Journal of Multidisciplinary Engineering Science Studies (JMESS)
ISSN: 2458-925X
Vol. 7 Issue 5, May - 2021

Iot-Based System Of Physical Environment Factors Into Monitoring Of Maize Storage

Ekuewa, Oluwaseun. I
Department of Electrical and Electronics Engineering
Federal University of Technology Akure, Nigeria
ekuewao@gmail.com

Ogunti. Erastus. O
Department of Computer Engineering
Federal University of Technology Akure, Nigeria
oguntig@gmail.com

***Abstract*—The economical benefits of agricultural grains(maize) makes it essential to constantly monitor the conditions of the maize stored for timely response to possible deterioration in real time. This paper presents the use of a sensors network and IoT to monitor in real-time the variation in temperature and humidity parameters affecting stored maize and automatically initializing control measure for the effect when necessary. It also adopts a mathematical optimization model using routing algorithm to explain the network lifetime in the three approaches such as the Hop Count approach, the measurement of the temperature and humidity approach, and the Multi-objective approach based on Free Space Loss and the output readings of the IoT nodes. IoT- based storage facility leads not only to tremendous requirements for communicating massive amounts of multiscale heterogeneous data, but also calls for designing efficient strategies for mathematical modeling of the sensed data while overcoming the storage facilities.**

Keywords*— *Monitoring, IoT, Maize storage

I. Introduction

Grains are the world's most significant staple food and will continue to be so in the coming decades, be it in terms of food safety, poverty mitigation, youth engagement, use of rare resources, or influence on the climate. Nowadays, more than 45% of our calories come from grains. Grains are the power energy of complex carbohydrates, which the body needs to make energy. The energy is essential for all the relevant systems in the body, such as the nervous system, heart and brain. One of the reasons we can continue moving, thinking and breathing is because of the energy that our body gets. Also, grains are also crucial bases of iron and B vitamins. Some grains also contain phytonutrients, that perform as antioxidants and prevent early aging. Grains serve as a good source of fiber that keep the digestive system working properly and regular bowel movements is ensured. It has been seen that people who consume whole grains regularly are at a lesser risk of getting many chronic situations and diseases, such as diabetes, gastro-intestinal problems, cancer and heart ailments [19]. One of the causes that grains have become such a central part of the human diet is that they have a long shelf-life. Unlike meat, dairy, and fresh produce, grains accommodate a lot of food energy (also known as calories) into a small, insubstantial package that can be stored for the foreseeable future without refrigeration or other preservation [10]. Since it is a staple food, is a food that is eaten regularly, often eaten fresh or stored as a seed. People who consume food filled with grains as part of a healthy diet have a lowered risk of some dreadful diseases. Grains contribute benefit sources of numerous nutrients, including vitamins B (niacin, thiamin, riboflavin, and folate), fiber and minerals (iron, selenium and magnesium) [2]. Maize, rice and wheat are the most common essential foods in the world. They are also the most widely planted crops and have been central to our evolution. A High level of fiber food such as grains aid in providing a feeling of richness with fewer calories. Making sure that a whole grain is served for at least half your daily servings may help maintain weight [4]. The lion share of the world's harvested grain is supply to feed animals. Most domestic animals, such as cattle, pig, chicken to mention few, are fed with food rich in grains and its peripherals.

Also, the major percentage of the world's cultivated grain stock is used in the generation of industrial products. Biodiesel is a fuel used for vehicles. Ethanol has the main constituent of biodiesel, which can be gotten from maize. Storage plays an essential role in the grain supply chain, and several researches stated that maximum losses occur during this operation [3]. In most places, crops are grown periodically and afterward harvesting, grains are stored for short or long period as food reserves and as seeds for next season cultivation. Studies report that in developing countries such as India, about 50%–60% of the grains are stored in the traditional structures at the household and farm level for self-consumption and seed [6].

Monitoring of stored grain condition and the capability of transmitting the information (data) has become an important problem to ensure its security. It is important to have enough, secure and stocks of grain. However, post-harvest stored grain that is missing is about 7% to 15% due to inapt storages. Since it is most consumed food over the decades and coming ones, and instead of chemical means of preserving it for longer period which may result to some deficiency while consuming, it is paramount to bring about a device that will have the ability to store it for longer period of time and save to consume. Whole grains must be carefully stored than their refined counterparts, since the hearty oils found mainly in the germ of entire grains can be weakly affected by heat, light and moisture. These losses are caused due to factors such as environmental conditions like grain's humidity, temperature and level of gases like CO_2 presence of pests or insects, microorganisms, and fungi in grain. Grain temperature and humidity are main factors responsible for the putrefaction of grain due to increase in metabolic activity and development of pest inside the grain large scale [18]. Insect can easily damage the seed both externally as well as internally as the environment is conducive.

Getting environmental information (data) using conventional and current methods such as visual inspection, uric acid measurement technique, radiographic technique, insect traps and grain probes, NIR spectroscopy, X-ray imaging are labor intensive, imprecise, expensive, and unsuitable [11]. Hence, there is a necessity for real time E-monitoring sensing system which is labor intensive, precise, rapid and cost effective. The collected data acquired can be used for analysis to foretell the condition of grain and to make decisions for the end users to take precautions, which can monitor in environment in stored grain such as silos, bags and metallic bin. Temperature, humidity, and moisture has become the factors affecting grains in storage, since it is most consumed food over the decades and coming ones, it becomes a necessity to implement a monitoring system which will help alleviate this problem in order to effectively manage the storage of grain and safe for consumption.

Agricultural product e.g. grain(maize) has faced with the problem of storage over the years. Some of the method employed is making use of chemicals as a preservative. The conventional method of using chemicals is not efficient because of its side effect upon consumption. The study shows that 7% to 15% of some of the grains got spoilt as a result of adverse effect of the chemicals and inapt storage [18]. The problem keeps regenerating over years and there is need for a modern solution on how the grains can be preserved for a longer period of time. With the advent of technology which has brought about development in some areas like communication, electronics, internet of things (IOT) and Embedded system. Electronic components, microprocessor, microcontroller, Arduino etc. are developed together to solve the lingering problem of storing grains for longer period of time. The proposed method is capable of monitoring the temperature, humidity and moisture of a grains by transmitting the information (data) about the condition of silo or warehouse. Appropriate measures are taken with help of the proposed system to keep the grains for a longer period of time and safe for consumption. The aim of this research is to design and integrate a method of using IoT to monitor the physical environmental factors of maize storage.

II. LITERATURE REVIEW

A. *Grain Storage Overview*

A storage system for grain is an artificial ecological system in which deterioration of the stored product results from interactions among physical (e.g. temperature, humidity, storage structure), chemical (e.g. carbon dioxide, oxygen) and biological (e.g. grain characteristics, microorganisms, mites, rodents, insects and birds) factors. Both pulse grain quality and quantity are affected by internal and external factors [7] as presented in figure 1. Among these, temperature, humidity and moisture content are the most significant factors of grain's shelf-life. Main aim of storage is mainly to avert deterioration of the quality of grain. Indirectly it is done through the control of temperature and humidity, and through preventing the attempt from microorganisms, pests and rodents. It is important that farmers throughout the world, mostly every country to store grain during hot or cold climate. The ability and propagation of biological agents in grain compliment to a great extent on the temperature and moisture levels. Inappropriate storage conditions affect the post-harvest storability of pulses. Several pests and microorganisms attack the pulses and their products during and after harvest, in storage, and also transportation to the market. The addition of pesticides results in chemical residues in the food that are extremely dangerous to health upon consumption. Establishment of efficient and effective post-production storage systems is warranted in order to minimize qualitative and quantitative losses [17]. Grains are sub-divided into three groups; cereals (maize, millet, wheat, rice, etc.), pulses (cowpeas, beans, peas etc.), and oil seeds (sunflower, soya beans, linseed, etc.).

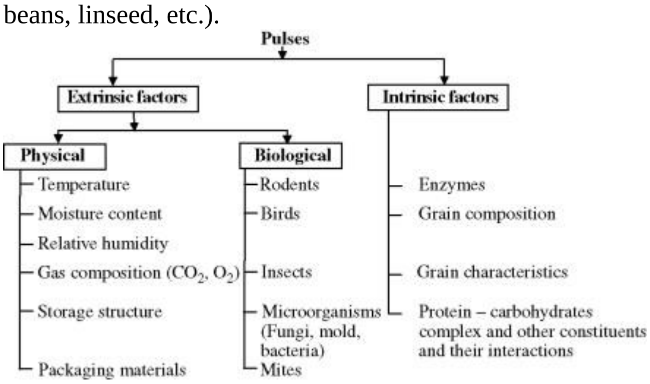

Fig 1: Factor affecting grain storage

B. *Internet of Things (IoT) Overview*

Internet of things (IoT) technology has now become ubiquitous, has touched almost every aspect of the world, and is affecting human life in unbelievable ways. However, the impact still continues. We are now in the time of even more penetrating connectivity where an extensive variety of appliances will be connected to the web. We are entering an era of the "Internet of things". Internet of things (IoT) can be defined as an interaction between the physical parameter and digital worlds [20]. The digital world connects with the physical world using abundance of sensors and actuators. [16] defines the Internet of Things as a model in which computing and networking capacities are embedded in any kind of possible object. These capabilities are used to question the state of the object and to change its state if possible. Likewise, the internet of things refers to a new kind of world where almost the entire devices and appliance that we use are connected to a network. it can be used collectively to attain composite tasks that need a high degree of intellect. For this intelligence and interconnection, IoT devices are equipped with embedded sensors, actuators, processors and transceivers. Sensors and actuators are devices, which aid in communicating with the physical environment. The information (data) accumulated by the sensors need to be stored and managed perceptively in order to derive valuable interpretations from it. An actuator device is mainly to effect a change in the environment such as the temperature controller of an air conditioner. Storage and processing of data can be done on the edge of the network itself or in a remote server. The storage and processing capabilities of an IoT object are also limited by the resources available, which are often very constrained due to limitations of size, energy, power, and computational capability. Communication between IoT devices is predominantly wireless because they are mainly installed at geographically disbanded locations. The wireless channels often unreliable and have high rates of distortion [14]. Internet of Things (IoT) can be applied in various areas such as Home automation, smart cities, social life and environment, health fitness, smart environment and agriculture, supply chain and logistics, energy conservation etc.

There are many research and various efforts on Internet of Things (IOT) technology to agricultural areas. The Internet of Things (IOT) has already brought innovative changes in agriculture. In this sector there are so many issues like, lands limitation, imbalanced use of fertilizers, high cost of funding, lack of awareness by farmers on better farming methods, lack of quality seeds, low production and productivity, lack of proper storage knowledge etc. Internet of Things inspire farmers or industries to deal with all these several challenges which they face. It is projected that by using IOT in this sector the industry must find out the remedy for various issues like increasing water shortages, shortage of lands, proper storage system etc. This new innovation has come to define all these challenges and helps to increase the quantity, quality, cost effectiveness, Food security and sustainability of agricultural production.

Just as grain, Internet of things can be applied in all aspects of grain, such as grain procurement, grain storage, grain logistics, and information tracking after grain processing. Advanced grain monitoring systems like those that are available for Grain Conditioning rely on the IoT. They connect sensors to software that foster how farmers will monitor their grain wellbeing, often without being present at the storage facility. The most advanced types of these systems can monitor grain temperatures remotely, manage fans, and even avert grain theft. With every system, you obtain real-time readings that alert you to any problems, so you can swiftly correct them. Sometimes these systems are seeming to be too expensive. This is one reason why some farmers sneer at the face of tech. It seems like every new improvement means a big investment. While the truthful costs are not minimal, the return on investment for the systems far compensates the initial price point. One of the ways this can be done with grain storage is by determining on getting portable grain monitoring systems first.

C. Related works

[15] work on web-based monitoring system for monitor of processes in plants from the soft real time point of view, the paper also demonstrates the importance of cold storage in the development of the food preservation system. It supplies the statistical information about the loss due to the absence of cold storages in many parts of Asia and Africa. They suggested a model that was designed to be able to give the assurance of the temporal and spatial consistency and transmit the monitoring data periodically via the intranet and the internet. The model generates one threads for monitoring management, one DB thread, one common memory, and corresponding monitoring threads to clients. The Java API for the server API, VRML, EAI (External Authoring Interface) and Java Applets for efficient dimensional WEB monitoring are used. The proposed model was implanted and tested for a FMS plant

[8] demonstrated the use of Wireless Sensor Network using Crossbow's TelosB motes integrated with sensors to measure the temperature and humidity values. Data from these sensors is acquired into an online database and this data is accessed from the web application.

[5] uses the capacity storage up to truck (trailer grain mass), soya beans as grain sample, Temperature, Relative humidity, Cardon dioxide as the environment parameters, K33-BLG sensor package with GPS, It deal with biological factor generally, however the monitoring probe has been designed and developed to identify, biological, environmental factor while transportation.

[12] demonstrated that efficient monitoring is based on temperature, humidity, light and other conditions without being present physically at the location helps us to get a better result. The primary purpose of his research was to observe, control and monitor the cold storage atmosphere, thus making the admin to manage the data in real time. Here the central node which is a web application is accountable for passing information to management mode using computer or mobile phone. The IoT based Automated Smart Storage management system is effectively designed and implemented by means of MySQL, CodeIgniter and APIs that can be considered as an IoT based framework. This system is proficient in reading, storing data using sensors and also produces some actions according to data. Storing data in database enables for future research and also regulate any irregularity in future which might be avoided to prevent forthcoming distress. Web application with a user-friendly interface makes it easier to understand and requires no special skills to operate the system

[21] sample of grains not specify, uses silo with aeration system, considering temperature, moisture content and carbon dioxide, also discuss various sensors, level of contamination was insect / molds / mites at the end it was discussed on wireless and web base grain monitoring system with cloud computing.

[13] did not specify the sample of grain, make use of silo to consider moisture content as environment parameter for analysis and uses sensor SHT21 connected with EZ430RF2500T, it was observed that a dependable

distributed system of sensor node is developed, calibrated values of sensor node are determined to get maximum accuracy.

From the literature review, most of the existing work mainly focuses on study of level of contamination (either affected by mold, fungus, microorganisms or insect) using traditional methods. Few works, has been done using sensors to improve the performance of the system in terms of accuracy and response time sensor on real time basis. Here few parameters are discussed to compare the existing work like type of sensor used, sensor network used, data acquisition and data processing techniques etc. most of the researcher focus on analysis of the effects of individual environmental factor on grain quality but few of them focuses on simultaneous and autonomous monitoring of environmental factor using sensor.

III. SYSTEM ARCHITECTURE

In the era of technology advancement, everything requires monitoring and controlling. In the system, Grain monitoring is done where sensors are used to collect information in the storage aspect of agricultural field. This work is designed by introducing internet of things IoT to facilitate food monitoring for protection of the maize, so that it would not get contaminated

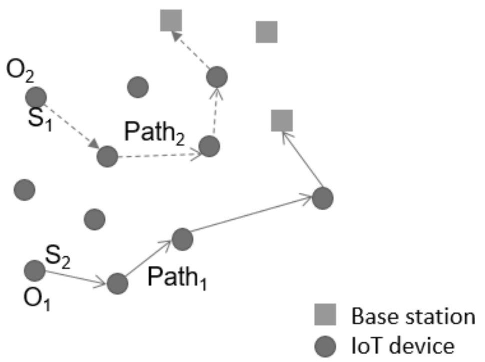

Fig 2: Example of an IoT Network.

due to surrounding conditions during storage. An effective monitoring of temperature, humidity, light and other conditions without being present physically at the location helps us to get a better outcome. Here the main purpose is to observe, control and monitor the storage atmosphere, thus making the admin to manage the data in real time. An example of IoT system is in figure 2, while the system Architecture for this research is in figure 3.

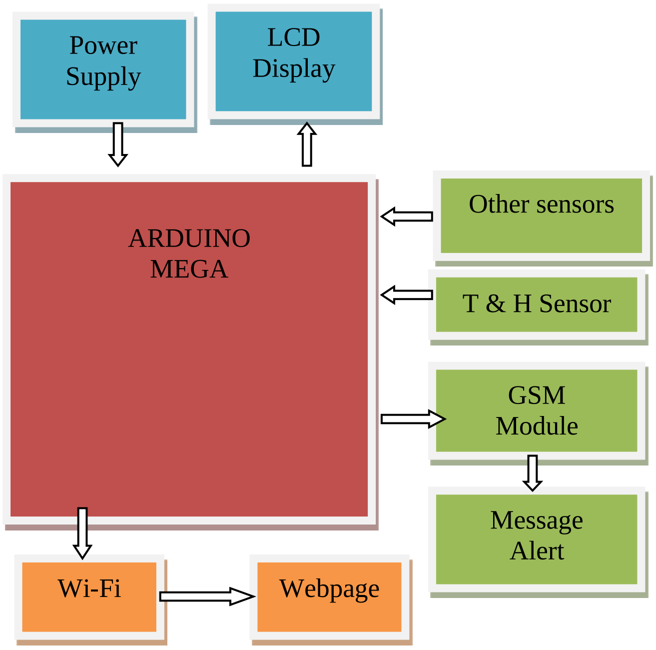

Fig 3: Architecture of the System.

The different sensors used are temperature and humidity sensor, moisture sensor, flame sensor, and passive infrared sensor coupled with other components. The information collected by the sensors is sent to the Arduino microcontroller ATmega. The collected information (data) can be displayed in a LCD display. A webpage is created and the information collected by the sensors is updated periodically in it through Wi-Fi. A GSM module is connected with the microcontroller through which the message about the farm condition is sent to the authorized person. Some of the hardware components used for the system are Arduino MEGA, DHT11 Temperature and Humidity Sensor, LEDs, GSM Module, Wi-Fi Module, Light intensity sensor. Also, for the software, the microcontrollers are characteristically programmed using a dialect of features from the programming languages C and C++. In addition, the use of traditional compiler toolchains, the Arduino project provides an integrated development environment (IDE) based on the Processing language project. The IoT architecture for monitoring physical environmental factors of maize storage is in Figure 4

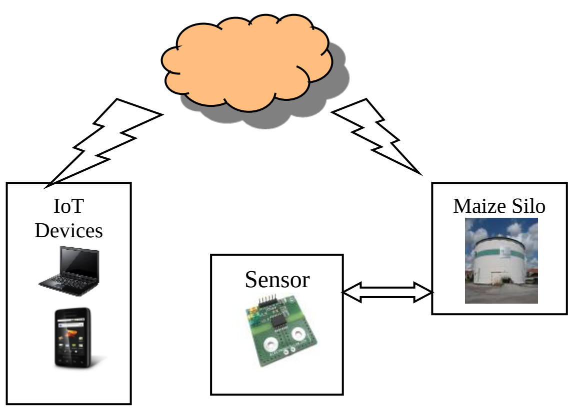

Fig 4: IoT Architecture for Monitoring Maize storage

A. MATHEMATICAL MODEL

The IoT mathematical model by [9] has been adopted for this research. The model is as follows:

a. Mathematical optimization model approach

In this section we present a multi-objective mixed-integer formulation of the mathematical model proposed for the problem described above.

Notation

The sets, parameters and variables required by our mathematical model are described in the Table 1

b. Objective functions

Our mathematical optimization model is applied considering different objective functions, depending on what we want to optimize. In this sense, three objective functions are proposed to be optimized: The Hops Count, the output reading of temperature and humidity approach, and a Multi-objective approach that considers minimizing the output reading and the Free Space Loss Indicator. Each of these objective functions will be explained below.

Table 1: Notations of the proposed model

Sets	**Descriptions**
N	Set of network nodes
O	Set of origin nodes
D	Set of destination nodes
I	Set of intermediate nodes: i∊N/i∊O⌣D
S	Set of services
OI	O ⌣ I
ID	I ⌣ D
Parameters	**Descriptions**
$Dist_{ij}$	Distance between an *i* node and a *j* node *(i-node = IoT device, j-node = base station/silo)*
u_{ij}	Bandwidth capacity for each (*i,j*)link
B^{so}	Bandwidth required by a$s-$service from an $o-$origin node.
S^{SO}	Indicates which $s-$service is active to be sent from an $o-$origin node.
E_{Ci}	Output of temperature and humidity at the $i-$node
Variables	**Descriptions**
X^{SO}	Is a binary variable that determines if the link (*i, j*) is used to send a $s-$service froman0-origin node to a d-destination node.
Y^{SOD}	Is a binary variable that determines if the $s-$service from the o−origin node will arrive at the $d-$destination node

c. Hops count

The hops count function is the main function of many routing algorithms. This function represents the number of links through which packets must pass from source to the destination nodes. The purpose of minimizing function 1 is finding the shortest path between any pair of nodes.

$$min \sum_{i\epsilon N} \sum_{j\epsilon N} \sum_{8\epsilon S} \sum_{0\epsilon O} \sum_{d\epsilon D} X^{SO} \quad 1$$

d. Measurement of Temperature and Humidity

An IoT network could be composed of heterogeneous nodes, and each one of them could have different output of Temperature and humidity in both transmission and reception. Given the nature of IoT networks, some nodes that belong to this network could be mobile phones, sensors, or laptops. Therefore, the proposed routing algorithm, in order to reduce readings of temperature and humidity should select the path with the lower overall readings of temperature and humidity to increase the response of these kinds of IoT devices. The objective function 2 takes into account both the output of temperature and humidity used by the source node in the transmission process and the readings used by the destination node in the reception process, over the entire path

$$\min \sum_{i\epsilon N} \sum_{j\epsilon N} \sum_{s\epsilon s} \sum_{0\epsilon O} \sum_{d\epsilon D} E_{Ci} * E_{Cj} * X^{SO} \quad 2$$

For the measurement of temperature and humidity is required to take into account additional considerations. If a node has to send a data packet of *K* bits to another node located at a distance *D*, then, the following are the expressions to calculate the output of temperature and humidity in the transmitter node as well as the receiver node. In the transmitter node, the output is $E_{elec}+ E_{amp}$, where E_{elec} is the readings for codification, modulation and filtering. E_{amp} corresponds to the output of temperature and humidity for the *Transmitter Power Amplifier*. In the same way, in the receiver node, the output corresponds to E_{amp}. Then, the expressions for the transmitter and receiver sensor are the following:

$$E_{tx} = (E_{elec} + E_{amp}) * K * D^2 \quad 3$$

$$E_{rx} = E_{amp} * K * D^2 \quad 4$$

In the constraint 3 there will have a output of temperature and humidity than constraint 4 because for transmission is required an extra reading for codification, modulation and filtering (E_{elec}).

e. Free space loss

This function defines the signal strength loss in free space conditions. This loss is directly related with the distance between the nodes and the transmission frequency. The aim of the following objective function 5 is the minimization of the maximum overall loss in the path.

$$\min \sum_{i\epsilon N} \sum_{j\epsilon N} \sum_{s\epsilon s} \sum_{O\epsilon 0} \sum_{d\epsilon D} Dist_{ij} * X^{SO} \quad 5$$

f. Multi-objective approach (E_{Ci}+ Free space loss)

This function combines our previous output of temperature and humidity function plus a function based on the Free Space Loss indicator, which represents the signal strength loss in free space conditions and is directly related with the distance between the nodes and the transmission frequency. In this sense, the Free Space Loss indicator (FSL) will be proportional to the distance between two pairs of nodes. The FSL indicator between two nodes is given by the following expression [1]

$$FSL_{ij}(dB) = 20\log D_{ij} + 20\log f + 92.45 \quad 6$$

Where D_{ij} corresponds to the distance (km) between two pair of nodes and *f* is an operational frequency used in an IoT

Journal of Multidisciplinary Engineering Science Studies (JMESS)
ISSN: 2458-925X
Vol. 7 Issue 5, May - 2021

technology to perform transmissions and receptions measured in GHz. Once an IoT technology is determined, its operational frequency is considered fixed for doing FSL calculations. However, while the operational frequency and the term 92.45 are considered constants in the FSL expression, the distance D_{ij} impacts proportionally the FSL calculation since D_{ij} is a parameter that changes depending on the distance between two pair of nodes.

The multi-objective function 7 is described in the following equation.

$$min \sum_{i\epsilon N} \sum_{j\epsilon N} \sum_{s\epsilon S} \sum_{0\epsilon O} \sum_{d\epsilon D} (w_1 * E_{ci} * E_{cj} * X^{SO} + w_2 * FSL_{i\,j} * X^{SO})$$

$$\text{Where } w_{1} + w_{2} = 1 \qquad 7$$

i. Model Constraint

According to the general problem statement, some activated services must be sent from origin nodes to any destination node (base station). This scenario is denoted in the following constraints

ii. Origin Nodes

The expressions 8 and 9 allow us selecting only one destination per activated service. An activated service represents a service that is required to be sent from an origin node to any destination node; whether a service is activated or not is determined by the parameter S^{so}

$$\sum_{d\epsilon D} Y^{SOD} = 1*S^{SO}\ \forall_S \text{€} S,\ \forall_O \text{€} \qquad 8$$

$$\sum_{j\epsilon N/j\epsilon ID} X^{SO} = Y^{SOD}\ \forall_i \text{€} N, \forall_O \text{€} O/i \text{€} O\ \forall_s \text{€} S, \forall d \text{€} D \qquad 9$$

iii. Destination nodes

Expressions 10 and 11 allow just one destination per service. If Y^{sod} is activated, that is, it is necessary to send a service *s* from *o* to *d*, we guarantee that one destination *d* is selected to receive the service *s*.

$$\sum_{i\epsilon N/i\epsilon OI} X^{SO} = 1*Y^{SOD}\ \forall_j \text{€} N, \forall d \text{€} D/j \text{€} D\ \forall s \text{€} S,\ \forall_O \text{€} O \qquad 10$$

$$\sum_{i\epsilon N/i\epsilon D} X^{SO} = 0\ \forall_{J\epsilon N}, \forall d \text{€} D/j \text{€} D\ \forall s \text{€} S,\ \forall o \text{€} O \qquad 11$$

iv. Intermediate nodes

Expression 12 represents the flow conservation law in order to find a path between *s* and *d* for activated services

$$\sum_{j\epsilon N/j\epsilon ID} X^{SO} - \sum_{J\epsilon N/J\epsilon OI} X^{SO} = 0\ \forall i \text{€} I, \forall s \text{€} S, \forall o \text{€} O, \forall d \text{€} D$$

v. Bandwidth

Expression 13 assures that different services could be transmitted in a specific link (i,j). Otherwise, the services must be sent for different (i,j)links.

$$\sum_{s\epsilon S} \sum_{0\epsilon O} \sum_{d\epsilon D} B^{SO} * X^{SO} \leq U_{i\,j}\ \forall i \text{€} N, \forall j \text{€} N \qquad 13$$

In summary, we have mathematical optimization model formulation that represents an IoT network with several origin nodes and destination nodes (base stations), at which is required to find optimal paths to transmit activated services from origin nodes to destination nodes (base stations). Depending on which objective function is considered, these paths are built minimizing the hops count, considering an efficient usage of the available data (readings)of the IoT devices, or considering a third approach which is a result of taking into account the output of temperature and humidity of IoT nodes plus minimizing the Free Space Loss indicator.

B. MAIZE MONITORING USING THE ADOPTED MATHEMATICAL MODEL SOLUTION

The previous mathematical model allows sending particular services from different origin nodes to any destination node for one time. The term “one time” must be understood as the mathematical model is executed one time to obtain a solution. However, due to network purpose corresponds to send as many services as possible until nodes reading allows it, the mathematical model must be performed several times in order to know the network lifetime. The algorithm1 illustrates how the mathematical model is handled to obtain the network lifetime.

The goal is finding a path to carry an activated service from an origin node to a destination node in a network; however, if our scenario is a disconnected network, it is possible that this path cannot be found. This means we have obtained an infeasible solution. For this reason, the mathematical model must run considering a connected network in order to find feasible solutions, which is guaranteed in the first line. The network randomness is in terms of nodes coordinates, guaranteeing that each node is not disconnected from the network.

Algorithm1: Maize monitoring using the Mathematical Model Solution in an IoT Environment.
1: Generate a *Random Connected Graph*
2: Initialize E_{Ci}
3: Establish the maximum reading capacity value $maxE_{Ci}$
4: Establish the monitored value E_{Ci}
5: Establish Activated Services $Sact^{so}$
6: Establish the Objective Function to *minimize*
7: numPeriods= 0
*8: **while** at least one origin node has a path P to send an activated service to any destination node*
i. ***do***
9: numPeriods= numPeriods+1
10: SolvePaths=Mathematical Model (Ec_i,$Sact^{so}$,F)
12: Update Ec_i ***do***
13: ***end for***
14: ***for*** *each i node in the network*
15: E_{Ci}=E_{Ci}- E_H
16: ***end for***
17: ***for*** *each origin node* ***do***
18: Find a path P in P aths to transmit

19: ***if*** *P=* ***then***
20: $Sact^{so}$=0
21: ***end if***
22: ***end for***
23: ***end while***
24: ***return*** *numPeriods*

Line 2 shows the measured reading of temperature and humidity of each node, which is initialized with a default value of 1. As nodes are selected for transmitting or receiving activated services, they increase the value of the measure temperature and humidity.

Line 3 establishes the maximum rate of temperature and humidity of each node. This value is the same for all nodes, except for destination nodes. Destination nodes are a particular type of nodes in IoT; usually, they are devices with enhanced processing, memory and battery resources in comparison with the rest of network devices. For this reason, we assume that this type of nodes has no limitations in terms of output readings from the sensors. Concerning the rest of the network nodes, if the value of the temperature and humidity of an *i* node, E_{Ci}, surpasses the maximum rate of temperature and humidity $maxE_{Ci}$, this node has wasted all value of temperature and humidity and then, this node is not available anymore for transmitting or receiving a service in the network.
Line 4 defines the value of temperature, humidity and moisture content. This value is decreased from the E_{THM} due to value of temperature, humidity and moisture content coming the silo.
Line 5 establishes which services will be activated; that is, from all available services in the origin nodes, which of them finally require to be sent from an origin node to a destination node. In other words, by modifying $Sact^{so}$ (1 or 0), we can define which service will be activated or not. From line 8 to 24, a Period means how many times it is possible to do transmission from an origin node to a destination node. Each time that it is possible to find at least one path from an origin node to a destination node, *numPeriods*is increased, that is, the network lifetime has been extended. If none path is found, it means that some nodes required for building any path from an origin node to a destination node have depleted all of its available monitored value.
In the Implementation and Results sections, *numPeriods* is equal to the number of transmissions, that is, the number of times at which it was possible to send services from all source nodes (silo) to a destination node before all these source nodes (IoT device) have depleted all of its available monitored values of temperature humidity and moisture content.

C. MIGRATION OF IoT IN MAIZE STORAGE

Temperature and humidity check if there are any change in temperature and humidity within the storage facility. Moisture content also known as water content of the grain (maize) should be checked before transferring the product to the storage facilities to save the product from maximum loss. Few products need specific lighting facility in order to maintain their quality; hence LDR sensors are placed at such locations. It generates an output voltage with change in their surrounding environment. These output voltages are fed to pins of ADC unit of Arduino. This Arduino processes the incoming voltages from the sensor depending on the program embedded within it. Output is passed to web app where the user is able to view and control settings. A web application is being created which receives all data from hardware and is being displayed. Here we have a login

system for the admin wherein he can view and monitor the environmental conditions of maize storage. The flowchart of the migration is as presented in fig 5

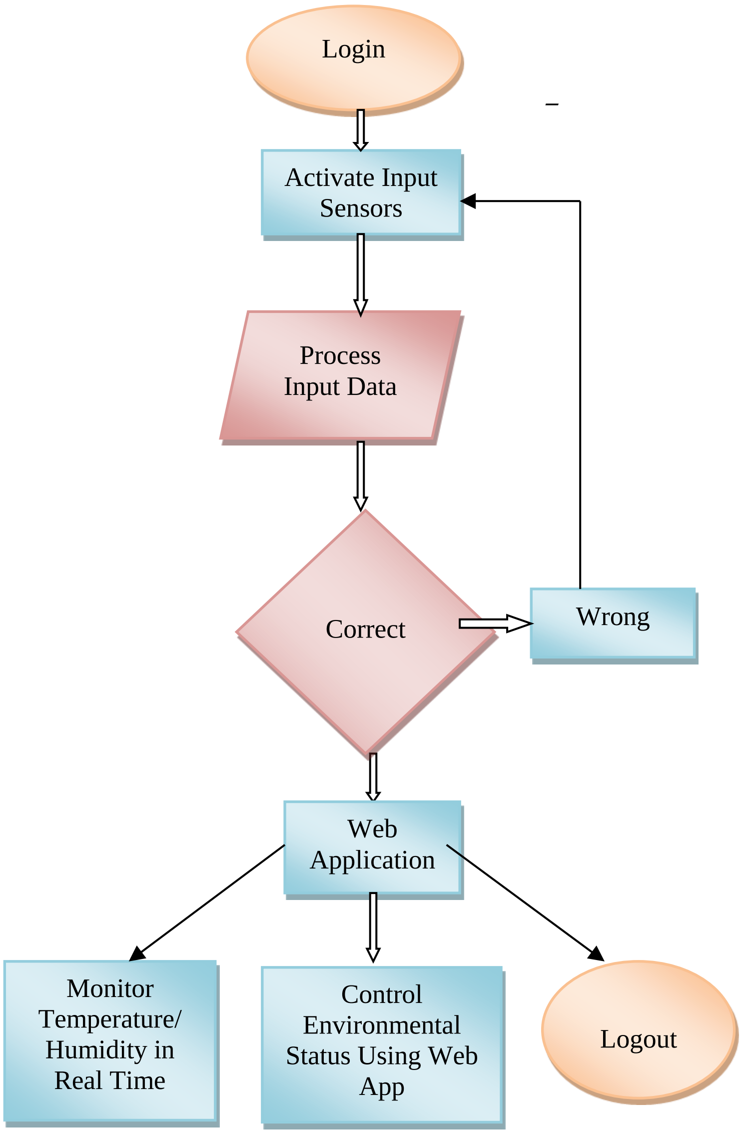

Fig 5: Flowchart of the design.

CONCLUSION

One of the greatest challenges facing farmers and food scientists' technologists especially in Nigeria today is the upgrading of the traditional methods of food preservation in most cases, the traditional methods of food preservation remain at the speculative level. They are still rather unrefined are not standardized and are not based on sound scientific principles making them in their present form unsuitable to large scale industrial production. The process is often laborious and time consuming and invariably the quality of products requires substantial improvements in upgrading these technologies, the food scientists is faced with the challenge of modernizing the processes and equipment while still retaining the traditional attributes of the food products crucial to consumer acceptance. All these stated above challenges faced by farmer on agricultural products storage will catered for if the proposed methodology is implemented.

REFERENCES

[1] Agriculture, U. D. (2015, March 8). Retrieved from ChooseMyPlate.gov Website: http://www.choosemyplate.gov/food-groups/grains-why.html.

[2] Akyildiz, I.F.; Vuran, M.C. (2010). Wireless Sensor Networks, John Wiley & Sons Ltd, 2010

[3] Aulakh, J., Regmi, A., Fulton, J., and Alexander, C. (2013, August). Developing a consistent global estimation framework. In Proceedings of the Agricultural & Applied Economics Association's 2013 AAEA & CAES Joint Annual Meeting. *Estimating post-harvest food losses*, 4-6.

[4] Benzie , C. S. (2014). Antioxidants in food: context, measurement, significance, actions, cautions, caveats, and research needs. *Adv Food Nutr Res.*, 1-53

[5] Danao, M. G. C., Zandonadi, R. S., & Gates, R. S. (2015). Development of a grain monitoring probe to measure temperature, relative humidity, carbon dioxide levels and logistical information during handling and transportation of soybeans. *Computers and Electronics in Agriculture*, *119*, 74-82

[6] Grover, D. and Singh, J. (2013). Post-harvest losses in wheat crop in Punjab. *Past and present. Agric. Econ. Res. Rev*, 293- 297.

[7] Jayas, S. N. (2007). Sensors for grain storage. *ASABE: A Meeting presentation paper*.

[8] Koo, P., and Ho, H. Y. (2016). An IoT-based Occupational safety Management system in Cold Storage Facilities.

[9] Lozano-Garzon, C; Montoya,G. A. and Y. Donoso, 'A Green Routing Mathematical Model for IoT Networks in Critical Energy Environments' International journal of computers communications & control Online ISSN 1841-9844, ISSN-L 1841-9836, Volume: 15, Issue: 4, Month: August, Year: 2020 Article Number: 3914, doi.org/10.15837/ijccc.2020.4.3914

[10] Monica Reingel, N. D. (2011, March 22). Retrieved from https://www.quickanddirtytips.com/health-fitness/healthy-eating/are-grains-really-necessary-for-a-healthy-diet

[11] Neethirajan,S. C. (2007). Detection Technique for Stored-product insects in Grain. *Food Control- Elsevier*, 157-162.

[12] Naveen, B.G,Nandhini,S. V,Mithra, N.P, and Naveena, R. IoT Based smart crop monitoring in Farm land. *Imperial Journal of Interdisciplinary Research*, 2018.

[13] Onibonoje, M.O, Jubril, A.M and Owolarafe, O.K (2012). Determination of Bulk Grains Moisture Content in a Silo Using Distributed Sensor Network. *In Proceding of the OAU Faculty of Technology Conference*, 58-63.

[14] Pallavi, S., and Smruti R., S. (2017). Internet of Things. *Architectures, Protocols, and Applications*, 1-25.

[15] Park, H. S., Jeong, M. S., and Kim, B.S. (2001). Architecture of Web-based real-time monitoring systems. *Journal of institute of control, Robotics and systems,*, 632-639.

[16] Pena-Lopez, I. (2005). Itu internet Report. *The Internet of Things*.

[17] Rangarajan Jagan Mohan, and Tiwari Brijesh K. (2011). Post-harvest technology of pulse. *Pulse Food*.

[18] Rekha Kaushik, J. S. (2019). An approach for the development of a sensing system to monitor contamination stored grain. *6th international conference on signal processing and integrated networks (SPIN)*, 880-884

[19] Rocketswag. (2012). *health-benefits-of-grains-ga.htm.* Retrieved from rocketswag.com: http://recipes.howstuffworks.com/fresh-ideas/healthy-dinners/

[20] Vermesan, P. F. (2011). Internet of things strategic research roadmap. *Internet of things: Global technological and Societal Trends*,, 9-52

[21] Singh, C. B., and Fielke, J. M. (2017). Recent developments in stored grain sensors, monitoring and management technology. *IEEE Instrumentation & Measurement Magazine*, *20*(3), 32-55