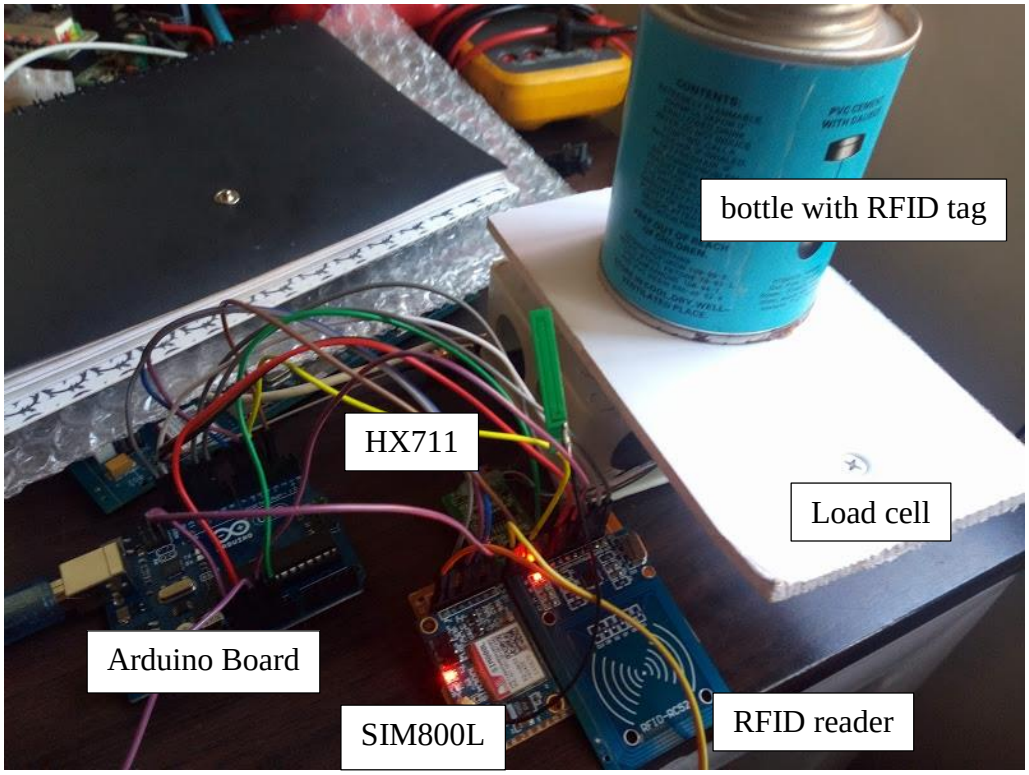


Figure 17: System Prototype

4.1 Weight Sensor/Load cell

The loadcell made of 4 resistors where one is a variable resistor which is varied to represent the changes in weight on the load cell and this is calculated to represent the number of bottles added. It uses a strain gauge load cell where the force is being sensed by deformation of strain gauges on the element. The load cell has a maximum weight of 20Kgs which reflects the max weight of the fridge in this case. It is first connected with the Arduino Uno for calibration. This is as shown in the image below.

The load cell has 2 pins Data_out and Serial_Clock. These are connected to pin 2 and pin 3 of the Arduino respectively. It also has the ground and 5V pins.

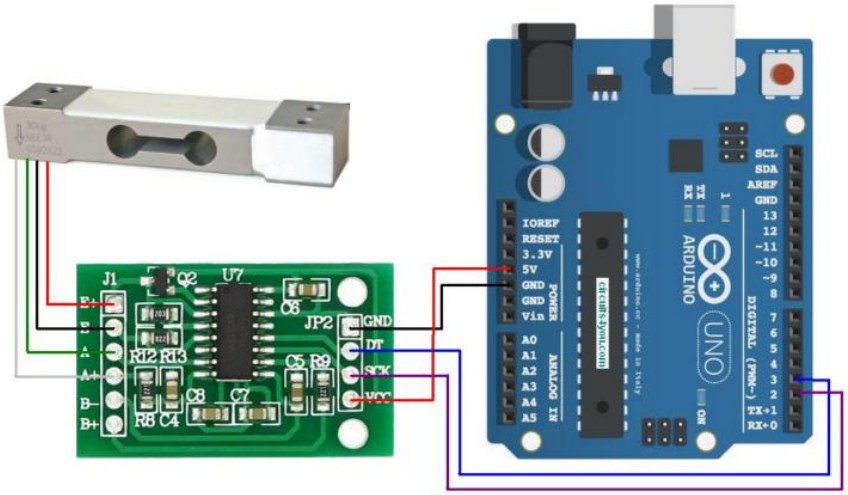


Figure 18: Load cell interface with Arduino

It is calibrated to read values in kilograms as shown below. It was calibrated at 0.1kgs to detect the smallest changes in weight as possible. The results are as shown below.

```
Remove all weight from scale
After readings begin, place known weight on scale
Press + or a to increase calibration factor
Press - or z to decrease calibration factor
Zero factor: -34283
Reading: -0.1 Kgs calibration_factor: -96650.00
Reading: -0.1 Kgs calibration_factor: -96650.00
Reading: -0.1 Kgs calibration_factor: -96650.00
Reading: -0.1 Kgs calibration_factor: -96650.00
```

Figure 19: Load cell calibration readings

Later this was integrated with the RFID tag. Each drink has a specific weight assigned. In this project, we work with 3 weights assigned to the drinks.

4.2 RFID Reader and RFID tags

RFID tag codes are stored on the memory of the tag each corresponding to a particular drink type. The RFID reader keeps looping to search for new RFID readings. The RFID uses the SPI interface and hence the SPI library is installed in Arduino. MFRC522 module is used in this project. The RFID reader recognizes items scanned and stored on the EEPROM of the Arduino.

When a change in the weight has been detected by the weight sensor but no RFID code has been detected by the reader, “Illegal product” message is sent to the database and the RED LED goes on to notify the client as well. This case is made on assumption that a product without an RFID tag has been inserted in the fridge.

When an RFID code is detected but is not matching to those stored on the memory, then an error of illegal product will also be generated. Not every product with RFID tag can be inserted in the fridge.

If the RFID tag code is recognized by the reader, then the type of product added will be added to the products added table in the database as shown below. The company can use this data to review daily estimated consumption of the drinks. When the product is inserted but when its weight exceeds the normal weight in the memory, it is assumed that the item was scanned but a wrong item was added in the fridge instead. This is shown in the figure below of the serial monitor. An alert is also sent in the violations table as well.

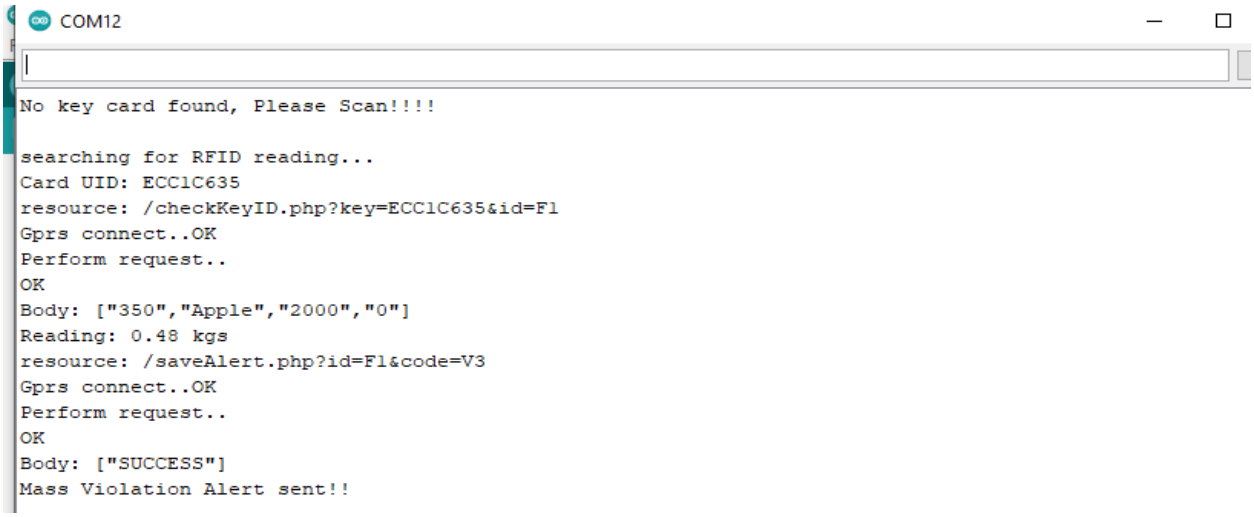


Figure 20: Serial Monitor reading for RFID

4.3 SIM800L module

This is programmed to send data to the remote database. It has an antenna which enhances connectivity and uses the MTN SIM card since it has good coverage. It is connected to 2 pins of the Arduino for Reception and transmission. It sets up a GPRS connection whenever there is a need for transmission and closes the

connection when no transmission is being done to save power consumption. The GSM LED lights different patterns for different connectivity status.

```
searching for RFID reading...
Card UID: DC5DA4BB
resource: /checkKeyID.php?key=DC5DA4BB&id=F1
Gprs connect..OK
Perform request..
```

The GSM performs connection request as shown in figure 13 above when a reading is detected

4.4 Remote database

The database is accessed through the page in the figure 18 below.

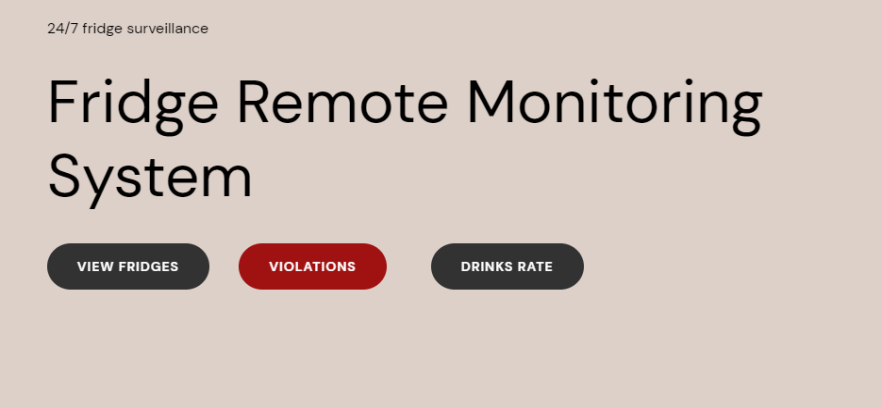


Figure 21: web monitoring platform

Detailed information about each individual fridge is stored in the remote database, and information about each drink and the corresponding RFID tag and the weight of the product. The table in figure 19 below includes the registered drink types and the corresponding details. I have 4 RFID tags am working with, hence registered 4 types of drinks. The website is hosted on a free site called 000webhost.

KEYID	NAME	MASS
19270810	Coke	500
4BFEAE1B	Orange	500
DC5DA4BB	Coke	350
ECC1C635	Apple	350

Figure 22: Table of registered drinks

The fridges are registered and details captured for ease of tracking. This can be as shown in the figure 14 below. Since I am using one system, I have one registered fridge in the table. The data of maximum fridge load helps the company to ensure the items are not overloaded. The data of previous load helps the company to know if the item is underutilized. This data is updated automatically every time a new product is inserted in the fridge.

FRIDGEID	Owner	Location	MAXLOAD	PREVIOUSLOAD
F1	Nawoya Sarah	Kisaasi, kampala	2000	1

Figure 23: Fridge details table

When an item is added to the fridge, the "previousload" column is updated and it will be the new reference for the next reading. This is as shown in the figure below. During prototype, I did not exceed maximum weight which is 2 kgs. In case this is exceeded, an alarm is sent the company and the fridge owner is notified. All the data is generated from fridge ID F1 since I have only one prototype.

FRIDGEID	Owner	Location	MAXLOAD	PREVIOUSLOAD
F1	Nawoya Sarah	Kisaasi, kampala	2	0.47

Figure 24: Updated fridge details table

The online system helps the company to receive data in the field regarding the fridges and also register fridges which have been issued out to the retailers. It also enables deleting an already registered fridge from the database, view the data regarding the registered fridges and also view the fridge abuse logs.

The system is able to issue a notification to the company for them to act in the shortest time possible, hence minimizing the need for supervisors to visit the retailers when not necessary. The figure 15 below shows the different violation codes registered by the company. Illegal product message is generated when a product is added without capturing its RFID code, the maximum load violation code is generated when the load limit is exceeded to avoid fridge overloading. The Load violation message is generated when an item is scanned, and added but weight exceeds normal registered weight.

SMSCODE	MESSAGE
V1	Illegal product added
V2	Maximum load Exceeded.
V3	Load Violation

Figure 25: Violations codes table

4.5 Results Analysis

When illegal products are inserted in the fridge, an error V1 is generated and the notifications table is updated. When an item is scanned, but the weight doesn't correspond to the detected RFID tag, an error V3 is generated which is also indicated in the notifications table as indicated below. When any item is detected, a request is sent to the website to get a comparison

ID	FRIDGEID	SMSCODE	TIME
158	F1	V3	2020-11-17 12:10:55pm
159	F1	V1	2020-11-17 12:11:12pm
160	F1	V3	2020-11-17 12:11:42pm
161	F1	V3	2020-11-17 12:52:48pm
162	F1	V3	2020-11-17 01:06:10pm
168	F1	V1	2020-12-02 02:54:00pm
169	F1	V1	2020-12-02 02:55:30pm
170	F1	V1	2020-12-02 02:58:14pm
171	F1	V3	2020-12-02 02:59:12pm
172	F1	V3	2020-12-02 03:01:25pm
173	F1	V3	2020-12-02 03:03:51pm
174	F1	V3	2020-12-02 03:05:36pm
175	F1	V3	2020-12-02 03:06:29pm

Figure 26: Fridge Abuse Logs table

The system generates information about violations of the fridge in terms of insering wrong items, and exceeding the set weight for the fridge. This information includes an auto generated ID the violation, the Fridge ID in which the violation has occurred, and the time in which the incidence occurred. This is is as shown in the figure 22 above.

An analysis of this data is done to group the error rate of illegal products and weight violations as indicated in the figure below. From the chart below, it shows a percentage of 38% for error V2, which corresponds to products added without RFID reading. Error V3 is at 32% which indicates the number of cases of products scanned in RFID but the weight added doesn't correspond to the reading. V1 indicated a wrong RFID reading detected.

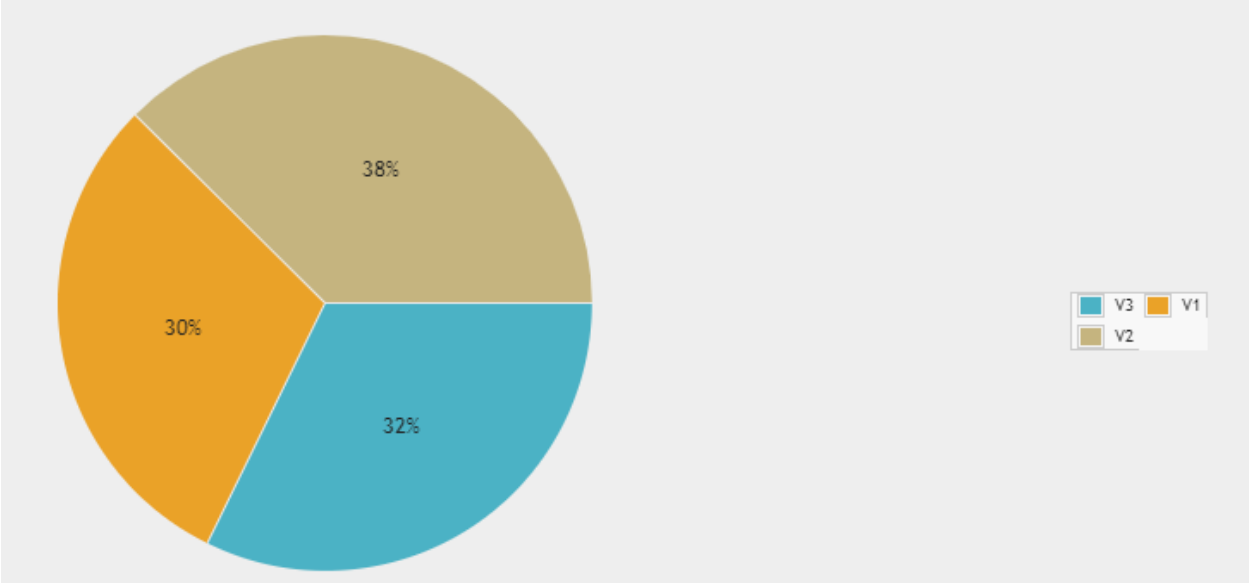


Figure 27: A chart showing grouping of illegal products and weight violations

The violations per day can also be obtained as shown in the graph below. This shows the rate of violation in a given time.

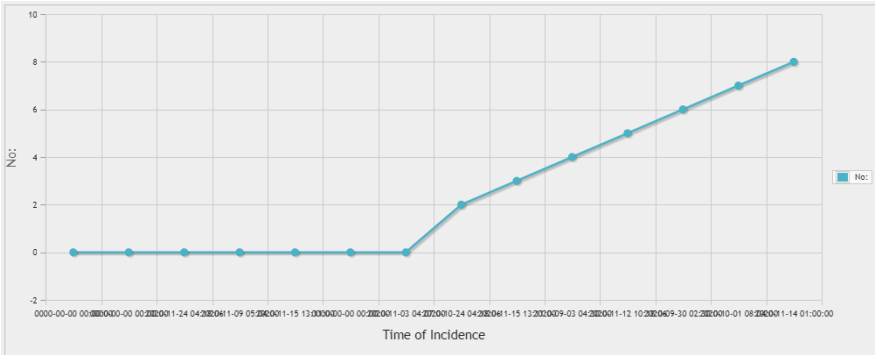


Figure 28: A graph of number of incidences against time of occurence

When a correct product is added to the fridge, the Products added table is incremented. This is used by the company to make business decisions in terms of customer preferences. This is shown in the figure 23 below. This updates the entry ID, the fridge ID, the code of the product and the

ID	FRIDGEID	KEYID	NAME	MASS
244	F1	ECC1C635	Apple	350
245	F1	DC5DA4BB	Coke	350
246	F1	4BFEAE1B	Orange	500
247	F1	ECC1C635	Apple	350
248	F1	ECC1C635	Apple	350
249	F1	4BFEAE1B	Orange	500

Figure 29: A products added table from the database

Using this data, the company can access the most demanded product in a particular area using this information and make production decisions based on this.

Below is an analysis of the data obtained from the products added table, it can be seen that Apple is the most demanded product at 42%, followed by coke and orange both at 29%.

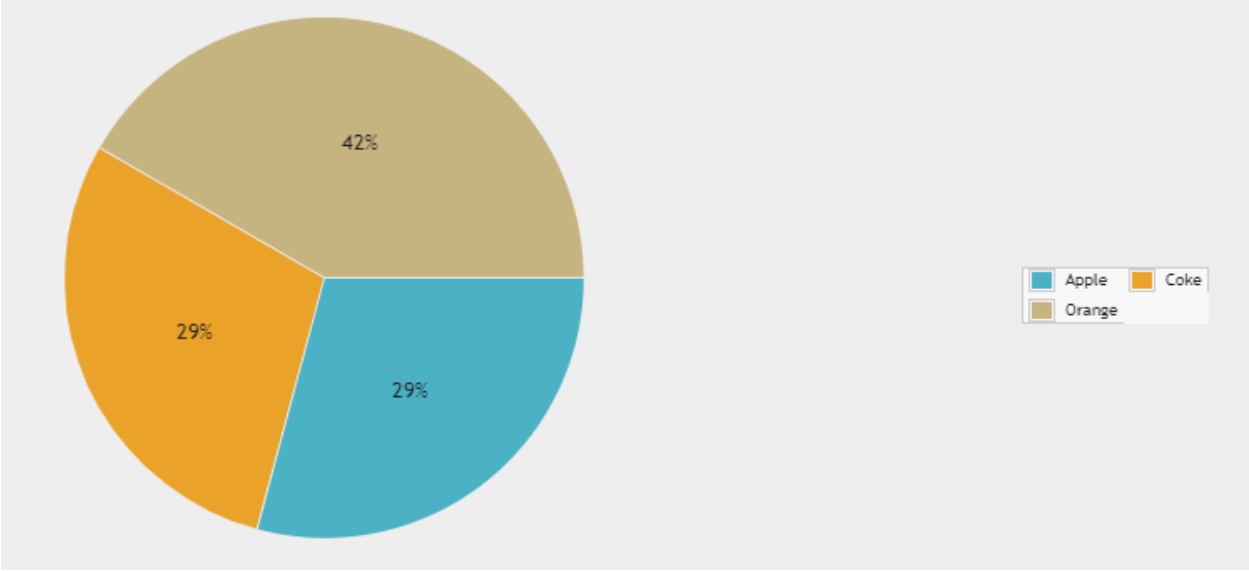


Figure 30: A chart showing analysis of the products added in fridge F1

The system experiences delay in recognizing the new products which is about 5-20 seconds. This hinders the accuracy of the readings. It cannot read multiple RFID tags at once. These challenges can be addressed in prototyping by using Ultra High frequency RFID reader, this will also be able to read in a range of about 5 meters.

The RFID reader has also been proven to work in cold environments with an accuracy rate of 90% making it possible to be implemented in the fridge. RFID tags do survive in harsh cold environments as well, which makes them suitable to be attached on the bottles.

6.0 CONCLUSION

The items inserted in the fridge are recognized using the weight sensor and the RFID reader with the help of the microcontroller. The system gives notification when a wrong unacceptable product is inserted in the fridge which makes it easy for the beverage company to monitor the assets. The system enables remote monitoring of the fridges by reducing on supervision costs and generating necessary data needed for business insights. Compared to the existing literature, this system which majorly focuses on smart home, this paper presents an interesting application of RFID. This enables beverage companies to remotely monitor their fridges.

This system is proven to work better than the existing systems in terms of generating notification by identifying products belonging to the company. This is also allows generating of business insights with the data generated.

6.1 FUTURE WORKS AND LIMITATIONS

This project can be improved to include monitoring of fridge mechanical conditions to cater for timely maintenance of the fridges. This can also be improved to include monitoring of temperature inside the fridge to gather data about the preferred temperatures of the drinks. Machine learning can also be included in the system where it uses a camera to recognize the items inside.

The system does not read many RFID tags at a once. It reads one by one. This is one of its limitations. The RFID reader available could not read many tags at once, but this can be improved to have a more efficient system. The company is not able to remotely control the fridge by switching it on and off.

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