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Cold Storage Traceability System

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Abstract: Cold chain is one of the important tools for farmers of perishable produce, pharmaceuticals to connect with markets and to realize meaningful productivity. Due to lack of cold storages and lack of information about the demand-supply of the cold storages, many farmers are unable to save their produce for future sellers, hence causing sharp price dips, due to over production and wastage of crop in the case of food. A dearth of continuous electricity, absence of any warning systems, and labor power add to the troubles of cold storage owners. A smart IoT connected device which acts as a data acquisition device and a controller serves the problem solution. The health status of the cold storage can be viewed using a web application or mobile application in almost real-time. The system detects risky scenarios and provides early warning notifications or alarms in case of a critical condition.

Index Terms: Cold chain management, Cold storage, Critical conditions, Internet of Things, Food wastage.

I. INTRODUCTION

Food is considered as one of the essential thing for our lives. It is important to reduce food waste and increase the production-consumption ratio. The continuous growth in the cold chain management has been reflected in the growth of globalization. Eighteen per cent of India's fruit and vegetable production, valued at INR 133 billion, is wasted annually. Shortage of government owned cold storages and cold storages owned by mostly the upper-class people in towns, making it unavailable for the poor or low class farmers. Moreover, a dearth of continuous electricity, absence of any warning systems, and labor power add to the troubles of cold storage owners. Evidently there is a lack of comprehensive technology for the entire produce range of vegetables, fruits, flowers, meat and cereals.

Naturally food begins to spoil the moment it is harvested. Micro-organisms which are responsible for spoiling the food cannot survive at extreme temperatures. Food can be saved at very high and very low temperatures. It is tedious to attain higher temperatures and therefore we basically choose the later one to store food.

Farmers struggle and work hard to produce the crops and if we cannot utilize or consume it fully, all the work of farmers will go into vain. A proper storage mechanism should be incorporated to avoid the food wastage. Demand can irrespective of seasons which in turn avoids fluctuation in price of the product.

Currently many warehouses are deployed where the crops can be stored and this system lacks transparency in the entire process. Farmers are getting looted by the third parties who buy the crops at very low price compared with market price. This is a major loop hole in the legacy system and needs to be overcome. Full control over a product from incubation stage to delivery stage should be given to the person who is sole responsible for the product.

Col chain management plays a vital role in storing the products at sustainable environment. Cold- chain is a temperature specific supply chain. It enhances the shelf life of the products such agricultural produce, dairy products, sea food, pharmaceutical drugs, chemicals etc. A perfect cold chain includes production, storage, distribution activities which should be desirably done under low temperatures. Storage is considered as one of the important task in the cold chain.

Cold storages need to be monitored continuously to avoid unwelcomed situations. A proper alarm system should be deployed in the cold storages which alerts the users at bizarre conditions. Monitoring can be done by using a platform which displays the status of the cold storage. Sensors can be used to sense the environment and this data can be presented to the users. Temperature can be controlled by the users.

II. OBJECTIVES

A. To utilize Raspberry Pi based tools and standard sensors for monitoring the cold storage.

B. To have a centralized view on the production-consumption statistics.

C. To improve occupancy rate in the storages by software driven stocking and dispatch planning.

D. To scale down the food wastage effectively.

E. To notify in real time and enable to take appropriate measures quickly.

III. RELATED WORK

Research on remote monitoring of cold storages has been started many years ago and got increased when the technologies like Internet of Things, wireless sensor networks emerged. Increased awareness on food waste and storing techniques also paved a way to focus on cold storages. Many researches and theories are being stated by many people. Here are some of the researches that are made both at national and international level from last few years.

A. Abel Avitesh Chandra, Seong Ro lee (2014)[1]: This work deals with different sensors and Xively sensor cloud that can be used to monitor the staus of cold storages. They used different Arduino libraries and hardware designs to connect with the internet. They have used email service for notification purpose. The inventory of the environment is also monitored using NFC/RFID shield.

B. Sandeep Kaushik, Charanjeet Singh (2013)[2]: This work deals with monitoring and controlling of food storages using ZigBee and Bluetooth modules. They concluded that using ZigBee consumes less power, economical and more efficient when compared with Bluetooth.

C. Y.P. Tsang, K.L. Choy*, T.C. Poon, G.T.S. Ho, C.H. Wu, H.Y. Lam (2016)[3]: This works deals with the implementation of IoT-OSMS, and ensured the occupational health and safety and improves working performance in cold storages. Fuzzy Logic and Real-Time positioning are integrated to achieve their goal. They used Bluetooth Low Energy (BLE), a kind of RFID solution to locate and collect accurate information of the workers who are working in cold storages.

D. Sulman Farrukh, Muhammad Shahzad, Usman Khan, Talha Chughtai, and Ali Nawaz Khan (2013)[4]: They proposed an economic solution for cold storage management. Sensors are connected and at different levels as the temperature vary at different levels. This leads to the dumping of very accurate and reliable data from the sensors which in turn makes the whole system reliable and robust.

E. Mira Trebar (2015)[5]: This work deals with the logistic management in cold storages where radio frequency identification (RFID) technology is used. Temperature has been monitored by using prototype UHF RFID data logger, semi passive RFID tag. This tag helps to log the sensor values using the respective time-stamp. The work also includes some features like data protection, automatic sensors signal acquisition, smart power supply. The data is stored using innovative analogue nanotechnology architectures.

F. Zhao Xiaorong, Fan Honghui, Zhu Hongjin, Fu Zhongjun, Fu Hanyu (2015)[6]: In this paper, a novel IoT architecture based on object named service (ONS) which captures and stores the information in the web has been introduced. High volume products can be tracked using RFID tracks and low volume products can be tracked using bar codes. The data from the sensors, bar codes and RFID tags have been analyzed to obtain the shelf life and product quality.

G. Yanan Li, Yulin Peng, Lei Zhang, Jiefeng Wei, Dan Li (2015)[7]: This work adopts wireless sensor networks, ZigBee and research the performance and integrate mode of the technologies. It is designed to achieve a larger and longer communication distance transmission network. Easy access of product information is done which helps to enhance the product quality and safety.

Volume 5 Issue V, May 2017
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

H. Elhadi Yahia Kazuz, Jennifer Smolak[8]: This work explains the importance of cold storage in the improvement of the food maintenance system. It provides the statistical information about the loss due to the lack of cold storages in many parts of Asia and Africa.

I. Shobhit Kumar Nagpal, S.Sudha[9]: This paper is addressing the storage problem in India for maintaining fruits and vegetables. The solution provided is to build a cold storage using wireless sensor network by analyzing all the environmental parameters like temperature, humidity, toxic substances etc.

J. Sulman Farrukh, Muhammad Shahzad, Usman Khan, Talha Chughtai, and Ali Nawaz Khan[10]: This paper work provides an accurate, low cost and reliable solution which automates the industrial effort in maintaining the cold storages.

K. Kim, W.R.; Aung, M.M.; Chang, Y.S.; Makatsoris, C.[11]: This paper deals the storage conditions within the refrigerators considering the environmental conditions of temperature and humidity using RFID and WSN.

L. Badia-Melis, R.; Garcia-Hierro, J.; Ruiz-Garcia, L.; Jiménez-Ariza, T.; Robla Villalba, J.I.; Barreiro, P[12]: This paper concentrates on the dynamic and vigorous changes in the behavior of the sensors used in the cold storages. A classical study is made to find ways to tolerate fluctuating changes in temperature.

M. C. Chen, T. Chen, C. Zhang and G. Xie[13]: This paper is all about the logistics and transportation of the cold storage products to keep track of the food items and reduce the loss due to any abnormal situations through the mobile user interface.

N. R. Gormley, M. Brennan and F. Butler[14]: This work deals with the storage of consumer food products and also explains the advantages of super freezing the products and also the effects of fluctuations in temperature. The adverse effects of super freezing and rapid temperature variations are shown by the free fatty acids and peroxide values.

O. K. Likar and M. Jevšnik[15]: This paper is about the work on all the procedures after the production has been done like storing, monitoring and transportation. A comparative study has been made by using experimental setup of three different sized cold storages.

P. S. Li, L. Xu and S. Zhao[16]: This paper gives the recent intervention of Internet of things to fulfill the current world requirements. Definitions, architecture and also the technologies to be used for making IoT based devices are discussed.

Q. X. Xiao, Q. He, Z. Fu, M. Xu and X. Zhang[17]: This work gives a method to monitor the temperature inside the cold storage using WSN by sending the data with Compressed Sending (CS) which is implemented on the real time cold storages in China.

R. V.R. Lakshmi, S. Vijayakumar[18]: This work is about the transportation and the logistics of the food products by providing alerts in case of bizarre conditions to the truck owner and also the owner of the food being transported.

S. K. Zhang and J. Liu[19]: This work is on making man simulated intelligent control method for freezers and regulate the temperature and humidity inside it. Circuit connections are made using transducer, A/D convertor etc., without using arduino or raspberry pi.

T. D. Y. Lim, Y. J. Ryoo, J. Y. Gwark, Y. H. Chan g, and C. J. Moon[20]: This paper is on providing remote cold storage monitoring through serial communication. This method is applied for measuring the temperature within the storage.

U. R. Freitas, F. Soares, V. Vieira, J. Machado[21]: This work is focused on the controlling the vast refrigeration system inside a commercial store. It provides an optimized solution by using Omron temperature controllers using LabView software. In case of emergency the system sends a GSM message to the concerned people to handle the situation.

V. M. Murad, K. M. Yahya, G. M. Hassan[22]: This work is on 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 collected into an online database and this data is accessed from the web application.

W. M. Mancuso and F. Bustaffa[23]: In this paper, sensicast devices are used to apply WSN in agriculture. They aim to make the most reliable system without the data loss. It maintains the correlation within the acquired data through fuzzy logic.

X. Akyildiz I. F., Su W., Sankarasubramaniam Y., Cayirci E[24]: This paper focuses on building the sensor networks. It also discusses about the algorithms and protocols to be used in each layer of the sensor network connection.

Y. Hong -Seong Park, Myoung -Soon Jung, and Bong -Sun Kim[25]: This paper is on the work of giving a web based monitor using Java applets.

Volume 5 Issue V, May 2017
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

IV. DESIGN

A. Block diagram

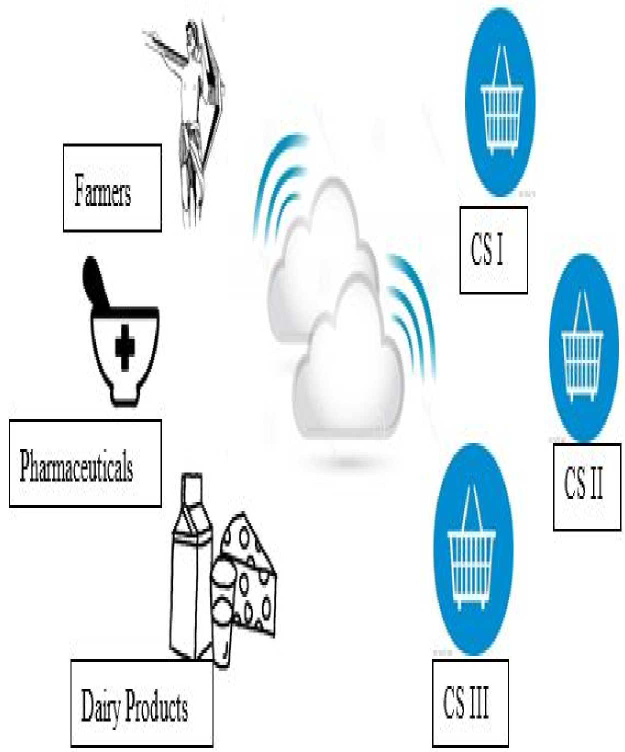

Figure 1.Block Diagram of the cold storage monitoring system

Block diagram of the proposed solution can be viewed in the figure 1 which is the highest level of the design.
This solution uses sensor modules to acquire sensor values. The real- time health status of the entire cold storage is visible on the display device for the intended user who got complete access or control over the cold storage. The system detects risky scenarios and provides early warning notifications or alarms in case of a critical condition.
Initially, all the data related to cold storages should be stored and maintained in the centralized database. Information includes the location of cold storage, capacity and its specifications.
A portal/application is developed and maintained which acts as a common platform to all the intended users. All the data related to cold storage can be viewed through the application.
Users can register themselves in the application/portal and can see various cold storages available in an area.
User can request for a cold storage and once the request is reviewed, a code will be sent to the user through which all the data of the respective cold storage can be accessed and can be personalized.
Acquired sensor values can be viewed by the user and can monitor their stock. When bizarre conditions such as fire or higher temperatures are detected, an alert will be sent to the user through the application and the user can take relevant action accordingly.
Leacy data can be used to help the novice users by providing all the relevant data such as temperature, humidity etc., to maintained for a product/crop which can be implemented as a future enhancement.
This system mainly avoids the third-party intervention in stocking and dispatching the goods and users can do alone. Transparency is maintained in the entire process starting from the spawning stage to consuming stage.
Based on the requests from the users, the demand for the cold storage is estimated and action can be taken accordingly. Detailed log of user activities will be maintained in the database which helps in enhancing security to the entire system.

Volume 5 Issue V, May 2017
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

B. Architecture Diagram

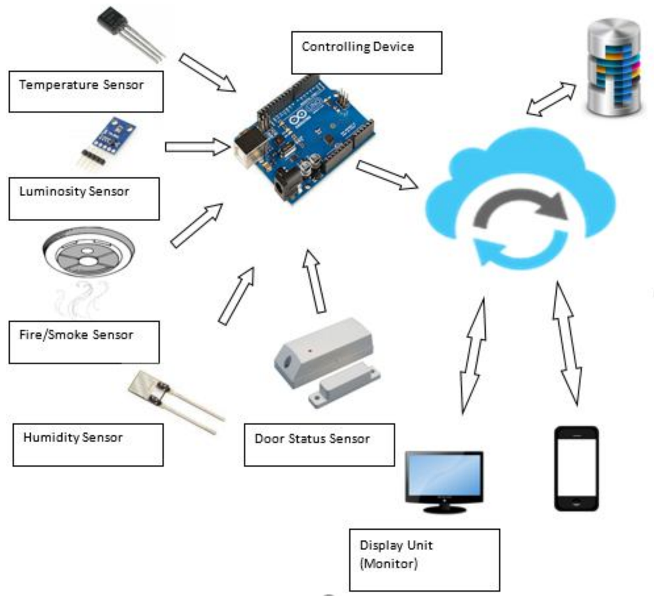

Figure 2: Architecture diagram of the cold storage monitoring system

An object of this invention is to prevent adversities of cold storage unknowingly.
An object of this invention is to notify an alert message in case of abnormal conditions like door left open, variations in temperature, humidity and smoke in terms of fire accidents.
Another object of the present invention is to notify in real time and enable to take appropriate measures quickly.
nother object of the current invention is to indicate quality of air in closed environment i.e. temperature, humidity, contaminants etc.
Yet another object is to provide a better sensitivity and accuracy for the recognition of Gases and estimating the metrics.
Another object is to provide outputs through cloud to multiple devices at user convenience along with constant display.
Another object of the current invention is to design and provide a device that can be integrated with large cold storages.
Another object is to make the whole-system cost effective compared with the existing systems.

C. Summary of Invention

The above said objectives are achieved through the development of the current invention that can monitor the status of cold storage. The current invention can be viewed as both product and tool. As a product, it can be a part of the market where people can buy it. As a tool, it can be integrated with storage devices like cold storages and can be part of manufacturing process of such products.

D. Brief Description of the Drawings

Example embodiments of the present invention and their advantages are best understood by referring to the drawings, like different sensors being used for evaluation and corresponding parts of the various drawings.
Figure 1 is a block diagram of proposed model. All the end users of the product i.e, farmers, pharmaceuticals and dairy product owners can store their food products in the different cold storages available in various parts of the country. All this data about the cold storage and the food products stored in it are stored in the web application. Data from the sensors are collected in the cloud storage which is displayed in the respective user's dashboard.
Figure 2 shows the Architecture of the system. Here first data from different sensors like temperature, humidity, smoke, proximity sensors are sent from the sensors to the cloud storage through the Raspberry Pi by converting analog data from the sensors to digital data using ADC convertors. This data from the cloud is always updated in the website for that particular user. Thingspeak cloud is

International Journal for Research in Applied Science & Engineering Technology (IJRASET)

used for storing the data on the cloud. Data in this cloud are stored as separate channel from each device. Data at each channel can be obtained to the maximum of 4 events/sec in this cloud. Data is collected for time stamp for a specific time interval. Web portal displays the average of all the values collected for a particular time interval. If the average value exceeds a threshold level then an alert message is given to the user.

Web portal also maintains the details of all the cold storages in the country along with the availability in that cold storage. This helps the farmers to keep a track of all cold storages in his/her nearby locations.

E. Detailed Description of the Invention

Figure 1 shows a schematic view of the main components of an embodiment of the invention. AM2302 sensor is used for monitoring the temperature conditions inside the cold storage. This sensor is also used for measuring the moisture levels within the storage area. Through proximity sensor we can monitor the status of the door by checking if the door is in contact with the sensor.

All these sensors values are passed from raspberry pi to the cloud storage.

To gt the location of our device GPS is used to send the device's location to have a track record of all the devices at various locations in the data storage.

Raspberry Pi is used for converting the analog sensor data to give the digital output to raspberry pi. Raspberry Pi collects the sensor values and passing them to the cloud storage.

Thingspeak, a cloud storage where the collected data from each cold storage is stored under a separate channel with different sensor values as separate fields. All the updated values of the data are collected from the cloud storage periodically.

Algorithm for alert generation in cold storage

WAMP server is used to host the website on the local machine. It is a web development environment. It allows to create web applications with Apache2, PHP, and a MySQL database.

F. Working Examples

We consider few real-world scenarios of the usage of the device.

G. Working Example 1

Consider that the door is open for the cold storage simulation environment created. Then the proximity sensor gives the status alert that the door has been left open.

H. Working Example 2

Consider the situation when the temperature and humidity values in the cold storage is altered. Then the variation in

International Journal for Research in Applied Science & Engineering Technology (IJRASET)

```
Id: id of the device in a cold storage
entry: a group of 15 readings taken from a sensor
cloud: The cloud storage used to maintain the data collected from the sensors
total_entries: list of entries stored for future risk assessment
latest_entry: Entry recently added to the cloud storage
Δ: The maximum value allowed in the Standard deviation variation

total_entries=NULL
Risk_assessor (latest_entry):
    data:={temperature,humidity,door_status,fire_status}
    for value in data:
        Avg:=prev_avg*total_entries+latest_entry[value]
        //logic to compare this avg with previous entry averages
        Res:=Check_for_local_maxima(latest_entry[value])
        If res==true
                                    If (σ total_entries+latest_entry)>( σ S.D of total_entries)+Δ value
                                Discard the value
                                            Return 1
            Else
                Add the entry to the list of total_entries
                Return 0
        Else
            Add the entry to the list of total_entries
            Return 0
alert_generator(id):
    //for every sec
    cloud.refresh()
    If clouddata_lastentry.old!=clouddata_lastentry.new
        Latestentry:=clouddata_lastentry.new
        Val:=Risk_assessor (id,latestentry)
        If val== 1
            RaiseAlert(id)
            //Graph of the alert scenario
            GiveStatus(id)
            Latestentry_graph(id)
        Else
            GiveStatus(id)
            Latestentry_graph(id)
Main():
//start a thread for each registered cold storage
for mem in len(id)
    t[i]:=thread(target=alert_generator(id))
    t[i].start()
```

these values are displayed in the web portal as the average values at that timestamp exceeds the threshold limit.

Volume 5 Issue V, May 2017
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

I. Working Example 3

Consider the situation when smoke is generated due to fire in the cold storage. Then presence of smoke in that storage is given as a notification.

J. Pseudo code for all the sensor data collection

```
#!/usr/bin/env python
import httplib, urllib
import time          # Allows us to call the sleep function to slow down our loop
import RPi.GPIO as GPIO          # Allows us to call our GPIO pins and names it just GPIO
GPIO.setmode(GPIO.BCM)          # Set's GPIO pins to BCM GPIO numbering
INPUT_PIN = 3          # Sets our input pin, in this example I'm connecting our button to pin 4. Pin 0 is the SDA pin so I avoid using it for sensors/buttons

GPIO.setup(INPUT_PIN, GPIO.IN)
print GPIO.input(INPUT_PIN)
t_end= time.time()+3
temp=[]
while time.time() < t_end :
        temp.append( int(GPIO.input(INPUT_PIN)) )
        time.sleep(1)
params = urllib.urlencode({'field1': temp, 'key':'S3V9F6CE7CKL0HXY'})        # use your API key generated in the thingspeak channels for the value of 'key'
# temp is the data you will be sending to the thingspeak channel for plotting the graph. You can add more than one channel and plot more graphs
headers = {"Content-typZZe": "application/x-www-form-urlencoded","Accept": "text/plain"}
conn = httplib.HTTPConnection("api.thingspeak.com:80")
conn.request("POST", "/update", params, headers)
response = conn.getresponse()
print temp
print response.status, response.reason
data = response.read()
conn.close()
```

V. RESULTS AND DISCUSSION

A. Screenshots

As shown in the fig3, temperature readings over time are taken and a graph is plotted.

Volume 5 Issue V, May 2017
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

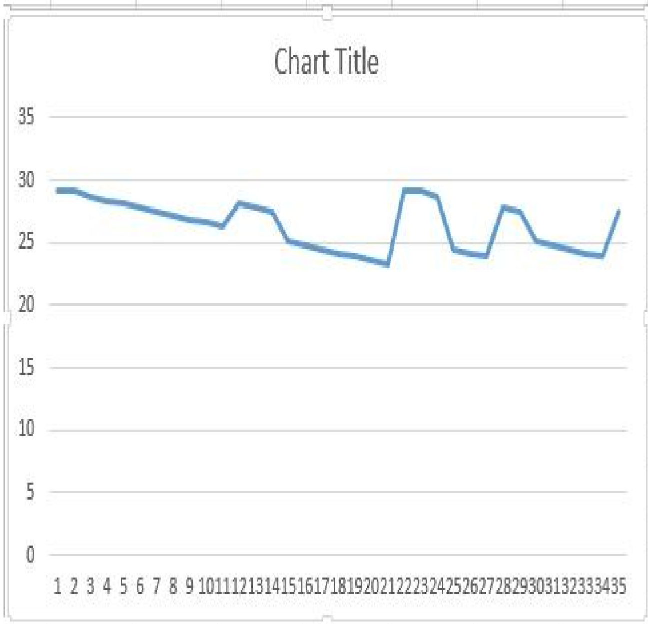

Figure 3 Temperature Readings

Humidity values over time are taken and the plotted graph is shown in fig4.

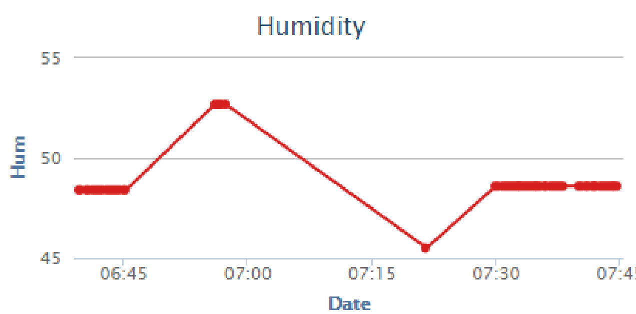

Figure 4 Humidity Readings

The status of the smoke sensor when placed in a closed container is shown in Fig5.

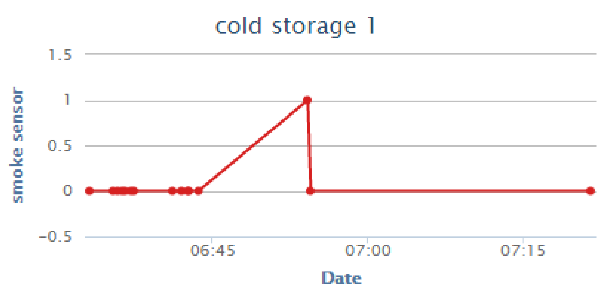

Figure 5 Smoke Sensor Readings

The latitude and longitude coordinates of the corresponding device is measured over time in fig6 and fig7.

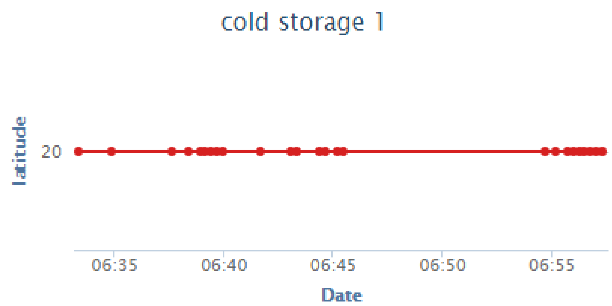

Figure 6 Latitude coordinate of the setup

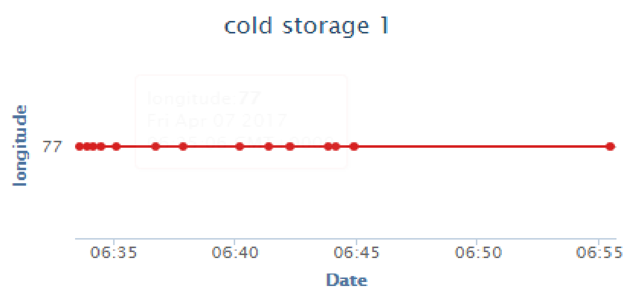

Figure 7 Longitude coordinate of the setup

Status of the door of the cold storage is gathered for a range and time and the respective plotting is shown in fig8.

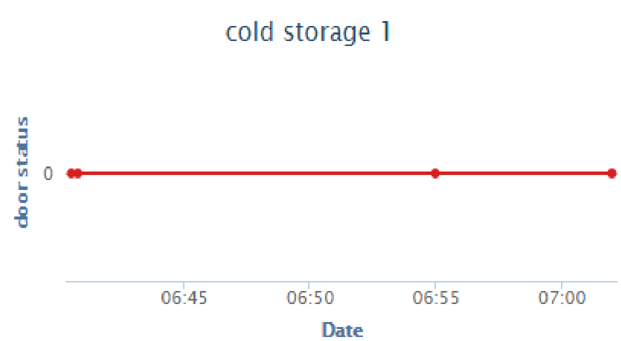

Figure 8 Door status Readings of the cold storage

Figure 3 shows the chart with temperature readings obtained from the data uploaded by the temperature sensor to thingspeak cloud storage. Similarly, graphs are plotted for all the sensors we are using which makes us easy to visualize entire sensor data in the cloud storage.

Figure 4 shows the relationship between humidity and temperature values obtained from the respective sensors which can be used to predict one value from the other one. This feature helps us to keep track on any one data and can be used to check for the emergency conditions. Using these relationships, computing effort can be reduced.

VI. CONCLUSION

Monitoring of cold storages is a tedious task and it is made easy using Internet of things technology. Continuous monitoring by the real owner of the product can be done in almost real time. All the sensors are very economical when compared with the sensors used in the other works and yields almost same results. Computational effort is also greatly reduced by using correlated values of the

Volume 5 Issue V, May 2017
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different sensors.

A. Future work

This project can be further extended by adding additional features like analyzing the requirements of cold storage in a area and deploying it if the proposal is feasible. Further using certain algorithms sensor data can be predicted for a product using the legacy data. Early warning notification can also be sent to the users by matching the previous patterns of the sensor data with the current data.

VII. ACKNOWLEDGMENT

We would like to express our gratitude and sincere thanks to our professor Dr Swathi J.N., without her help and guidance this project would not have been completed. Thank you for motivating us to complete this project. We would like to express our thanks to Dr. G.Viswanathan, Chancellor, VIT University for providing the proper environment and facilities.

We are grateful to our parents and friends for their constant encouragement and support.

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