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Automated Irrigation System (AIS) In North-Western Nigeria.

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Abstract: *The fact that in the whole world both objects and humans can interact with each on the internet has led to the advent of Internet of Things concept. The application of Wireless Sensor Networks (WSN) and Radio Frequency Identification (RFID) makes the interaction between man and objects very easy. Agriculture employs these technologies to evolve Smart Agriculture which happens to be a household phrase nowadays. This paper designed an Automated Irrigation System in chikun local government council of Kaduna state, Nigeria that will enhance agriculture through the use sensors in the field. The objectives of this study is to design an Automated Irrigation System that conserves water usage for farmers in northern Nigeria where there is a long dry season. The novelty of this research is comparing the time it takes to start a water pump using Local Area Network as opposed to a GSM module.After a hypothesis, LAN is proposed as best way to control the Automated Irrigation System (AIS) for Nigerian farmers after a comparatively analysis of the mean time taken for each method. The results were gathered over three (3) days to get an accurate level of consistency. A Unified Modelling Language (UML), flowchart and use case diagrams show explicit what we want to achieve. The AIS was deployed with the aid of Arduino Uno Ethernet shield and GSM module such that the farm owner could view farm parameters from his mobile phone and from a PC browser.*

Keywords: *Internet of Things, Wireless Sensor Networks, Zigbee, Smart Agriculture, Arduino, Radio Frequency Identification, Automated Irrigation System*

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I. INTRODUCTION

Internet of Things is the networking of different physical objects in order for them to exchange information and share resources (Monica et al., 2017). IoT technology is usually deployed and founded on the five (5) essential sub-technologies, which are Radio Frequency Identification (RFID), Wireless Sensor Networks (WSN), middleware, cloud computing and the IoT application software (In and Kyoochun, 2015). The IoT is a technological revolution from the present internet which connects only computers to an internet that connects humans and non-living aspect of nature. According to Somayya et al. (2015), every object is going to be tagged, identified, monitored and controlled. The need to aid farmers in Nigeria with an automated method of watering farm crops has become pertinent. The Automated Irrigation System (AIS) in use today all over the world is subset of the Internet of Things. In this light the inability of north-western Nigeria to have rainfall for seven (7) months in a year means that during the dry season irrigation farming is employed (Katung, 2007).

II. RELATED WORK IN AUTOMATED IRRIGATION SYSTEMS

Monica et al. (2017) developed an irrigation system that was able to supply the right amount of water to plants based light, moisture and temperature readings sent from the sensors on the farm which allows the farm to see all these information on his mobile application. The aim of their study was the inclusion of a luminosity sensor which helped record the amount of sunlight deposited on plant leaves. In the event that the intensity of light was low it could provide some artificial light. In addition is the use of a Sparkfun software to store the data captured from the sensors and sending them to a cloud. Lastly doing a comparative analysis of the water consumption of their proposed system as compared to those already existent. Figure 1 is the implemented project of the entire irrigation system setup while figure 2 is depiction of the results returned by the mobile application from the sensors.

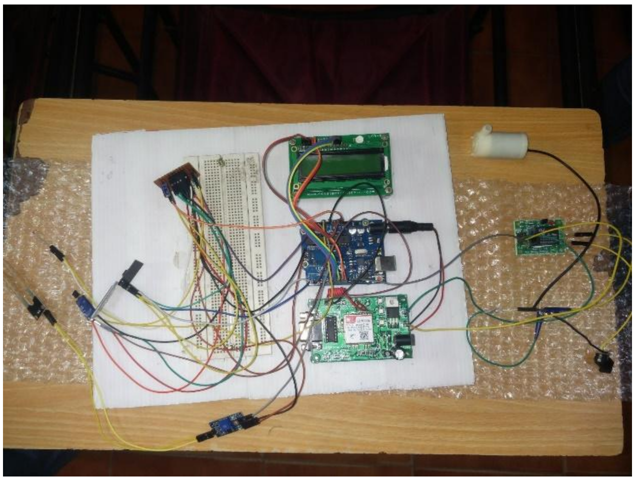

Fig.1. Project Implementation (Monica et al., 2017). **Fig.2**. Mobile Application (Monica et al., 2017).

Nandhini et al. (2017) proposed an arduino based irrigation system which would help in water conservation and detection of intruders such as pests (birds). The sensed parameters are recorded by the sensors and displayed through an LCD. The condition of the farm and parameters will be sent to the owner of the farm via SMS and at the same time updated on a web page. The intrusion is detected through the use of a PIR sensor which uses infrared to sense heat from a passing object within a radius of 10 meters. All these sensors are connected to the input pins of the arduino hardware which then coordinates the activation of the water pump relay. In figure 3 the block diagram for the proposed system is seen.

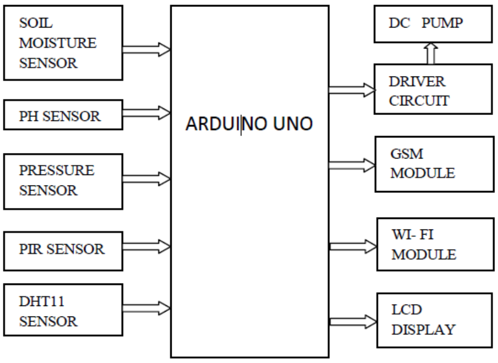

Fig.3. Block Diagram of the Proposed System (Nandhini et al., 2017)

In Bishnu et al. (2017) an automatic irrigation system was designed based on ATMEGA328 microcontroller. The microcontroller sends interrupts signals to the motor to start the water pump. A change in temperature and humidity of the farm from the sensors triggers a motor and an alarm when the pump is turned on. The sensors sense the parameters of the farm and sends them to the farmer through the GSM module thus he/she gets to know the status of the farm. When the moisture content threshold is reached the pump turns off itself. Figures 4 and 5 represents the block diagram and PCB layout of the system.

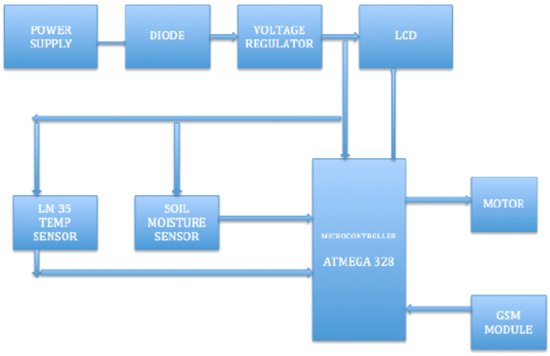

Fig.4. Block Diagram of AIS (Bishnu et al. (2017).

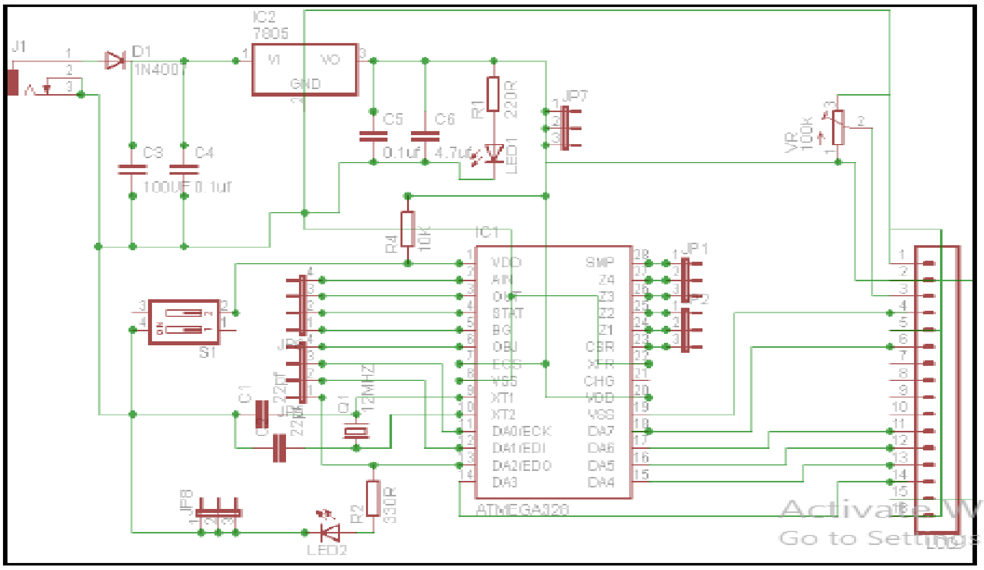

Fig.5.PCB Layout of the AIS (Bishnu et al., 2017).

Ateeq et al. (2017) proposed an automated irrigation system that relied on solar energy to power the entire setup. The system included a moisture sensor, humididty and temperature sensor. When the water leevel is low the system automaticaly triggers the motors to run the pump and immediately swich it off when the required threshold is reached. Anytime the motor starts or stops, the fam owner gets an SMS on his phone about the status of the farm. The hardware and software used in the project include PC with adruino software,soil moisture sensor, tempoerature sensor, LCD 20*4 display, DC motors and DC fan. A setup of the system is seen in figure 6.

Fig.6. Setup of the System (Ateeq et al., 2017).

Yuthika et al. (2017) digressed from the previous researches to develop an IoT based automated irrigation system such that farm data is gathered and reported with the aid of KNN (K- Nearest Neighbor) classification algorithm. The algorithm works by analyzing the data from the sensors and predicts whether the pumps needs to be triggered or not. KNN is a machine learning technique. The IoT mechanism gathers the information sent from the temperature and humidity sensor and transmits them to control unit that is based on Raspberry Pi. The Raspberry Pi holds the KNN algorithm. In this system uses intelligence because it gathers different data sets for different soil moisture level and trains the data set to know when to trigger the water pumps. Figure 7 shows the setup of their system.

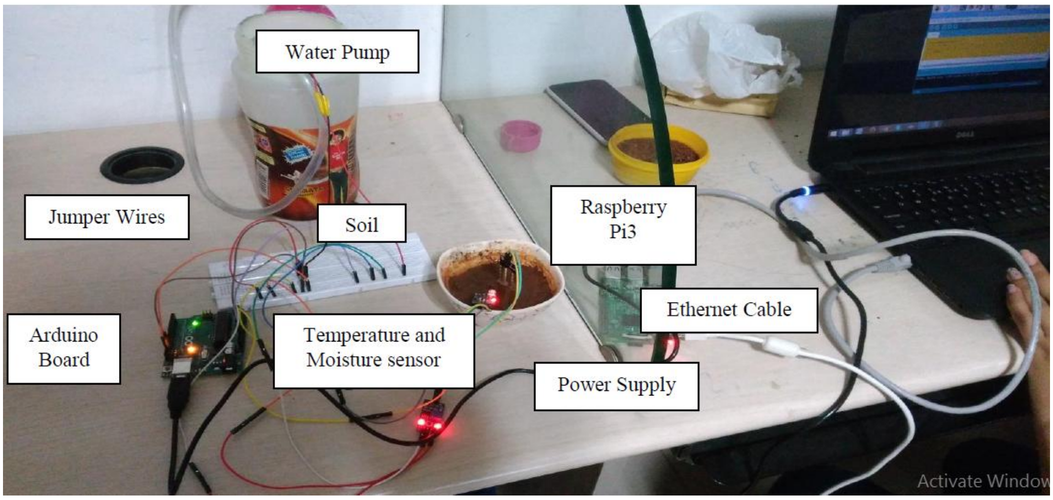

Fig.7.AIS based on KNN Classification Algorithm (Yuthika et al., 2017).

III. Proposed System

3.1 Method and Materials

The method used in this research was experimentation because it allowed us to see results and make comparisons. In Sonawane et al. (2015) an AIS was created such that it used a General Packet Radio Service (GPRS) to control water pumps for irrigation. In our research we recreated the scenario done in Sowane et al. (2015) using a GSM modem and then compared the time taken by the GSM modem to power ON or OFF with that of our Local Area Network. The LAN was achieved with the aid of Arduino Uno hardware which is a member of the Arduino family. The drive behind this research was to enable Nigerian farmers to achieve the level of development of their counterparts in Asia. This novel design used Wireless Sensor Network such that the sensors from the farm sent their values wirelessly via a Local Area Network (LAN) to a Personal Computer (PC) at the farm site. Based on the data conveyed by the sensors the farm owner sits on his PC and controls the water pump. If the sensor data says that the soil on the farm is dry and the temperature is high then the user can activate the pump by sending a command from his computer browser wirelessly through the router to thepump at the farm site. Figure 8 shows the entire system setup in the field.

Fig.8.The Connected Setup in the Farm

The hardware used in the project include DHT11 Humidity sensor, adruino Ethernet shield, GSM modem, PCB board, peripheral Interface Controller (PIC18F4520) Microcontroller, LCD and water level sensor.

3.2 Design Description

The design of the system prototype aimed to apply wireless sensor networks that will capture data from the surrounding environment of the farm. These sesnors include DHT 11 which captures both temperature and humidity of the vicinity. All of these are connected to a PIC microcontroller. As explained above, this prototype is going to use the sensors to collect certain environmental parameters and relay these information to the farm user sitting on a console to know what happening in the farm. This system will relay this information via the use of a Local Area Network (LAN) and a GSM module. The automated irrigation system was made up of a microcontroller and three sensors (water level, temperature and humidity). These sensors transmitted the data gotten from the farm wirelessly to the micro-controller that has been programmed in Micro C language to analyze the data and respond appropriately. This micro-controller was then connected to an Ethernet module which in this case is the Arduino Ethernet shield that interfaces with a LAN to pass the data of the sensors to the web-browser. Figures 9 and 10 respectively shows the design of the system.

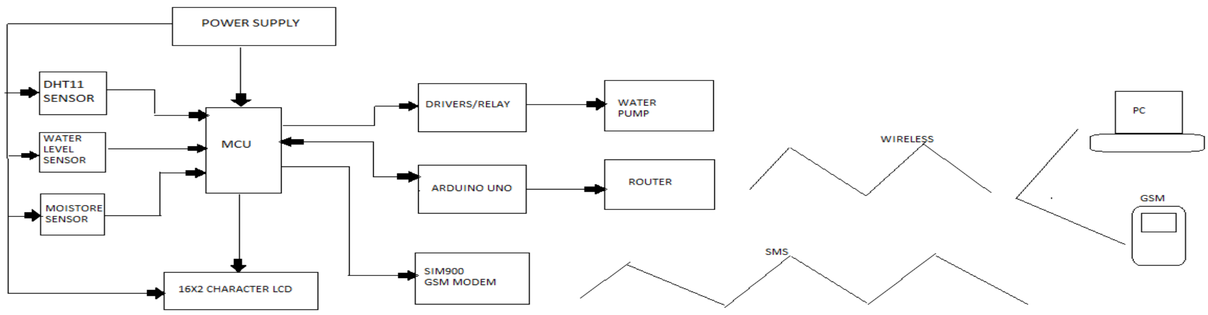

Fig.9. Block Diagram of Our Proposed System.

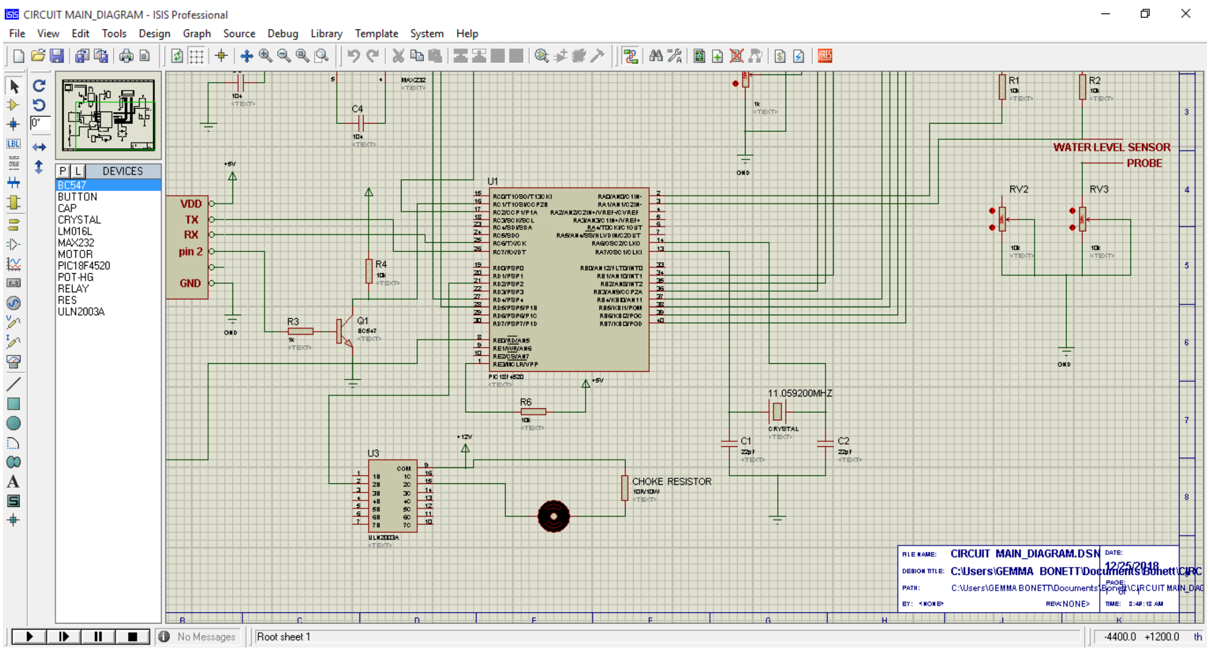

Fig.10. Circuit Diagram of Our Proposed System.

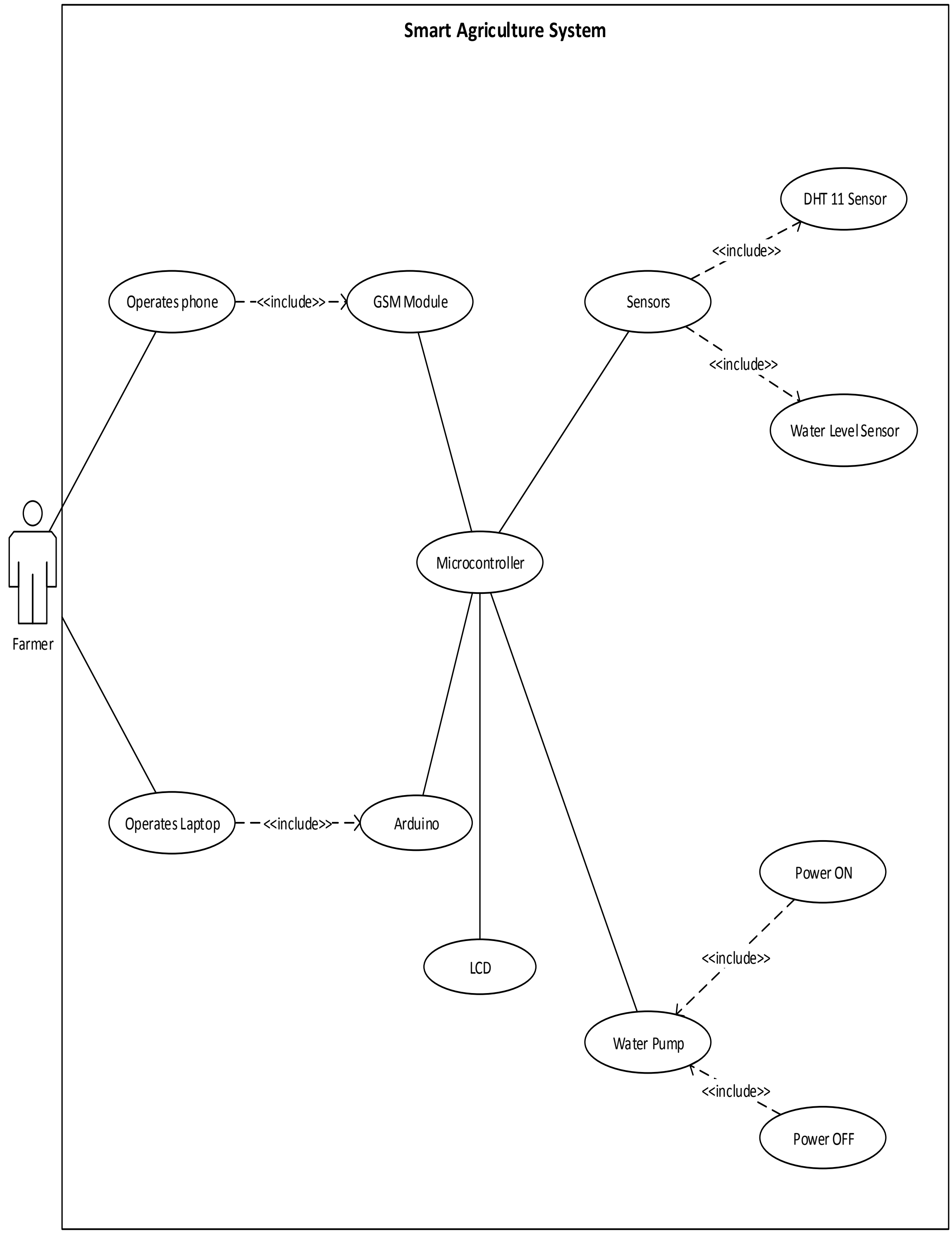

Fig.11. Use Case Diagram for Smart Irrigation System.

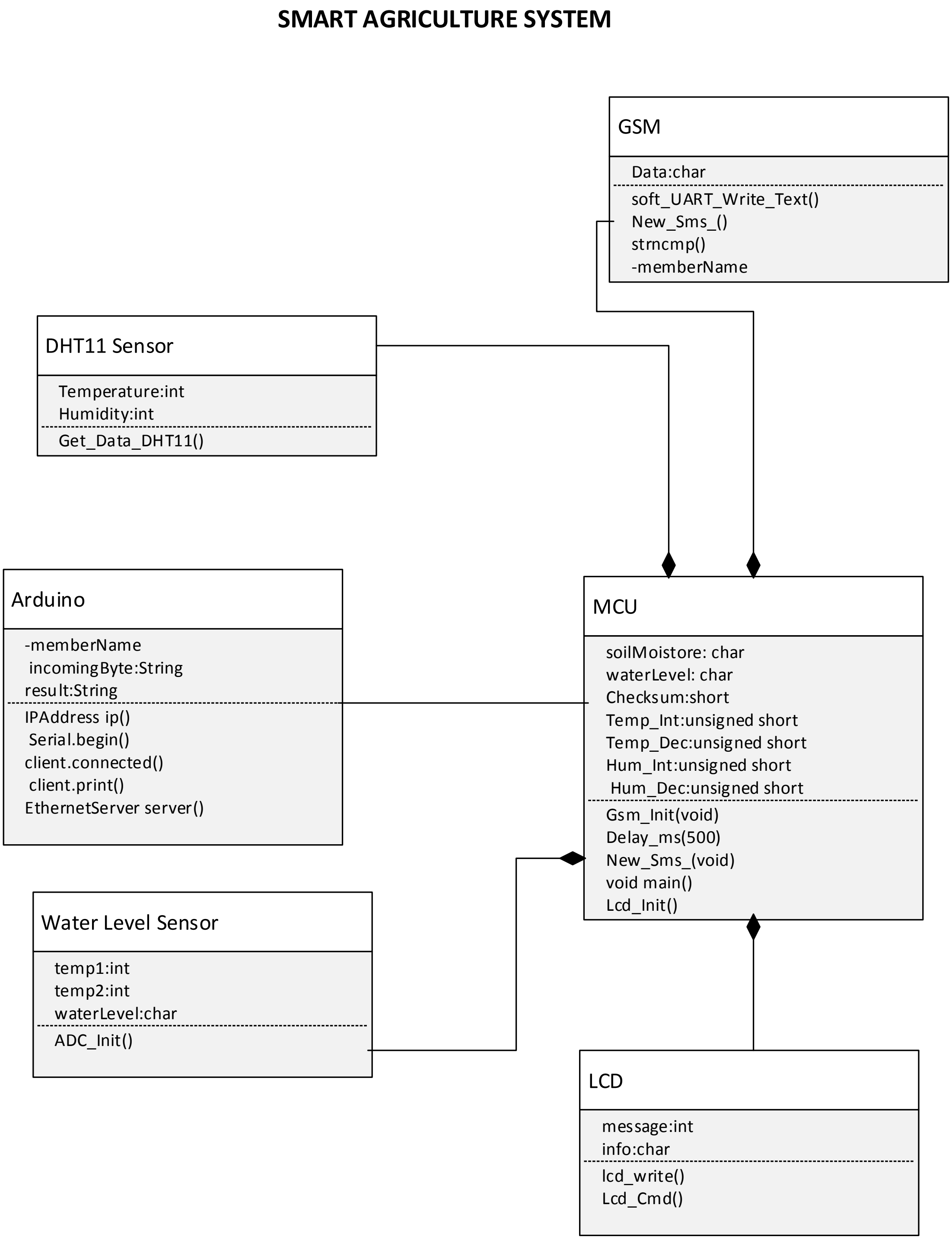

Fig.12. Class Diagram for Smart Irrigation System.

IV. DATA ANALYSIS AND TESTING.

A comparison of the time intervals it took to switch ON and switch OFF the water pump was carried out using a stop watch and analyzed using Paired-T test. A Paired-T test is used to compare two independent variables (which in this case is the LAN and GSM). The experiment was performed using the prototype to record temperature and humidity results as well as the switch ON and switch OFF time for the LAN and GSM. For each day there are four tables, the first table shows the sensor reading for the different times of the day (morning and afternoon), while the second table shows the time taken to start and stop the water pump on the farm. The paired-T test results are shown in the SPSS tables after each respective time taken table. The main area of interest is the time taken to operate the pump either through the LAN or through the GSM module. A Paired-T test was used to compare the two independent variables (LAN time and GSM time) in contention.

4.1 Testing and Integration

The result of the hypothesis testing is shown below:
H_0stated as: The average time taken to ON and OFF the pump for the LAN (C1) is the same as average time taken by the GSM (C2) module while the H_1as: The average time taken to ON and OFF the pump for the LAN (C1) is not the same as average time taken by the GSM (C2) module. While $\alpha = 0.05$, the null hypothesis H_0 is rejected and the alternative hypothesis H_1 is accepted at $p < 0.05$ as shown in Tables 3, 4, 7, 8, 11, 12, 15, 16, 19, 20, 23 and 24.
Note: Using Paired T Test
H_0: C1 = C2
H_1: C1 > C2
WhereC1 = LAN MODULE, C2= GSM MODULE.

Table 1 to 12 shows the sensor readings and time taken to switch ON and OFF the pump for day 1 (first day). The number of times the experiment was performed is five (5), which is represented by the instances. Hence for day 1 it was observed that amount of time taken at both times of the day taken to operate the pump for LAN was smaller as compared to that of the GSM, and hence the GSM had more significance. Therefore because the GSM took more time hence its mean and standard deviation will be more than that of the LAN.

Table 1. Day 1 Time Taken: Morning- 7.45 AM

Device Mode	1st Instance(Time Taken to Switch OFF & ON module in seconds)	2nd Instance(Time Taken to Switch OFF & ON module in seconds)	3rd Instance(Time Taken to Switch OFF & ON module in seconds)	4th Instance(Time Taken to Switch OFF & ON module in seconds)	5th Instance(Time Taken to Switch OFF & ON module in seconds)	Average Time taken to Switch OFF & ON module in seconds.
LAN MODULE	1	2	1	1	1	1.2
GSM MODULE	82	187.5	90	150.5	100	122

Table 2. Day 1-Morning(Paired Samples Statistics)

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	LANMODULE	1.20	5	.447	.200
	GSM_MODULE	122.000	5	45.3059	20.2614

Table 3. Day 1-Morning(Paired Samples Test)

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Lanmodule - Gsm_module	-120.8000	44.9452	20.1001	-176.6069	-64.9931	-6.010	4	.004

Table 4. Day 1 Time Taken: Afternoon- 1.00 PM

Device Mode	1st Instance(Time Taken to Switch OFF & ON module in seconds)	2nd Instance(Time Taken to Switch OFF & ON module in seconds)	3rd Instance(Time Taken to Switch OFF & ON module in seconds)	4th Instance(Time Taken to Switch OFF & ON module in seconds)	5th Instance(Time Taken to Switch OFF & ON module in seconds)	Average Time taken to Switch OFF & ON module in seconds.
LAN MODULE	1	1	1	1	1	1
GSM MODULE	2.5	5	2.5	2	2.5	2.9

Table 5. Day 1-Afternoon (Paired Samples Statistics)

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Lan_module	1.00	5	.000	.000
	Gsm_module	2.900	5	1.1937	.5339

Table 6. Day 1-Afternoon(Paired Samples Test)

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1 Lan_module - Gsm_module	-1.9000	1.1937	.5339	-3.3822	-.4178	-3.559	4	.024

Table 7 to 16 shows the reading for the second day (Day 2). It was observed for the second day that the GSM part of the experiment still takes a longer time as compared to the LAN part. Hence the mean and standard deviation for the GSM is greater than that of the LAN, showing that the LAN is better than the GSM.

Table 7. Day 2 Time Taken: Morning- 7.45 AM

Device Mode	1st Instance(Time Taken to Switch OFF & ON module in seconds)	2nd Instance(Time Taken to Switch OFF & ON module in seconds)	3rd Instance(Time Taken to Switch OFF & ON module in seconds)	4th Instance(Time Taken to Switch OFF & ON module in seconds)	5th Instance(Time Taken to Switch OFF & ON module in seconds)	Average Time taken to Switch OFF & ON module in seconds.
LAN MODULE	1.5	1	1	1	1	1.1
GSM MODULE	48.5	41	40.5	47.5	152.5	66

Table 8. Day 2-Morning **(Paired Samples Statistics)**

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Lan_module	1.100	5	.2236	.1000
	Gsm_module	66.000	5	48.4923	21.6864

Table 9. Day 2-Morning**(**Paired Samples Test)

	Paired Differences					T	df	Sig. (2-tailed)
				95% Confideence Interval of the Difference				
	mean	Std. deviation	Std. error mean	Lower	Upper			
Pair 1 LAN module- GSM Module	-64.90000	48.5379	21.7068	-125.1677	-4.6323	-2.990	4	.040

Table 10. Day 2 Time Taken: Afternoon- 12.33 PM

Device Mode	1st Instance(Time Taken to Switch OFF & ON module in seconds)	2nd Instance(Time Taken to Switch OFF & ON module in seconds)	3rd Instance(Time Taken to Switch OFF & ON module in seconds)	4th Instance(Time Taken to Switch OFF & ON module in seconds)	5th Instance(Time Taken to Switch OFF & ON module in seconds)	Average Time taken to Switch OFF & ON module in seconds.
LAN MODULE	1	1	1	1	1	1
GSM MODULE	4	4	4	4.5	4.5	4.2

Table 11. Day 2-Afternoon(Paired Samples Statistics)

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Lan_module	1.000	5	.0000	.0000
	Gsm_module	4.200	5	.2739	.1225

Table 12. Day 2-Afternoon(Paired Samples Test)

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1 Lan_module - Gsm_module	-3.2000	.2739	.1225	-3.5400	-2.8600	-26.128	4	.000

Table 13 to 18 shows the reading for the third day (Day 3). It was observed for the third day, the GSM part of the experiment still takes a longer time as compared to the LAN part. Hence the mean and standard deviation for the GSM is greater than that of the LAN, showing that the LAN is better in terms of performance than the GSM.

Table 13. Day 3 Time Taken: Morning- 10.20 AM

Device Mode	1st Instance(Time Taken to Switch OFF & ON module in seconds)	2nd Instance(Time Taken to Switch OFF & ON module in seconds)	3rd Instance(Time Taken to Switch OFF & ON module in seconds)	4th Instance(Time Taken to Switch OFF & ON module in seconds)	5th Instance(Time Taken to Switch OFF & ON module in seconds)	Average Time taken to Switch OFF & ON module in seconds.
LAN MODULE	1	1	1	1	1	1
GSM MODULE	5	4	4.5	4.5	4.5	4.5

Table 14. Day 3-Morning(Paired Samples Statistics)

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Lan_module	1.000	5	.0000	.0000
	Gsm_module	4.500	5	.3536	.1581

Table 15. Day 3-Morning(Paired Samples Test)

		Paired Differences					t	df	Sig. (2-tailed)
		Mean(sec)	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference: Lower	Upper			
Pair 1	Lan_module - Gsm_module	-3.5000	.3536	.1581	-3.9390	-3.0610	-22.136	4	.000

Table 16. Day 3 Time Taken: Afternoon- 1.13 PM

Device Mode	1st Instance(Time Taken to Switch OFF & ON module in seconds)	2nd Instance(Time Taken to Switch OFF & ON module in seconds)	3rd Instance(Time Taken to Switch OFF & ON module in seconds)	4th Instance(Time Taken to Switch OFF & ON module in seconds)	5th Instance(Time Taken to Switch OFF & ON module in seconds)	Average Time taken to Switch OFF & ON module in seconds.
LAN MODULE	2	1	2	2	2	1.8
GSM MODULE	4	7.5	9	9.5	9	7.8

Table 17. Day 3-Afternoon(Paired Samples Statistics)

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Lan_module	1.800	5	.4472	.2000
	Gsm_module	7.800	5	2.2528	1.0075

Table 18. Day 3-Afternoon(Paired Samples Test)

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference: Lower	Upper			
Pair 1	Lan_module - Gsm_module	-6.0000	2.2638	1.0124	-8.8109	-3.1891	-5.926	4	.004

4.2 Performance Evaluation

The performance evaluation of the previous system (GSM) and the new system (LAN) was performed with the aid of 3-D column charts that show the difference between the two systems. Figures 13 to 21 depict the performance in terms of time taken by the different systems to power ON and power OFF a water pump.

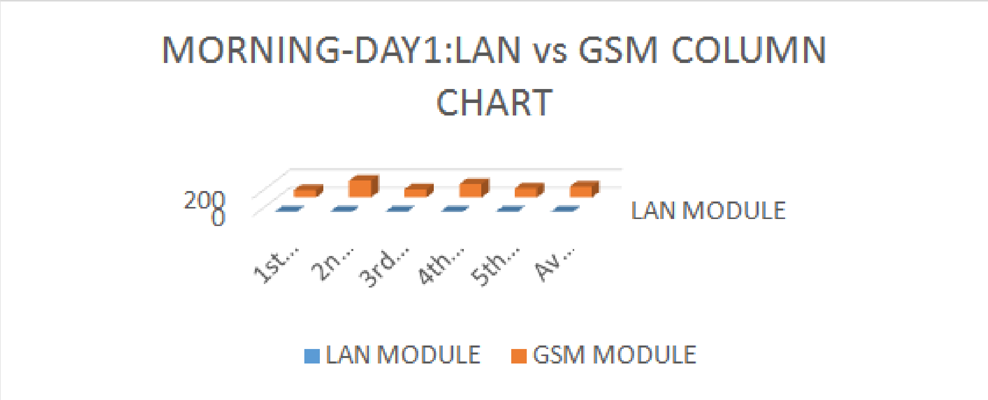

Fig.13. Column Chart for Morning Day 1

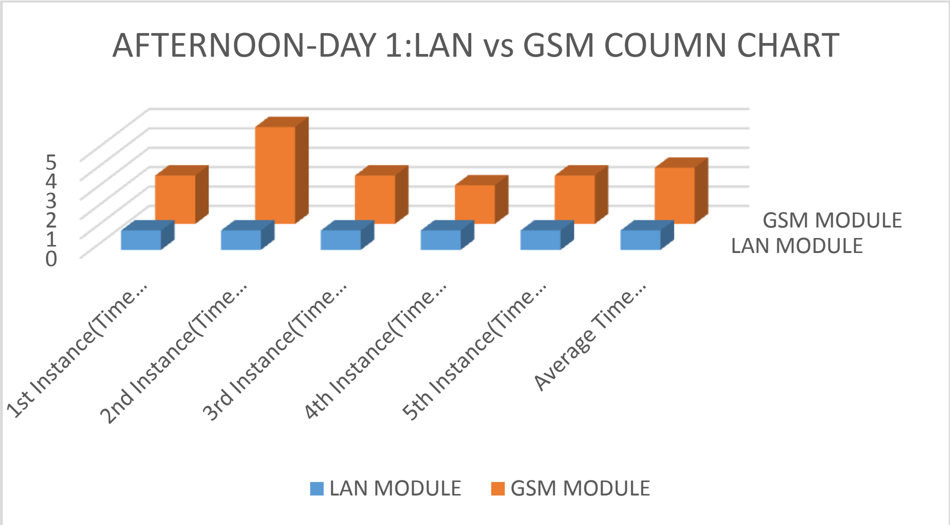

Fig.14. Figure 18: Column Chart for Afternoon Day 1

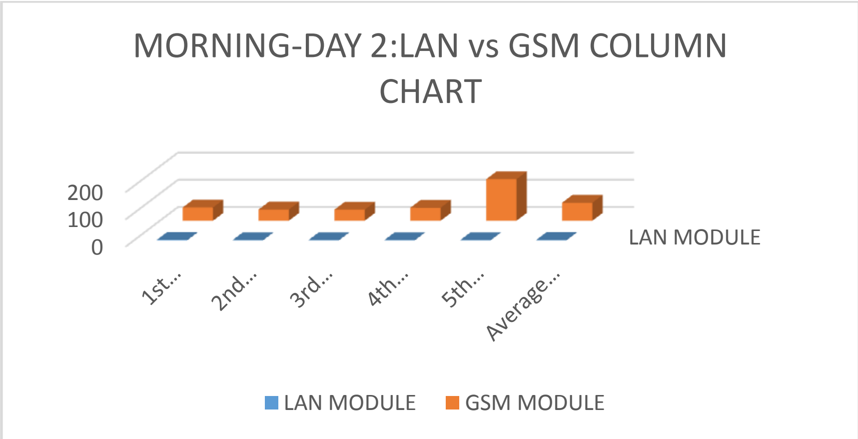

Fig.15. Column Chart for Morning Day 2

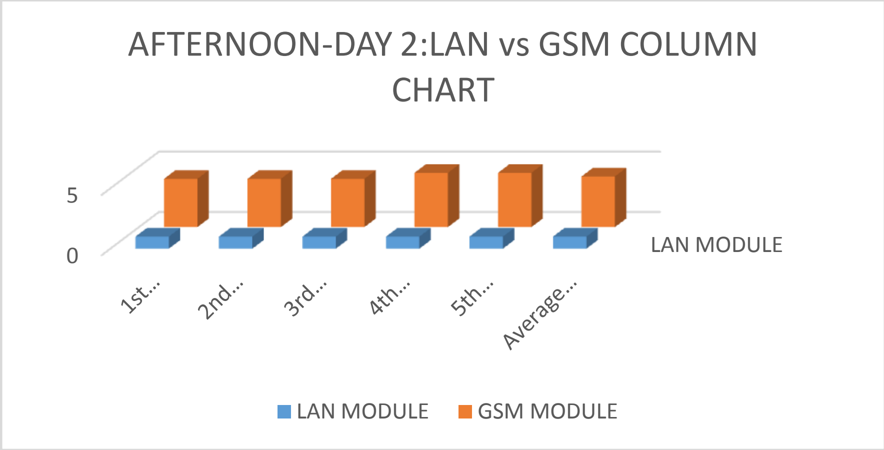

Fig.18. Column Chart for Afternoon Day 2

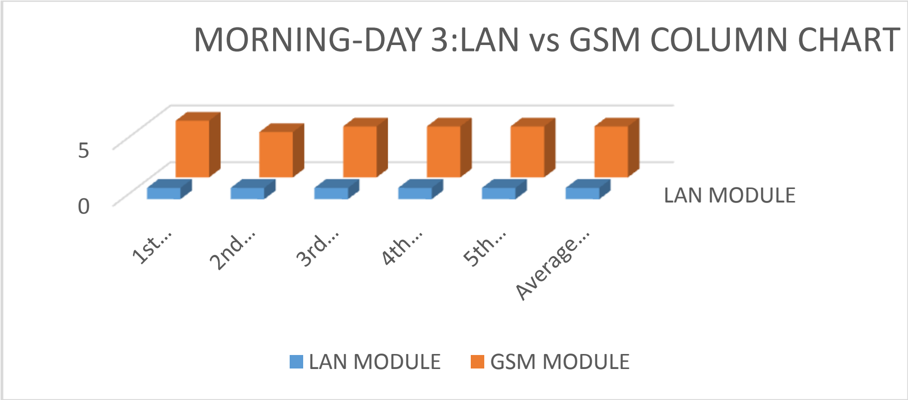

Fig.19. Column Chart for Morning Day 3

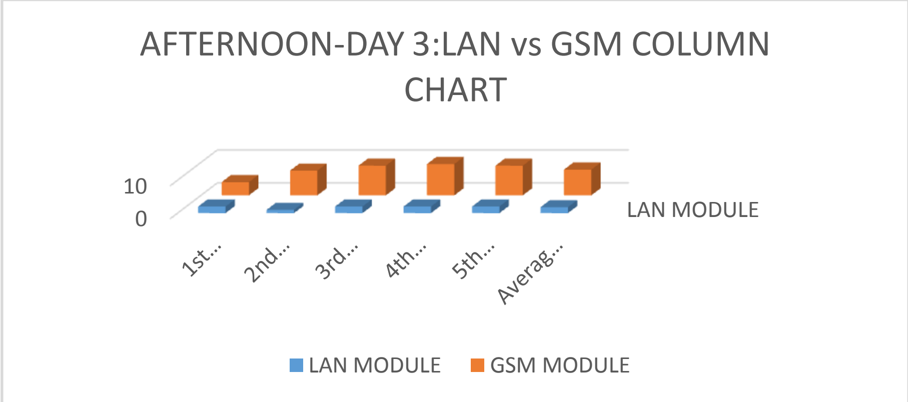

Figure 18: Column Chart for Afternoon Day 3

V. CONCLUSION AND FUTURE WORK

This system was designed to aid Nigerian farmers conserve water usage and proposed the use of a Local Area network set up within the farm to control the pumps. A LAN is better than the GPRS because GSM has latency and some of the causes of this is bulk SMS delivery, flash crowd events, message delivery failure, telecommunication bandwidth and Quality of Service (QoS). The following reasons contributed to a greater time taken to power up the water pumps using GSM network. Further work can be performed by adding sensors for detecting pests, for determining the level of sunlight on the farm. Also more work can be done by comparing the strength of GSM as it relates to 2G, 3G and 4G bandwidth speeds. Algorithms can be designed for checking efficiency of sensors in proximity in a very big hectare of farm where tens of sensors will be needed.

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