IoT Based Real Time Monitoring and Automated Agricultural Storage System

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DECLARATION

This thesis has been submitted to the department of Computer Science and Engineering, East West University in the partial fulfillment of the requirement for the degree of Bachelor of Science in Computer Science and Engineering by us under the supervision of Dr. Ahmed Wasif Reza, Associate Professor and Chairperson at Department of CSE at East West University under the course 'CSE 497'. We also declare that this thesis has not been submitted elsewhere for the requirement of any degree or any other purposes. This thesis complies with the regulations of this University and meets the accepted standards with respect to originality and quality. We hereby release this thesis to the public. We also authorize the University or other individuals to make copies of this thesis as needed for scholarly research.

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LETER OF ACCEPTANCE

The thesis entitled "IoT Based Real Time Monitoring and Automated Agricultural Storage System" submitted by S.M Mominul Haque Sejan, ID: 2013-2-60-009 & Muhammad Ramzan Hossain, ID 2013-2-60-017 to the department of Computer Science & Engineering, East West University, Dhaka 1212, Bangladesh is accepted as satisfactory for partial fulfillments for the degree of Bachelor of Science in Computer Science & Engineering in December 2017.

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Abstract

In this project, an IoT based smart storage system is developed for agricultural purpose in order to monitor and maintain storage environment both manually and automatically. Data is stored in MySQL database and the communication with the sensor data and web server is established with the help of Ethernet shield for Arduino. The project is supported by both website for computers and android devices via android app which increases its mobility. Monitoring and controlling can be done from website or android app. The web application also developed considering privacy and security issues so it makes it more secured. The system is tested on current environment and result was as expected.

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List of Abbreviations

IoT	Internet of Things
Arduino	Open source microcontroller
Shield	Peripheral boards that are designed to easily interface with Arduino microcontrollers
DHT22	Digital temperature and humidity sensor
LDR	Light Dependent Resistor
LED	Light-emitting diode
HTTP	Hypertext Transfer Protocol
TCP/IP	Transmission Control Protocol/Internet Protocol
MAC	Media Access Control
AC	Air conditioning
PC	Personal Computer
GUI	Graphical User Interface
HTML	Hypertext Markup Language
Apache	HTTP web server
PHP	Hypertext Preprocessor
MySQL	Database Service
RDBMS	Relational database management system
AJAX	Asynchronous JavaScript And XML
LED	Light Emitting Diode
Bcrypt	Bcrypt is a password hashing function

CHAPTER 1

INTRODUCTION

1.1 Background

Agriculture remains the most important sector of Bangladesh economy, contributing 16 percent of the national GDP and providing employment for the 47 percent of the population. It helps to meet the basic needs of human and their civilization by providing food, clothing, shelters, medicine and recreation. Agriculture provides food, fiber, fuel, furniture, raw materials, a free fare and fresh environment, plenteous nourishment for driving out starvation, favors companionship by wiping out battles. Freshly harvested agricultural product like potato, vegetables contain 70% moisture as a result these are perishable in nature. These crops cannot be saved from spoilage unless preserved. Farmers usually keep their agricultural product on the elevated platforms erected in their dwelling house.in Bangladesh, maximum agricultural products are stored indoors under room temperature. Due to high temperature, these products lose their weight gradually and ultimately get shriveled,rotten or sprouted. For example, more than 30% potato is lost in this way. Farmers are struggling 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 the price of the product. For large scale commercial preservation of agricultural products, cold storage are used in Bangladesh. A cold storage is a building or a group of buildings with thermal insulation and a refrigeration system in which perishable food products can be stored for various lengths of times in set conditions of temperature, humidity, moisture, light intensity etc. However, the absence of proper monitoring, controlling and any warning systems could cost huge losses of cold storage owners and farmers as well. Cold storages need to be monitored continuously to avoid unwelcomed situations. A

proper alarm system should be deployed in the cold storages which alert the users to unusual conditions. Monitoring can be done by using a web 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. Situations can be controlled by the users or it can be automated. Here we developed an IoT based real-time monitoring and automatic controlling agricultural storage system.

1.1.1 The Concept of IoT

The Internet of Things (IoT) is a system of interconnected computing devices or objects that are provided with unique identifier and the ability to transfer data to each other over a network without human interaction. In simple terms, it is a network in which physical objects can exchange data internally or with other connected machines. The concept of the Internet of things became popular in 1999, through the Auto-ID-Center at MIT and related market-analysis publications.

The major objective of IOT is to create a smart environment (smart buildings, smart agriculture, smart health, smart transport, etc.) using enabling technologies such as sensors, embedded devices, communication protocols. Physical devices such as microcontrollers, microprocessors, actuators, and sensors cannot directly communicate with the Internet but they do so by using an IOT gateway. Now it is generally considered as a network or system, which interfaces everything with the web by RFID, sensors, global positioning systems (GPS), laser scanners and other information sensing devices.

To do any project or research about IoT having knowledge of architecture of IoT is required. There are four layers of IoT architecture. They are Interface layer, Service layer, Networking layer, Service layer.

Interface Layer

This is the first layer of IOT architecture. This layer provides the interaction methods between users and application. For this, we need to create web-based application or mobile application that interact with devices and with the event-processing layer.

Service layer

This layer is used to create and manage services to satisfy user's needs. To do so, it process data deep processing. To make more user friendly application, it provides database with different data and divides work. This is an important layer for three reasons:

1. The ability to support an HTTP server and/or an MQTT broker to talk to the devices;
2. The ability to aggregate and combine communications from different sensing devices and to route communications to a specific device (possibly via Ethernet shield/GSM/GPRS).
3. The ability to bridge and transform between different protocols that is to offer HTTP based APIs that are mediated into an MQTT message going to the device.

Network layer

Internet, Mobile Communication Network, Satellite Communications Network, Cable Television Network, Information Center, Network Management Center.

Sensing Layer

RFID Reader, Sensor Network, Access Network, RFID Label, Sensor, Intelligent terminal.

1.1.2 IoT in Agriculture

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

1.1.3 Importance of IoT in Agriculture

Some advantages of using IoT in agriculture are givenbelow:

- Water Conservation
- Increased Production
- Increased Quality of Production
- Lowered operating Costs
- Improved Livestock Farming
- Reduced Environmental Footprint
- Real-Time Data and Production Insight
- Remote Monitoring
- Remote Controlling
- Sustainability
- Food safety
- Increased crop and food quality

1.2 Motivation

According to the scientists of Bangladesh Agricultural Research Institute (BARI) scientist every year tons of vegetables and fruits go to waste annually in Bangladesh due to a lack of sufficient technologies and knowledge on post-harvest handling, packaging, storage and transportation.

Referring to a Bangladesh Bureau of Statistics report, it showed that post-harvest losses among 12 fruits and vegetables ranged from the lowest 8.1 percent (litchi) to 32.4 percent (jackfruit) in 2010-11.

The second highest loss was in banana (30.8) followed by tomato (27.64), cabbage (24.44) and country bean (24.29). The other crops were mango, orange, pineapple, brinjal, cucumber and cauliflower.The report shows that the national level loss of jackfruit, banana and tomato were 3, 25,673; 2, 52,022 and 64,252 tons respectively in 2010-11 [12].The total average cumulative loss in post-harvest from harvesting to millingwas

13.52%. The drying loss varies from 1.63 to 2.84%, parboiling loss was1.93 to 2.75%. The height loss occurred during milling operation varyingamong 3.28 to 4.54% (FAO/BARI, 1986). The post-harvest loss of wheat,mustard and major pulses at farm level has been estimated 8-10% and 18-25%respectively. In peak season the post-harvest loss of fruitabout 50% due to inadequate processing facilities in Bangladesh.

Bangladesh has been suffering significant food losses for a long time due tovarious reasons like:

1. Inadequate postharvest activities
2. Lack of modern technologies and machineries
3. Inefficient marketing systems
4. Government support is not sufficient in research and extension sector.
5. Processing and preservation facilities are not sufficient of food.
6. Poor handling during loading and unloading at market point

   The post-harvest losses of rice in Bangladesh from producer to retailer level 11.43% and the estimated total post-harvest losses of rice at farm level is9.81

Table2.2: Estimated losses of rice in Bangladesh and Southeast Asia (%)

Activities	Estimated losses of rice in Bangladesh (Bala,1978)	Estimated losses in Southeast Asia(www.fao.org,2008)
Harvesting	1.06 - 6.50	1.00 - 3.00
Transportation	0.63 - 6.00	2.00 - 10.00
Threshing	1.65 - 2.00	2.00 - 6.00
Drying	1.56 - 5.00	1.00 - 5.00
Storage	3.05 - 7.50	2.00 - 6.00
Total	7.95 - 22.00	10.00 - 37.00

[13]

1.3 Problem Statements

Agriculture is considered as the basis of life for the human species as it is the main source of food grains and other raw materials. It plays vital role in the growth of country's economy. In Bangladesh the most important sector of economy is agriculture and it remains the largest employer in the country by far.Farmers are struggling 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. Freshly harvested agricultural product like potato and vegetables contain seventy percent moisture as a result these are perishable in nature. These crops cannot be saved from spoilage unless preserved. Unfortunately, many farmers still use the traditional method for storing their crops. Due to high temperature, these products lose their weight gradually and ultimately get shriveled, rotten or sprouted. Even sometimes agricultural product on cold storage also rotten due to lacking of proper monitoring and controlling in the cold storage. Here room temperature, humidity, moisture and light intensity is not maintained properly.

1.4 Research objective

From our background check we found out that almost every cold storages in Bangladesh have manual control system. So our main objective was to develop a simple yet efficient system which can maintain an entire storage on its own or with a little involvement of human effort.

And also most of the storages doesn't keep track of their storage inside environment data so in future it is impossible to track down any abnormality which can affect the stored agricultural crops. So getting preventative measures is not possible for them.

So our main objective is:-

1. Design a framework for our system structure for both monitoring and controlling.
2. Implement the system according to our structure for real time monitor and control and notification about abnormality in environment.

1.5 Thesis contribution

1. We have designed a system for real time monitoring for storage environment.
2. We also integrated our sensor data with web where monitoring and controlling will be available from any computer with internet connection.
3. Controlling has both manual and automatic feature.
4. An android app which can do same control and monitoring operations as we can do from computer.
5. Store sensor reading in database for future analysis or abnormality detection.
6. Developed a website and android application

1.6 Thesis Outline

The outline of the rest of this report has been structured as follows**.**

Chapter 2: Chapter 2 provides an overview of the literature review on agricultural storage and IoT related previous work on this field.

Chapter 3: Chapter 3 discuss our proposed methodology, describe the whole proposed system how its work and also give the algorithm for automation.

Chapter 4: Chapter 4 discuss whole monitoring process. Here we described details how a user will see how storage situation via the internet using the website or mobile application. Also described how sensor data send to the web server.

Chapter 5: chapter 5discusscontrolling process. Details discuss how user will be able to control the room condition. Details discuss both manual and automated control.

Chapter 6: In this section, we provide the experimental result of our research using different test environments.

Chapter 7: Describe outlines conclusion of this work precisely and also describes the scope of future work for possible extended application of the project.

CHAPTER 2

LITERATURE REVIEW

2.1 Review of Existing Techniques

Research on remote monitoring of cold storages has been started few 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 international level from last few years but there is no previous work at national level.

1. Elhadi Yahia Kazuz, Jennifer Smolak[1]: 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.
2. D. Y. Lim, Y. J. Ryoo, J. Y. Gwark, Y. H. Chan g, and C. J. Moon[2]: This paper is on providing remote cold storage monitoring through serial communication. This method is applied for measuring the temperature within the storage
3. M. Murad, K. M. Yahya, G. M. Hassan[3]: 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.
4. Hong -Seong Park, Myoung -Soon Jung, and Bong -Sun Kim[4]: This paper is on the work of giving a web based monitor using Java applets.
5. K. Zhang and J. Liu[5]: 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.

6. X. Xiao, Q. He, Z. Fu, M. Xu and X. Zhang[6]: 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.
7. K. Likar and M. Jevšnik[7]: 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.
8. C. Chen, T. Chen, C. Zhang and G. Xie[8]: 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.
9. Kim, W.R.; Aung, M.M.; Chang, Y.S.; Makatsoris, C.[9]: This paper deals the storage conditions within the refrigerators considering the environmental conditions of temperature and humidity using RFID and WSN.
10. Sandeep Kaushik, Charanjeet Singh (2013)[10]: 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.
11. Proposes an IoT framework for facilitating food monitoring for protection of the food **[11]**
12. Proposed Real time monitoring in agricultural warehouse using IoT **[16]**
13. Industrial Automation and Control System to Minimize Food Spoilage and Imports **[17]**

2.2 Summary

From the literature review, we have seen that all of the previous work on about monitoring and manual control. There were very little agricultural storage where automatic control system is implemented. There was also lack of sensor data which we could be useful for our system to perform automatically more efficiently like human.

CHAPTER 3

DESIGN AND METHODOLOGY

3.1 Proposed Framework

In the era of technology advancement, everything requires monitoring and controlling. We proposes an IoT framework for facilitating food monitoring for protection of the food, so that it would not get contaminated due to surrounding conditions during storage and transportation. In present scenario, the work done is in terms of the sensed values that have been recorded and a detailed analysis has been performed but automated control alternatives are not present. Efficient monitoring of temperature, humidity, light and other conditions without being present physically at the location helps us to get a better outcome. Here our main purpose is 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 responsible for passing information to management mode using computer or mobile phone.

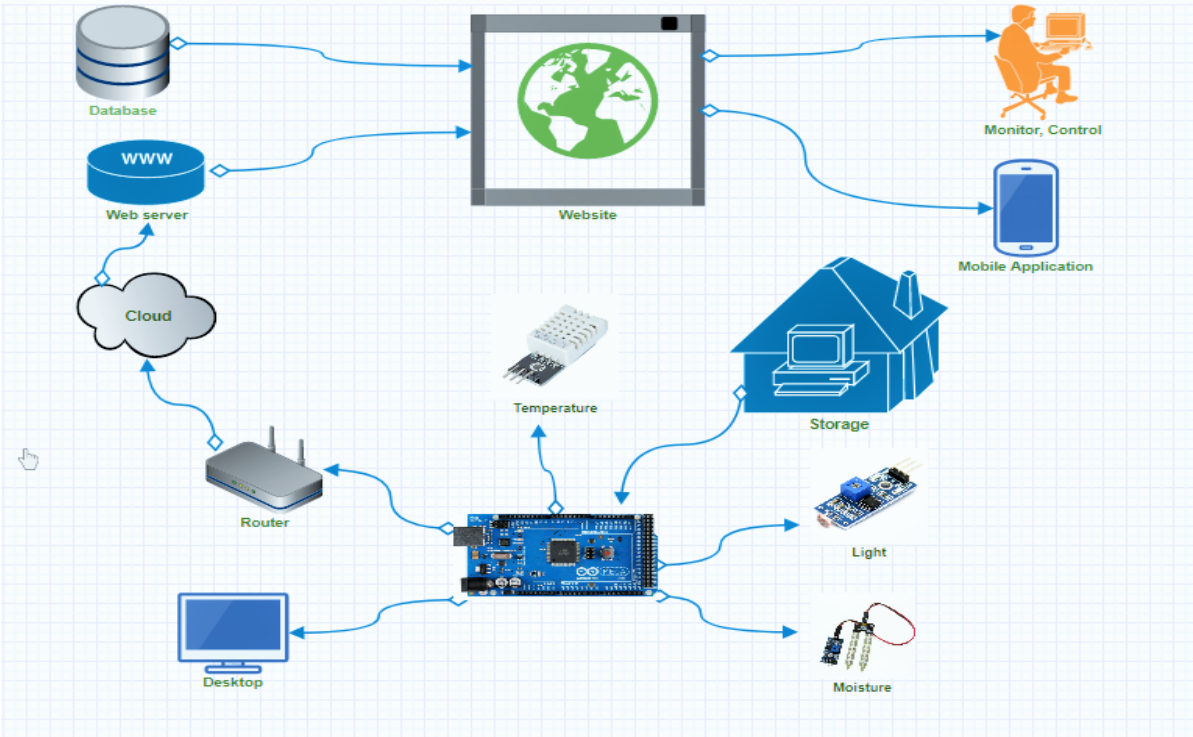

Figure 3.1: System overview

3.1.1 Communication with web server

The system will be communicating with web server though two ethernet shields where one is used to post sensor data to server and another to get manual control settings from server.

3.2 System implementation

3.2.1 Circuit connection:

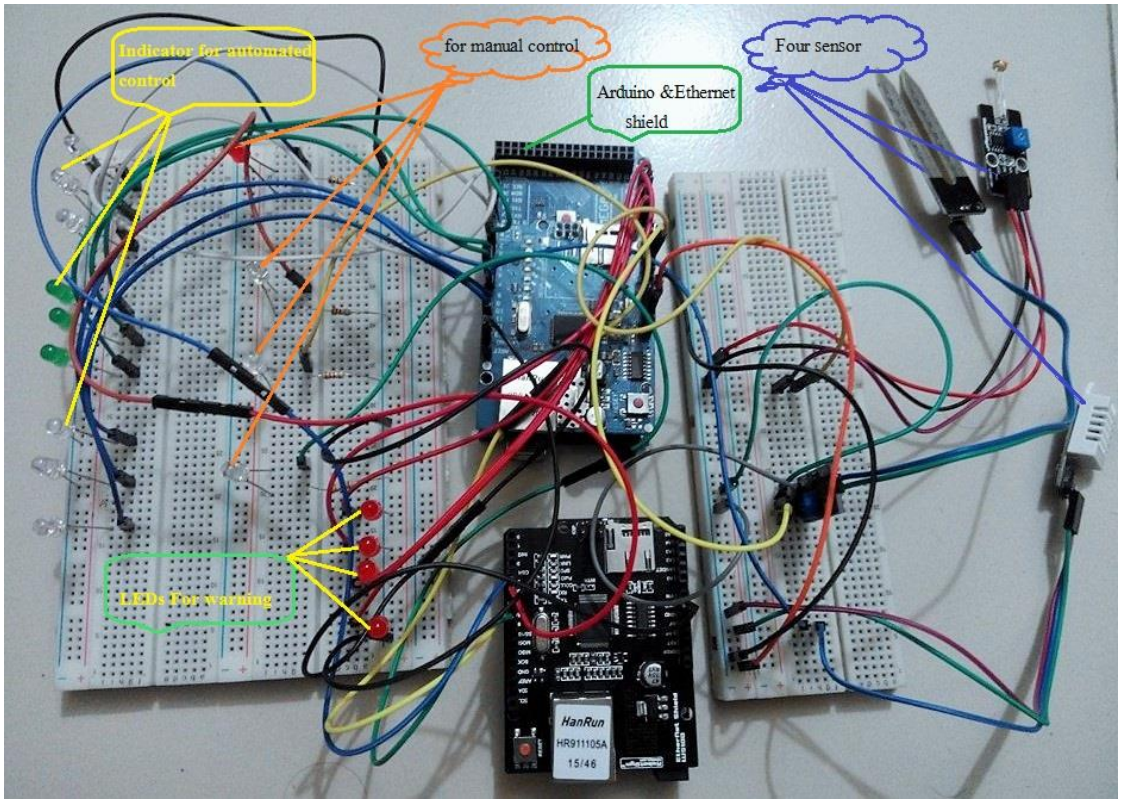

Figure 3.2: Actual circuit connection of our system

While implementing we divided our work in three parts to ease our implementation process.

- Monitor (Real time monitoring of storage status)
- Control (Enabling controlling devices like freezer,fan,light)
- Warning (Warn about abnormal environment inside storage)

3.2.2 Monitor

For monitoring storage environment we used DHT22(for humidity and temperature), Moisture sensor, LDR(light) with Arduino Mega and Ethernet shield and sensor data was sent to our MySQL database table *sensorreading* table every 5-6seconds.

3.2.3 Control

3.2.3.1 Manual control

Four control buttons were added for controlling four devices that used to maintain environment of the storage (freezer, fan, heater, light). An operator who will monitor storage environment consistently and he can manually control these devices to maintain storage environment.

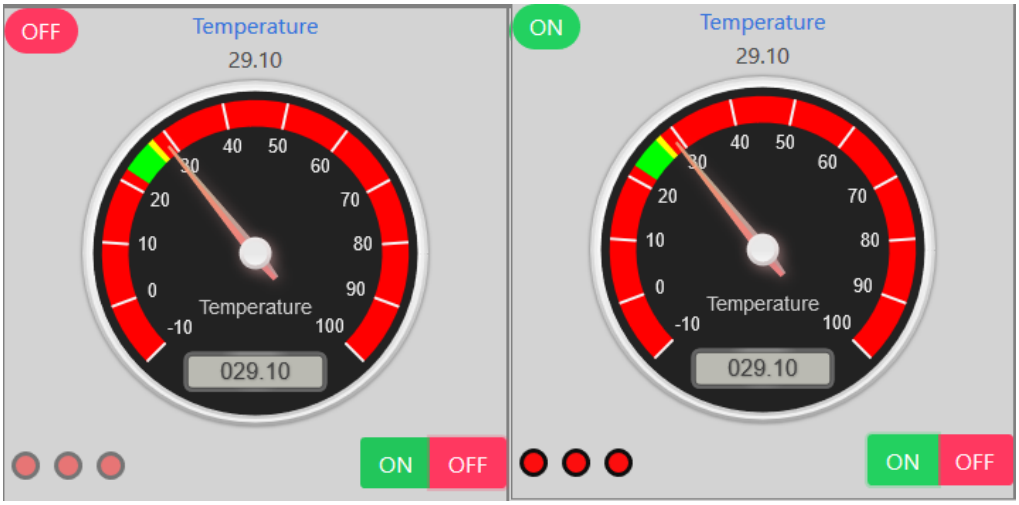

Figure 3.3: Manually control using website

3.2.3.2 Automated control

In case of there is no one present to monitor the storage our system can also monitor sensor readings and it will generate appropriate actions and warnings to maintain storage environment and alert to inform the proper authority.

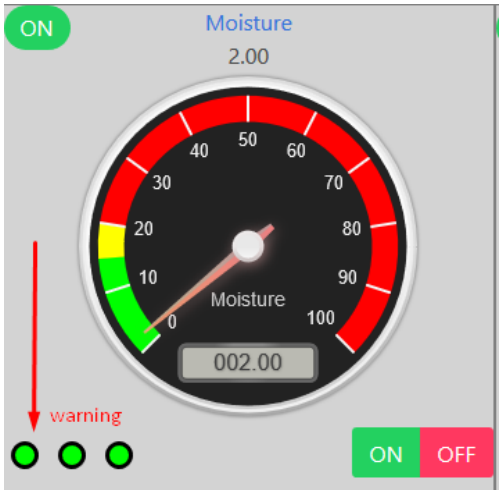

Figure 3.4: warning according to sensor data

3.2.3.3 Algorithm for automated control

Procedural flow of our automated system is given below:

Step 1: Start the program.

Step 2: Establish connection with web server

Step 3: Retrieve previous control settings

Step 4: Read sensor data

Step 5: If sensor value is not according to optimal value go to step 6. Otherwise go to step 3.

Step 6: Generate warning and adjust related device to get optimal environment and go to step 4.

Step 7: Stop.

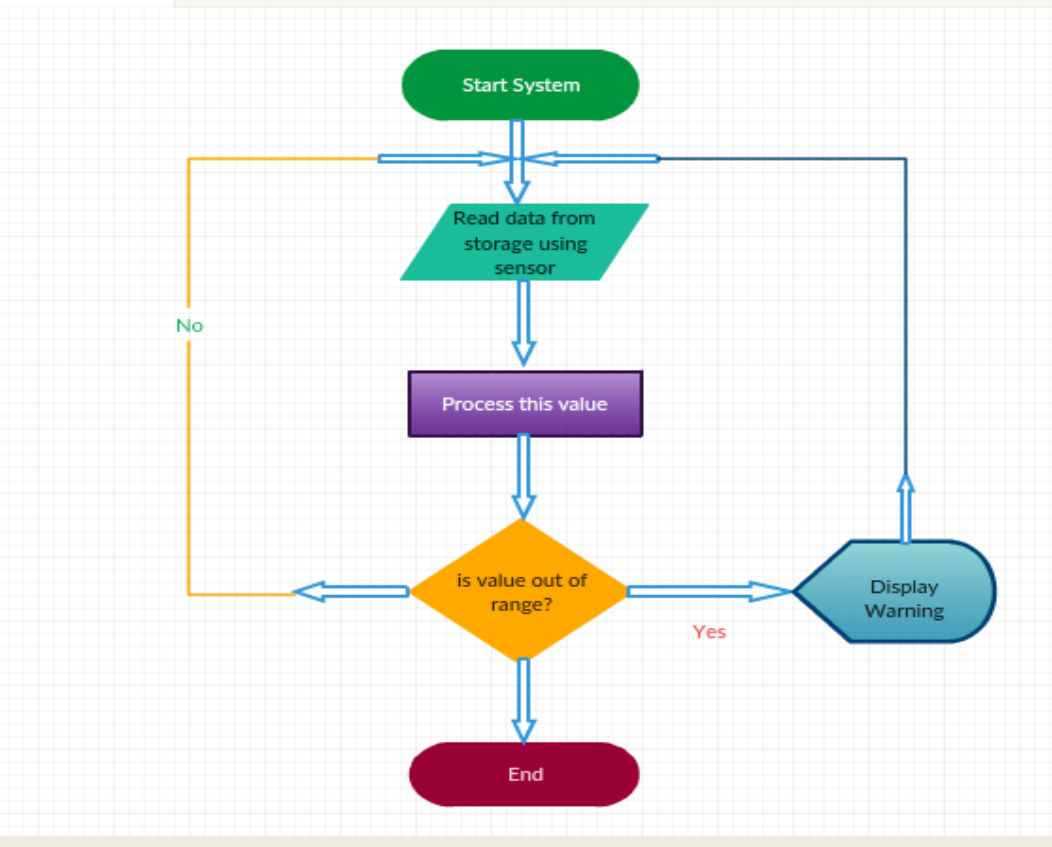

Figure 3.5: Flowchart for automated control

3.2.4 Warning

Warning are the indicator whether there is any abnormality inside the storage. These warning are parted in different stages to indicate the severity.

Warning level:

- Three green circles indicates that storage environment moisture is under control.
- If there are some abnormality
    - One red circle indicates for slightly off limit sensor value
    - Two red circle means sensor reading are off limits medium level.
    - Three red circle means sensor data is out of control
- If there are more than abnormal sensor values three red circles will appear and it will blink every 3 seconds.

This image shows the sensor, control and warning indicator on hardware alongside with website.

3.3 Website and android app

A web application has been developed to enable storage owners/administrators to monitor their storage environmental status live. Using this application administrators also can control inside storage devices to control the environment and also they will be notified if any irregular situation is created inside their storages. There will be admin who needs to be registered and logged in with proper credentials to perform control and monitoring.

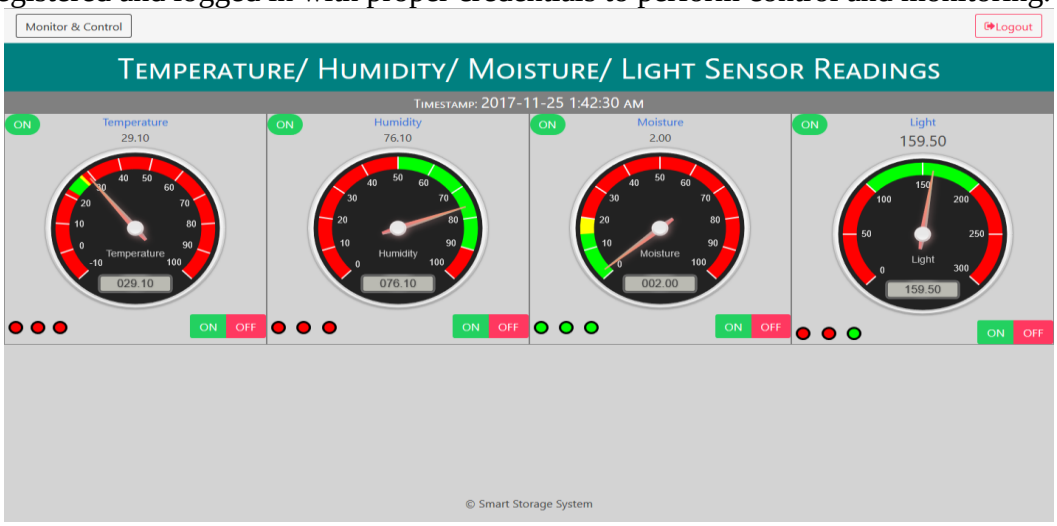

Figure 3.6: Website hosted at iot.itexpertsbd.com

Similarly the android app is also can be used for same purpose directly from mobile/tablet device

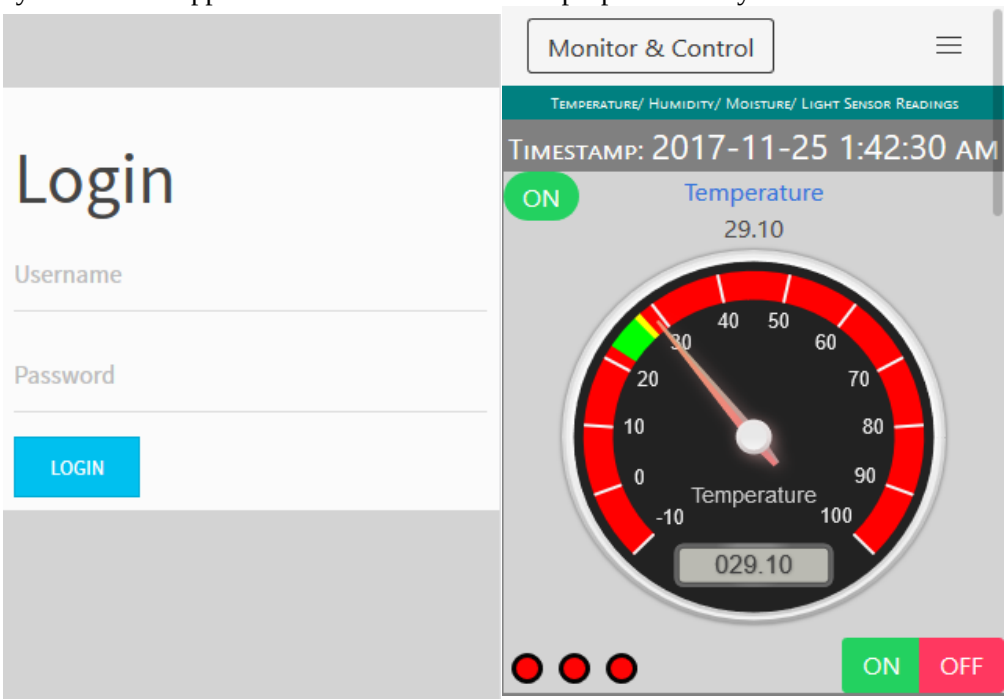

Figure 3.7: Android app interface

3.3.1 Authentication and password security

To prevent unwanted access only registered users can access the application main interface.
So without the correct username and password combination intruder will be redirected to login page every failed login attempt.
As per password encryption even our database is compromised password is stored as a hash value encrypted with bcrypt [12] with a salt [13] which makes its much stronger against brute-force attack or other decryption methods.

3.4 Summary

Our designed and developed system enabled storage owners to monitor and control their storage environment remotely. Our system provides also secured environment to prevent others from getting unwanted access with help of latest security measurements applied to our system

CHAPTER 4

MONITORING

The main purpose of the monitoring system is to obtain temperature, humidity, moisture and light sensor readings from the storage to be relayed to a remote user over the internet. These sensor reading are sent back into our control system to enable automated control.
The design components of the monitoring system are broken down into two main sections: hardware and website

4.1 Hardware

The monitoring system consists of four sensors that interface with the Arduino MEGA microcontroller. These sensors include a temperature sensor, humidity sensor, moisture sensor, light intensity sensor. Sensor data is uploaded to the web server from Arduino using the Ethernet shield.

4.1.1 Arduino MEGA

The Arduino Mega is a microcontroller board based on the ATmega1280. It has 54 digital input/output pins (of which 14 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with an AC-to-DC adapter or battery to get started. The monitoring system required a total of 10 digital pins and 5 analog pins making the Arduino MEGA a perfect candidate. The MEGA has a clock speed of 16 MHz and a flash memory of 32 KB which was more than enough to run and process the monitoring system code. Specifications of the Arduino MEGA are given below.

Table 4.1.1: Arduino MEGA specifications

Microcontroller	ATmega1280
Operating Voltage	5V
Digital I/O Pins	54 (of which 15 provide PWM output)
Analog Input Pins	16
Flash Memory	128 KB of which 4 KB used by boot loader
SRAM	8 KB
EEPROM	4 KB
Clock Speed	16 MHz

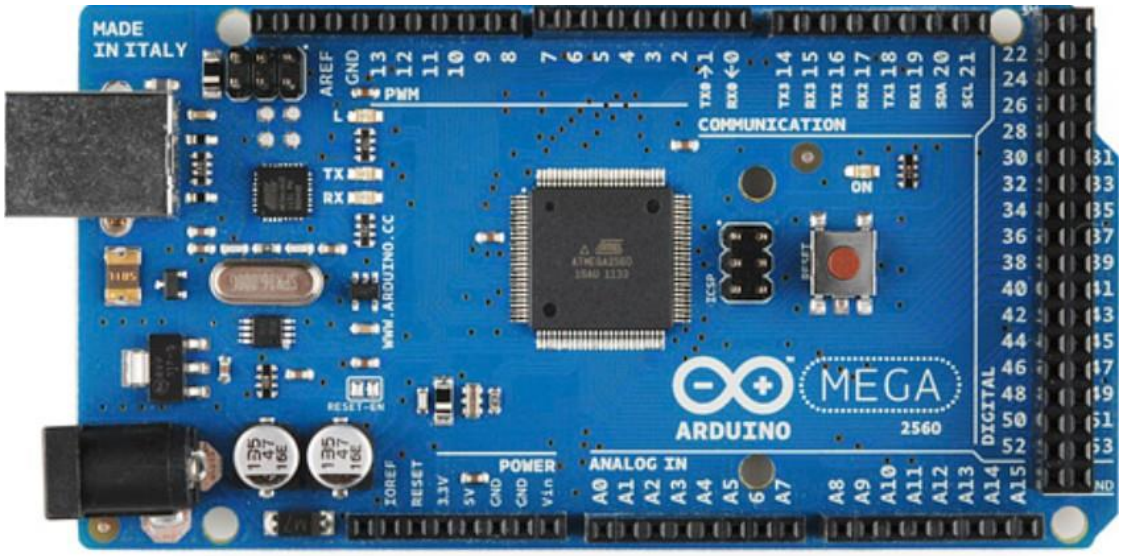

Figure 4.1: Arduino MEGA

4.1.2 Ethernet Shield

The Arduino Ethernet Shield allows an Arduino board to connect to the internet using the Ethernet library and to read and write an SD card using the SD library.

Table 4.1.2: Ethernet Shield specifications

Parameter	Ethernet Shield
Working voltage	+5V
Control mode	Control by seeeduino/Arduino
TCP/IP Ethernet Controller	Wiz5200
Power supply mode	5V pin of Arduino/Seeeduino
Standard Shield	Yes
SD Card Socket	Support Micro SD card in FAT16 or FAT32, maximum storage is 2GB.
Grove Connector	UART and IIC Connector
Ethernet jack	Minimal RJ45

Figure 4.2: Ethernet Shield

4.1.3: DHT22 Temperature and Humidity Sensor

The DHT22 is a dual temperature and humidity sensor, meaning that it can read both temperature and humidity. A higher accuracy temperature sensor is implemented instead. This sensor uses serial communication that is reliable and has long-term stability.In our research, we use this sensor for taking the storage internal temperature and humidity as well then send to the web server for real-time monitoring purpose.

Figure 4.3: DHT22 module

Technical Specifications:

Table 4.1.3: DHT22 module specifications

Specifications	Humidity	Temperature
Power supply	3.3-6V DC	3.3-6V DC
Output signal	digital signal via single-bus	digital signal via single-bus
Sensing element	Polymer capacitor	Polymer capacitor
Operating range	0-100%RH	-40~80Celsius
Accuracy	+-2%RH(Max +-5%RH)	<+-0.5Celsius
Resolutionor sensitivity	0.1%RH	0.1Celsius
Repeatability	+-1%RH	+-0.2Celsius
Sensing period	Average:2s	Average:2s

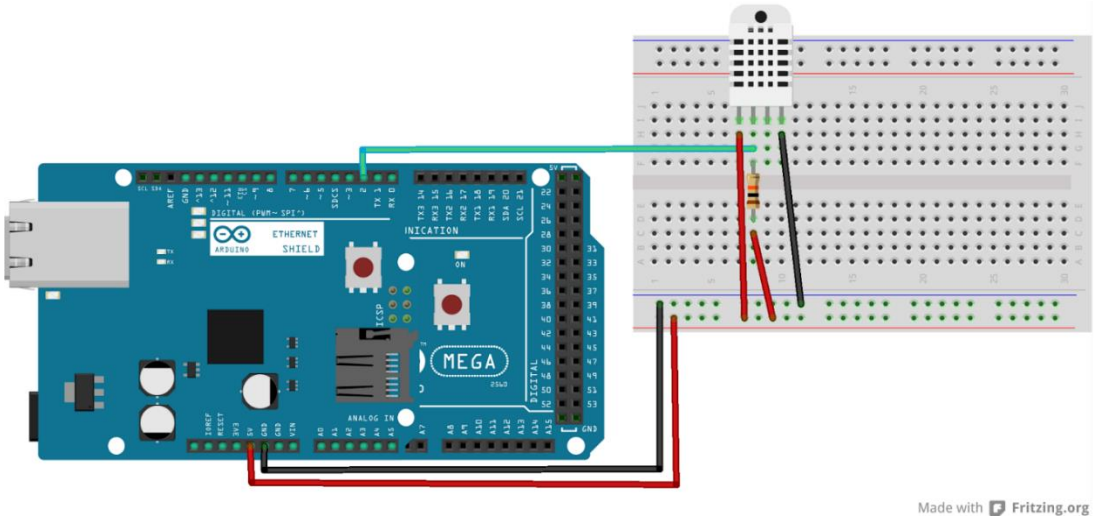

Figure 4.4: DHT22 sensor connections with arduino mega

4.1.4 LDR Light intensity sensor

An **LDR** is a component that has a (variable) resistance that changes with the light intensity that falls upon it. This allows them to be used in light sensing circuits.

The most common type of LDR has a resistance that reduces with an increase in the light intensity falling upon the device. The resistance of an LDR may typically have the following resistances:

Daylight = 5kΩ

Dark = 20000kΩ

The Lux is calculated using following equations:

The relationship between the resistance R_L and light intensity Lux for a typical LDR is

$$R_L = 500Lux \text{----------(4.1)}$$

If the LDR provided voltage Vin through a Rxk resistor, using the voltage divider rule, the output voltage of the LDR is

$$V_{out} = RLRL + RxVin \text{----------(4.2)}$$

Substituting RL from equation 1 into equation 2, we obtain the light intensity

$$Lux = 2500Vin - 500Rx \text{----------(4.3)}$$

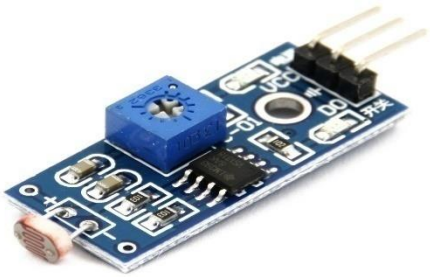

Figure 4.5: LDR sensor

Light sensor connect on breadboard with arduino.

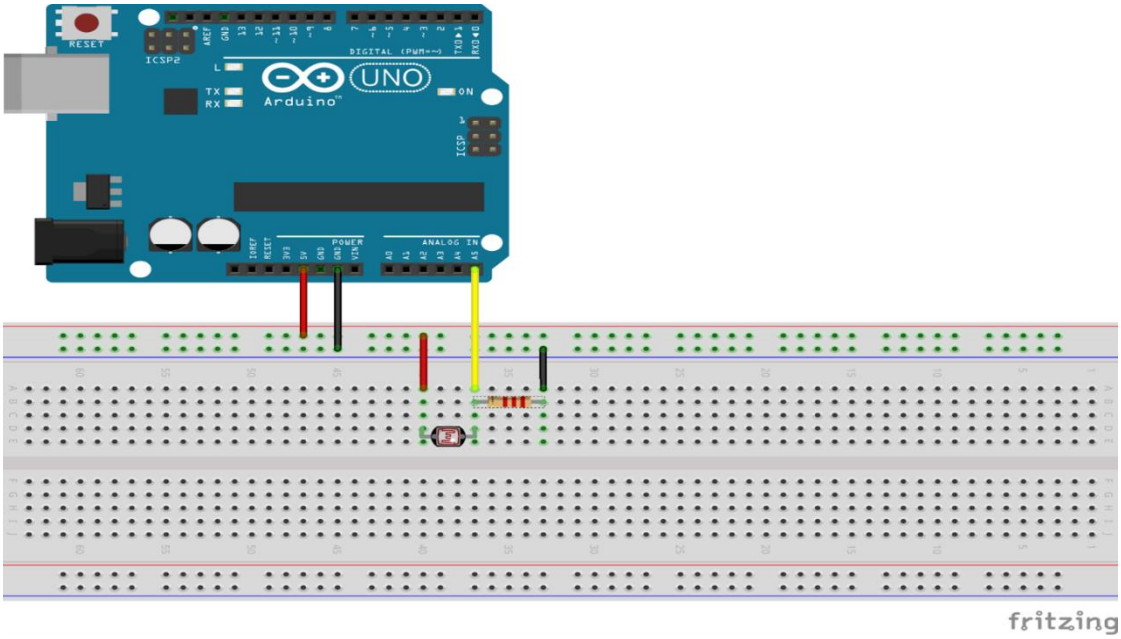

Figure 4.6: LDR sensor connectivity diagram

4.1.5 Moisture Sensor

Soil moisture sensors measure the volumetric water content in soil. Since the direct gravimetric measurement of free soil moisture requires removing, drying, and weighting of a sample, soil moisture sensors measure the volumetric water content indirectly by using some other property of the soil, such as electrical resistance, dielectric constant, or interaction with neutrons, as a proxy for the moisture content. The relation between the measured property and soil moisture must be calibrated and may vary depending on environmental factors such as soil type, temperature, or electric conductivity. Reflected

microwave radiation is affected by the soil moisture and is used for remote sensing in hydrology and agriculture. Portable probe instruments can be used by farmers or gardeners.

Generally sensor value varies from 0 to 1023 so we need to use map function to get the sensor value in percentage

map(sensorValue,0,1023,100,0);

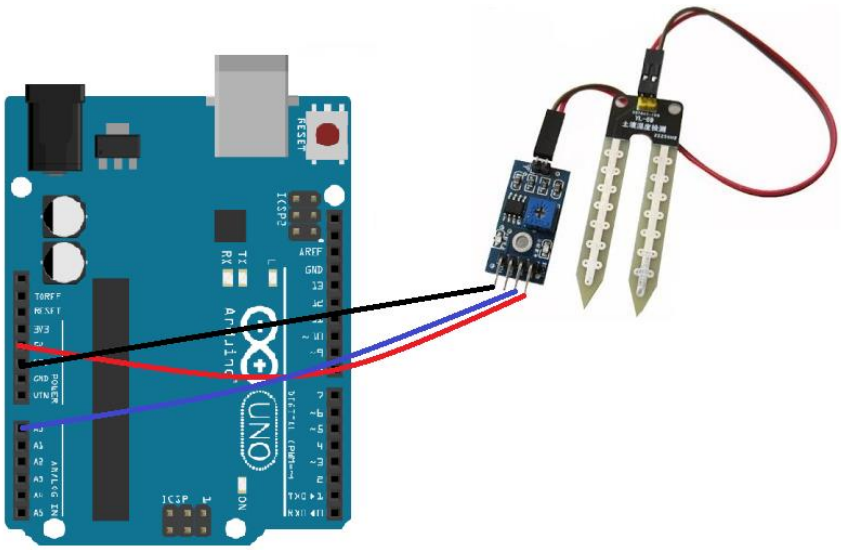

Figure 4.7: Moisture sensor connectivity diagram

4.1.6 LEDs

Basically, LEDs are just tiny light bulbs that fit easily into an electrical circuit.LEDs have polarity, which means they will only light up if you orient the legs properly. The long leg is typically positive, and should connect to a digital pin on the Arduino board. The short leg goes to GND.The bulb of the LED will also typically have a flat edge on this side.

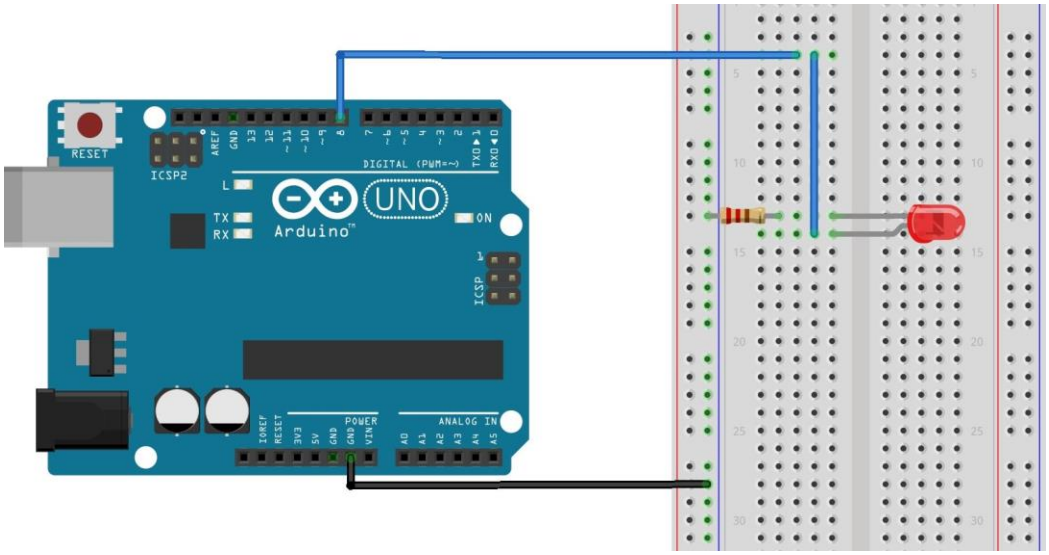

Figure 4.8: Connect LED arduino breadboard

4.2 Integration

Temperature,humidity, moisture and light sensors are connected to the Arduino MEGA via a breadboard. These sensors will take values from the environment then will send these values to the web server via internet for further processing.

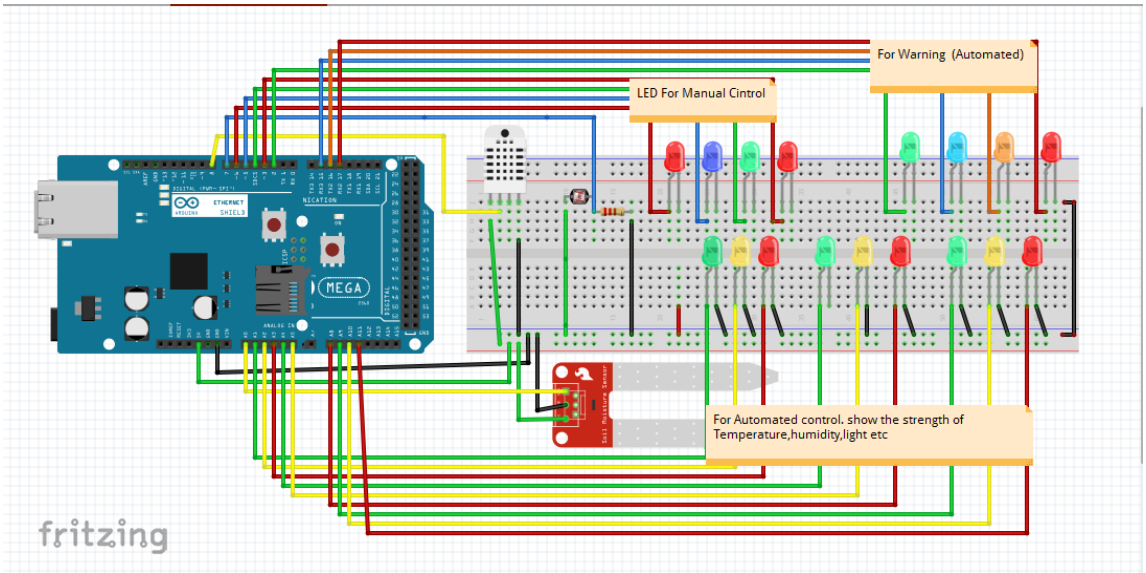

Figure 4.9**: Integration of full circuit**

4.3 Web server

We used apache HTTP web server for PHP and MySQL as database.

Apache: The Apache HTTP Server is free and open-source cross-platform web server software, released under the terms of *Apache License 2.0*. The Apache HTTP Server is cross-platform; as it can be used in both Windows and Linux operating systems.

MySQL: MySQL (pronounced "My S-Q-L" is an open-source relational database management system (RDBMS).

"SQL" the abbreviation for Structured Query Language.

Procedure:

Temperature and humidity sensors checks if there is any change in temperature and humidity within the warehouse or cold storage facility.moisture sensor is used for checking the moisture and it is very important to save product from 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 microcontroller. This microcontroller 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 cold storage as shown in flowchart below.

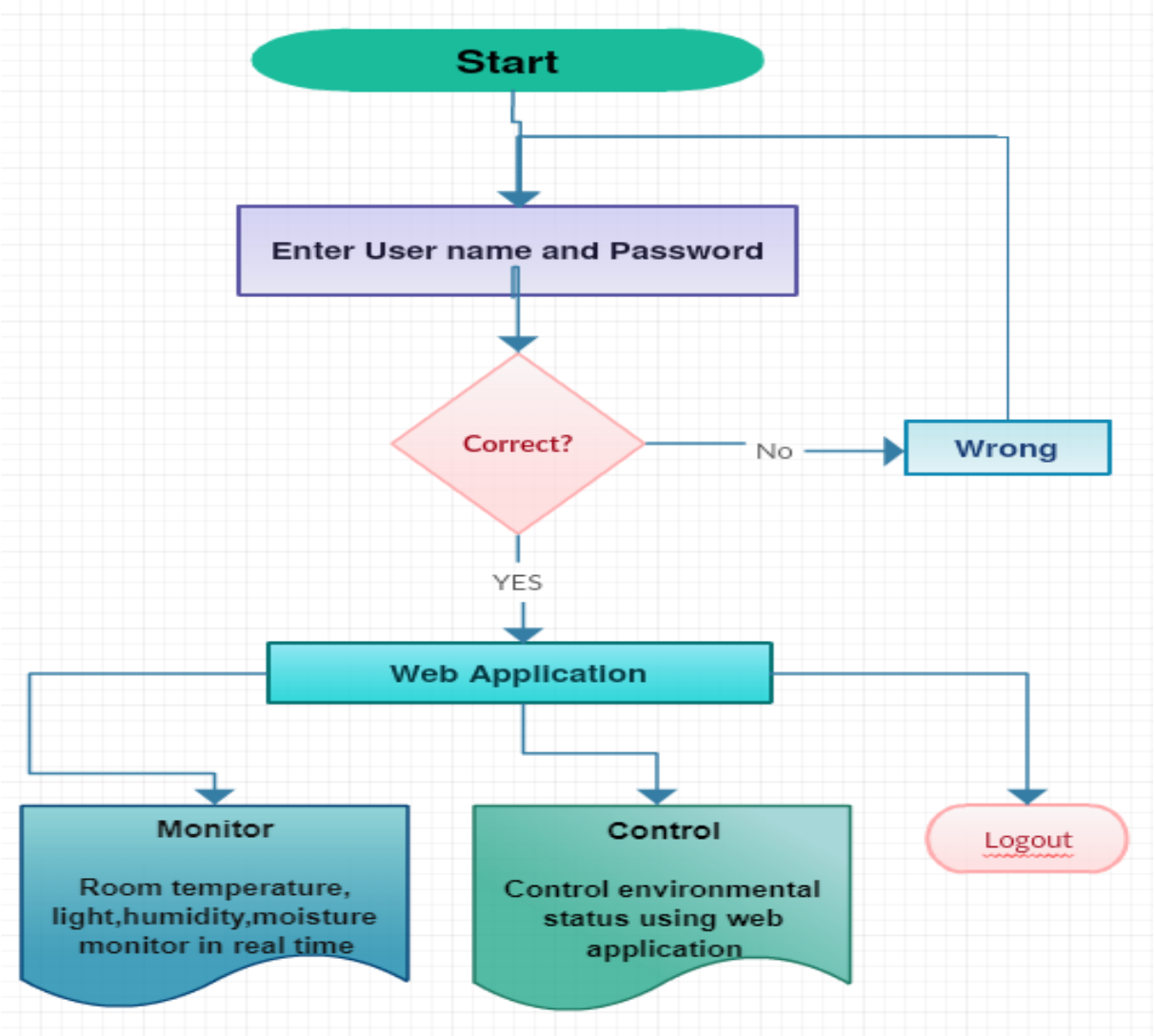

Figure 4.10: Monitor and Control flowchart

Database table name "sensorreading" is used for storing the the current value of these four sensor which is come from arduino via internet.

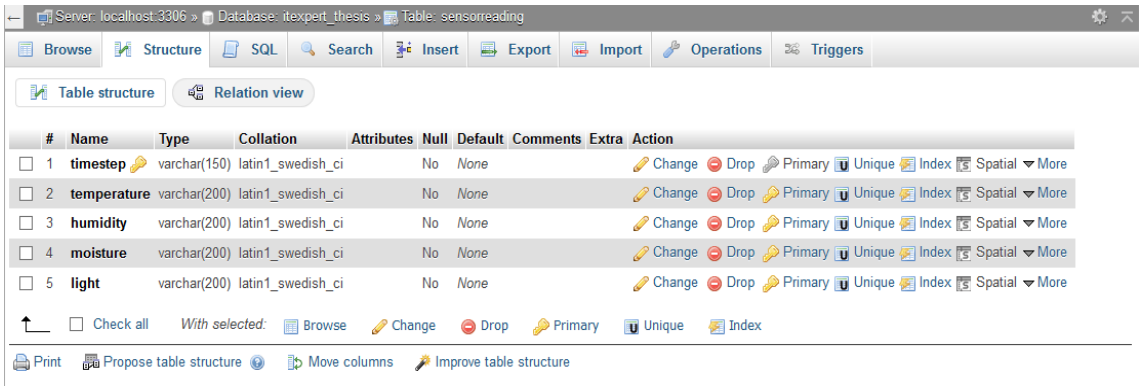

Figure 4.11: structure of table '*sensorreading*'

Some sensor value reading example

Server: localhost:3306 » Database: itexpert_thesis » Table: sensorreading

Browse | Structure | SQL | Search | Insert | Export | Import

+ Options

	timestep	temperature	humidity	moisture	light
Edit Copy Delete	2017-11-25 1:42:30 am	29.10	76.10	2.00	159.50
Edit Copy Delete	2017-11-25 1:42:23 am	28.80	97.40	2.00	159.50
Edit Copy Delete	2017-11-25 1:42:16 am	28.70	99.90	2.00	159.50
Edit Copy Delete	2017-11-25 1:42:09 am	28.30	99.90	1.00	159.50
Edit Copy Delete	2017-11-25 1:42:02 am	27.80	99.90	2.00	159.50
Edit Copy Delete	2017-11-25 1:41:56 am	27.30	97.70	2.00	159.50
Edit Copy Delete	2017-11-25 1:41:49 am	26.90	88.20	2.00	159.50
Edit Copy Delete	2017-11-25 1:41:42 am	26.80	58.70	2.00	159.50
Edit Copy Delete	2017-11-25 1:41:35 am	26.70	58.60	2.00	160.00
Edit Copy Delete	2017-11-25 1:41:28 am	26.80	58.70	2.00	159.00
Edit Copy Delete	2017-11-25 1:41:21 am	26.70	58.70	2.00	159.00
Edit Copy Delete	2017-11-25 1:41:14 am	26.70	58.80	2.00	160.50
Edit Copy Delete	2017-11-25 1:41:07 am	26.80	59.10	2.00	159.25
Edit Copy Delete	2017-11-25 1:41:00 am	26.70	59.00	2.00	166.00
Edit Copy Delete	2017-11-25 1:40:53 am	26.70	58.60	2.00	255.75
Edit Copy Delete	2017-11-25 1:40:46 am	26.70	58.50	1.00	188.25
Edit Copy Delete	2017-11-25 1:40:39 am	26.70	58.60	1.00	147.00
Edit Copy Delete	2017-11-25 1:40:32 am	26.70	58.60	1.00	147.25

Figure 4.12: Sample of sensor reading

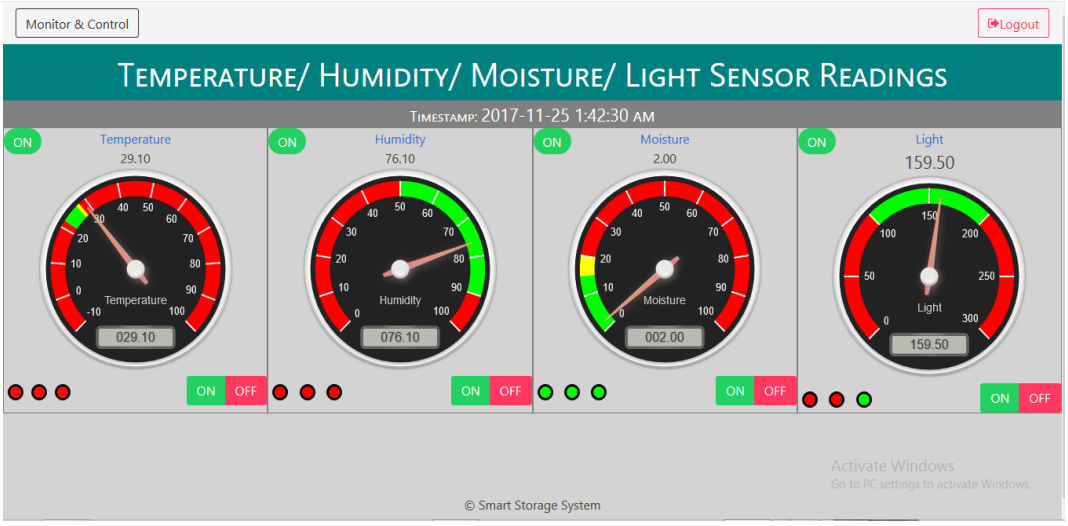

Figure 4.13: Real time monitoring

CHAPTER 5

CONTROL

The main purpose of the control system is to allow storage internal environment to be controlled remotely via web server as well as mobile application. Means if an unexpected situation is created then admin can control the situation via the internet using website and mobile application as well. The secondary purpose is to automate this process where everything like storage temperature, humidity, light is automatically maintained without human interaction. The automated control mode can be overridden by admin commands sent from the system admin via the website or mobile application.

The design components of the controlling system are broken down into three main sections: hardware and software

5.1 Hardware

The control system consists some LED that interface with the Arduino MEGA microcontroller. Due to some restrictions, in both cases manually and automated control we control LEDs instead of direct control AC, window, light or fan and all LEDs connect to the Arduino. Admin can control these LED from the web server and mobile application as well.

5.1.1 LED

For both, manual and automated control there are 13 LEDs has been used as an indicator. All of the LEDs are connected to Arduino. Four of them are used as an indicator of manual control from the web server or mobile application via internet. And rest or the LEDs are used for the purpose of automation

5.2 Software

The control system has two modes of operation automated and manual control. In manual control mode, the commands come from system admin from the web server or mobile application which are used to operate the four LED indicators. On the other hand,

automatic control modes use the four sensor reading. Based on these sensor reading it takes the decision and controls the internal environment (temperature, humidity, moisture and light intensity) of storage.

5.2.1 Manual control

While in the manual mode of control, the control system takes inputs from the system admin over the internet via 8 buttons. 2 buttons (ON/OFF) for control temperature, 2 for control humidity, 2 for control moisture and 2 for control light intensity in the internal environment of storage. These buttons are used to control the 4 indicators on the Arduino board.

When admin press on/off button from our website it sends an AJAX POST request to server and updates the corresponding value of our control table. And for the next get request from Ethernet shield it shows the updated control status to bread-board LED.

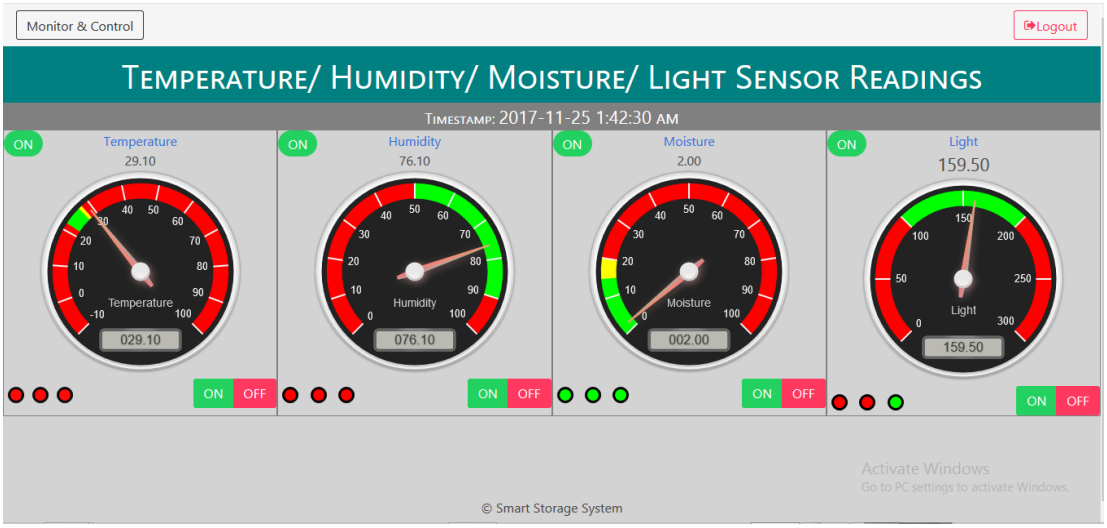

Figure 5.1: manual control from web server

Four LEDs on Arduino are used for as an indicator of four sensor. When user turn on or off any control from website/mobile app then led on Arduino will on/off for specific sensor. By these LEDs we indicates that it will turn on AC/Fan/Window/Light in real time.

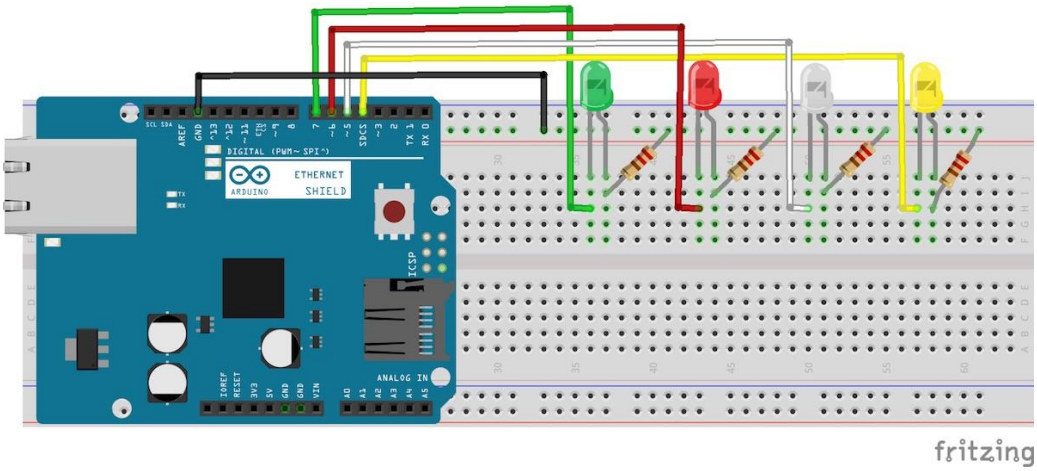

Figure 5.2: LEDs connectivity diagram

5.2.2 Automated control

In this feature overall environment will be controlled automatically in case of absence of any human expertise. This feature also makes less error than human. For this operation there were certain ranges and conditions have been identified and for every situation a specific action and warning is assigned. So if any of this situations occurs it would notify with warning and also take its associated action. And if none of the situation matches with the knowledge base it will also generate a warning that the situation need to handled immediately.

For automated control both web app and Arduino code analyze the sensor reading immediately to generate an action and warning according to sensor reading data.

5.2.2.1 Room temperature control

The automated control system for room temperature has been programmed for five temperature ranges. And based on this range it will take the decision whether it turn on AC or Heat inside the room. Also based on this range it will do alarm and notify the user.

Table 5.2.2.1: Room temperature control conditions

Temperature Range	Control			
Device	AC	Window/Fan	Heat	Warning
<2	OFF	OFF	ON	YES
2-below 5	ON	ON	OFF	NO
5- below 10	ON	OFF	OFF	NO
10- below 15	ON	OFF	OFF	NO
15+	ON	ON	OFF	YES

5.2.2.2 Room humidity control

The automated control system for room humidity has been programmed for five humidity ranges. And based on this range it will take the decision whether it turn on AC or Heat inside the room. Also based on this range it will do alarm and notify the user.

Table 5.2.2.2: Room humidity control conditions

Humidity Range	Control			
Device	AC	Fan	Heat	Warning
<50	OFF	OFF	ON	YES
50-below 60	OFF	ON	ON	NO
60- below 80	ON	OFF	OFF	NO
80- below 90	ON	ON	OFF	NO
90+	OFF	OFF	ON	YES

5.2.2.3 Room Lighting

A proper lighting on cold storage is very important not only for the worker but also it will save agricultural product from attack of bacteria and other bacteriophage as well.Few products need specific lighting facility in order to maintain their quality.The automated control system for room lighting has been programmed for four light ranges. And based on this range it will take the decision whether it turn on or off light inside the room. Also based on this range it will do alarm and notify the user.

Table 5.2.2.1: Room lighting control conditions

Humidity Range	Control			
Status	Light-1	Light-2	Light-n	Warning
<100	ON	OFF	OFF	YES
100-below 150	ON	ON	OFF	NO
150- below 200	ON	ON	OFF	NO
200+	ON	ON	ON	YES

CHAPTER 6

RESULT AND ANALYSIS

6.1 Experimental Scenarios

In our test scenario we used generated data used for only temperature to indicate that our system performs accordingly.
In test scenario there were conditions for temperature

1. Three red blinking - temperature <10 and >25
2. One red - temperature is >=12 and <15
3. Two red - temperature >=15 and <20
4. Three red - temperature >=20 and <25
5. Three green - temperature within 10-11

In this scenario warning system was tested for temperature whether test data was confined within 11℃ - 18℃
In the first scenario temperature is 17.85 and according to prefixed condition there would be two red circles and the warning sign shows as expected

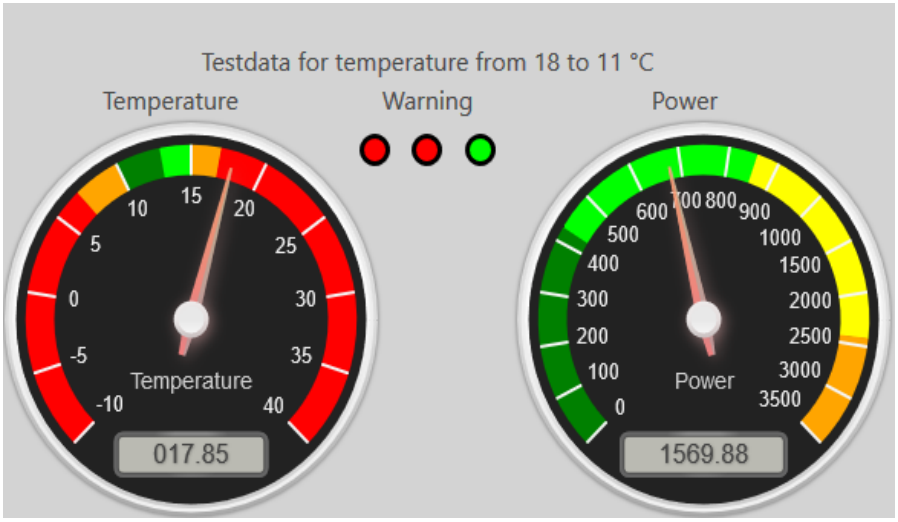

Figure 6.1: Experiment output for scenario 1

In the second scenario temperature is at 13.83 degrees and there are one red warning circle.

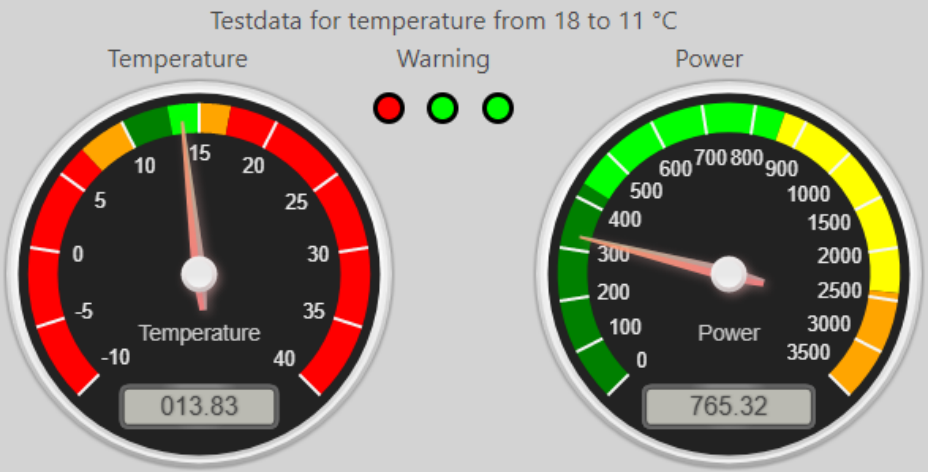

Figure 6.2 Experiment output for scenario 2

The power consumption scale to the right indicates that when temperature is decreasing the cooling units consuming less electricity because the temperature is coming to optimum condition in our test case its 10℃.

6.2 Summary

Test result were successful and satisfied approximate output

CHAPTER 7

CONCLUSION

7.1 Overall Conclusion

The IoT based Automated Smart Storage management system is successfully designed and implemented using MySQL, CodeIgniter and APIs that can be considered as an IoT based framework. This system is capable of reading, storing data using sensors and also generate some actions according to data. Storing data in database enables for future research and also determine any abnormality in future which might be avoided to prevent future discomfort.

Web application with a user friendly interface makes it easier to understand and requires no special skills to operate the system. Due to lack of data required for this research to be more effective and accurate but we managed to build a working system which was tested on our normal environment and succeeded according to our created environment.

7.2 Future Works

Our implemented system is not constructed as our whole plan due to lack of data and time. In the future, this system will be improved and more accurate.

It will also send warning text message using GSM feature to authority in case of emergency.

A better automated system will be implemented which can learn from monitoring human interaction with the system. Monitoring system can be implemented with **artificial intelligence.** Also it may be used as not only agricultural purposes also in every household to maintain a better environment by maintaining temperature, humidity and other facts which makes the residents feel more comfortable. That means system also can be used as **smart home**

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