TOWARDS THE CONNECTION OF AGRICULTURE WITH THE INTERNET OF THINGS IN COLOMBIAN FARMS

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Abstract. Inefficiency of traditional methods of control and monitoring used in agriculture can be seen reflected in loss of time and resources for farmers. Modern monitoring systems allow performing tasks such as recording information, detecting anomaly situations or taking early corrections. However, most of the agriculture productive processes in Colombia are carried out in areas without access to internet networks limiting its application. In this way, proper solutions must be implemented by using electronic devices with wireless internet access to communicate important information and control actions among the farmers and their crops, including also low cost and intuitive interfaces. Furthermore, in the absence of power networks, these systems could be supplied by using solar photovoltaic units embedded in the same device reducing the need of batteries or at least reducing their size.

The present work describes the design and implementation of an on-line sensor system to collect environmental data into crops performing real-time acquisition of relevant variables using an Internet of Things IoT platform based on low cost electronics. The system consists of some slave stations powered by solar panels, which acquire the agrometeorological data from the crop and send it via radio frequency (RF using ZigBee) to a master station with electricity and internet connection through 3G communications, publishing the evolution of variables on an open internet website with public access. Hardware and software design, including electronic signals conditioning, software filters for data, early warning protocol and battery protections are presented and described in detail. Preliminary experimental results obtained in laboratory are compared with data generated by meteorological stations providing discussion elements for future developments.

Palabras clave. Precision agriculture; Internet of Things; Wireless sensor Network.

INTRODUCTION

Colombia is at a point where decisions must be made that define the type of development that its society follows in the future and the quality of life of its population. In particular, in the field of agriculture, Colombia faces a series of important challenges that must be faced appropriately. The agricultural production of Tolima region is not different to this situation, since for some years this climatic phenomenon has had repercussions on several crops such as rice, one of the most consumed products in the country and of great importance in the region. As a first step in favor of this initiative and under the initiative of the Ministry of Agriculture, formal studies have been developed on the effects of climate variability on rice production, generating a rather daunting scenario for producers in the region. Given the great participation that the Department of Tolima has in the arrogant market of the country, this situation presents a great concern for multiple points of view, affecting factors such as: the participation of rice in Colombian exports, the number of people and families benefited directly from the rice economy, and the importance of rice in the diet of Colombians. In this way, is necessary to generate solutions that reduce the impact of climate changes on rice production as little as possible. However, in order to implement strategies to mitigate these effects, is vital to have the appropriate information and tools to study them.

The increase in temperatures recorded in the last 25 years has produced a decline in rice production in various parts of the world, between 10% and 20%, according to a study published in 'Proceedings of the National Academy of Sciences' (Órtiz, 2012). In this way, researchers have stated that as minimum daytime temperatures rise, or that the nights are hotter, rice production will continue to fall. In Colombia, the "Institute of Hydrology, Meteorology and Environmental Studies" IDEAM and the Ministry of Agriculture, have taken measures in this regard through agroclimatological study projects in the region with the main result being alerts towards the communities of farmers and researchers in order to establish deep field studies that generate particular solutions and strategies to mitigate the climatological effect on rice production in the region (Fernández, 2013) (Cortés & Alarcón, 2016). One of these worrying warning signs corresponds to the prediction of potential yield in irrigated rice crops for the region, specifically for the municipalities of “Espinal” and “Purificación”, for which a decrease of 60% would be expected. 90%, taking into account that the Tolima region has a very low water availability index (Dry) from October to January according to the IDEAM. Given the aforementioned climate change scenarios, a negative water balance could be expected, especially in the second half of the year, associated with few precipitation contributions in Tolima, an increase in reference evapotranspiration rates and an increase in maximum and minimum air temperatures. For this reason, it is advisable to make a thorough analysis of crops, irrigation systems and water storage systems in order to improve the sowing of the rice crop, the management of irrigation and finally study strategies to mitigate the negative impact in the crops.

The main concern of this application is that in order to make an accurate diagnosis it is necessary to have reliable online measurements of the main parameters of the crop area in real time as well as a history that records their corresponding trends, too many precision agriculture applications have emerged from this kind of systems: (Guo & Zhong, 2015), Machine Learning Support (Murcia, Gonzalez, & López, 2017) and connections with other systems (Polo, Duijneveld, Garcia, & Casas, 2015). If there is no certainty and total reliability in the measurement, it is not possible to execute actions on the crop, since there is a risk of affecting it negatively. As an initial response to this situation, the present work seeks to make a contribution to the technology of agricultural practices, creating precision farming tools that allow knowing the specific needs of crops for optimum performance. Thanks to the collective interest of the D+ TEC research groups of the University of Ibagué and region farmers, the design and implementation of a localized measurement system on crops is proposed as a solution to these needs, which has the ability to detect microclimates within the crop and that allows the recording and monitoring of the most relevant variables in its performance as whatever it is: The temperatures and humidity of the soil, air and solar brightness.

MATERIALS AND METHODS

System architecture

The proposed system consists of different measurement stations located on different points into the crop as shown in the Figure 1a and a collector node which receive information from the stations to process it and send it to an internet server via 3G communication, this structure has been successfully tested in similar applications (Peña, Murcia, Londoño, & Botina, 2017). Each station was optimized for low energy consumption and is powered by a solar panel with a LiPo Battery to guarantee their operation 24 hours a day. The soil temperature, soil water potential, air temperature, air relative-humidity, visual solar intensity, ultraviolet light intensity, infrared light intensity, internal system temperature and geoposition (GPS) are acquired every ten minutes in each station. Each one of the measured variables has an associate sensor on board of the “AgroSensor” shield (see Figure 1b), an electronic board designed to be compatible with a popular open source and low-cost development system: The Arduino Mega 2560, a microcontroller board based on the ATmega2560 with 54 digital input/output lines (of which 15 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button (Arduino, 2018). Besides the instruments, the “AgroSensor” has the conditioning circuits, protections and soft filters to improve the information extraction from the signals in each case.

a) b) c)

Figure 1. General system description: a) Measuring station into the crop, b) pictorial user web interface, c) AgroSensor: Shield for Arduino.

The information package is labeled according to the station and variable, then is sent to the collector node by using Xbee devices (Communication modules which can be configured in a network with multiple connections on a collector node) in a Wireless Network (Digi, 2018). On the other side, the collector node receives the data from all the stations located into the crop. It consists in an embedded system Raspberry Pi with 1.4GHz 64-bit quad-core processor, dual-band wireless LAN, Bluetooth 4.2/BLE, faster Ethernet, and Power-over-Ethernet support (Raspberry, 2018) with internet connection by using a cellular modem GSM/GPRS which is used to upload the crop data to a web site through the “ThingSpeak”, a web server with an open access IoT source information platform that comprehensive in storing the sensor data of varied ‘IoT applications’ and conspire the sensed data output in graphical form at the web level (Maurerira, Oldenhof, & Teerntra, 2011), (Jaishetty & Patil, 2016), (ThingSpeak, 2018) ; and to communicate the system with the user or developer in a remote

Secure Shell "SSH" session by using Logmein Hamachi software, a hosted Virtual Private Network VPN service that lets you securely extend LAN-like networks to distributed teams, mobile workers (LogmeIn Hamachi, 2018) . The station executes a control algorithm based on C++ programed in Arduino, the Raspberry Pi executes a Raspbian operative system based on Linux Debian and a control algorithm for the system programed in Python, both available on (Murcia, AgroSense GitHub, 2018) . The Figure 2, illustrates the main components of the system and its relation.

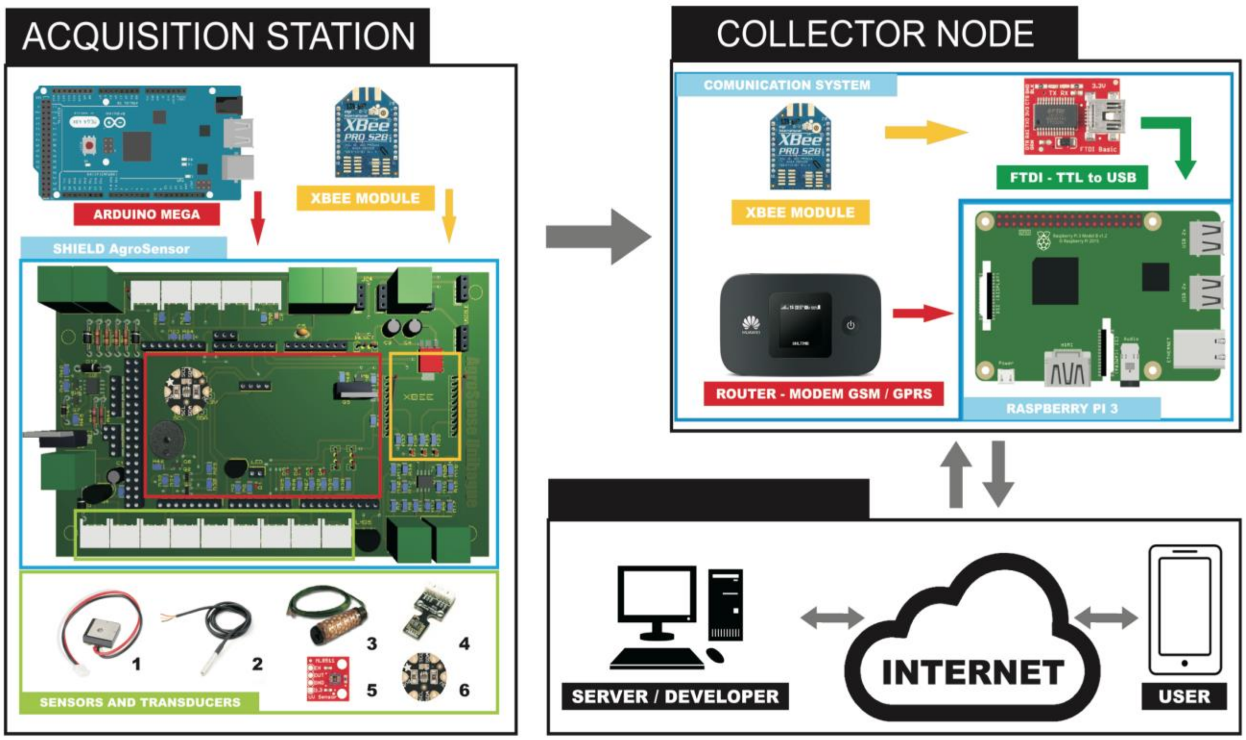


Figura 2. Block diagram description for the main system elements. Sensors and Transducers: 1) GPS, 2) Soil temperature, 3) Soil Matric Potential, 4) Air Humidity/temperature, 5) Sunlight 1, 6) Sunlight 2.

On-board Sensors

The sensors represent the direct measurement elements that interact with the crop, their variation can change in function of type of the sensor, so each sensor has a proper electronic circuit for acquisition and conditioning, e.g.: The measurement of Soil Matric Potential SMP is carried out by using the: Waterlink 200s (Allen, 2000), an electrical resistance device from Irrometer which consists of electrodes embedded on a porous matrix with resistance variation in function of the soil water potential in Kpa, a wet soil has close zero pressure values and dry soils have high negative pressures which are related to the plants radicular effort (Paayero, Khalilian, Mirzakhani-Nafchi, & Davis, 2017). The Figure 3 illustrates the input for each sensor and the associate electronic circuits in the schematic diagram.

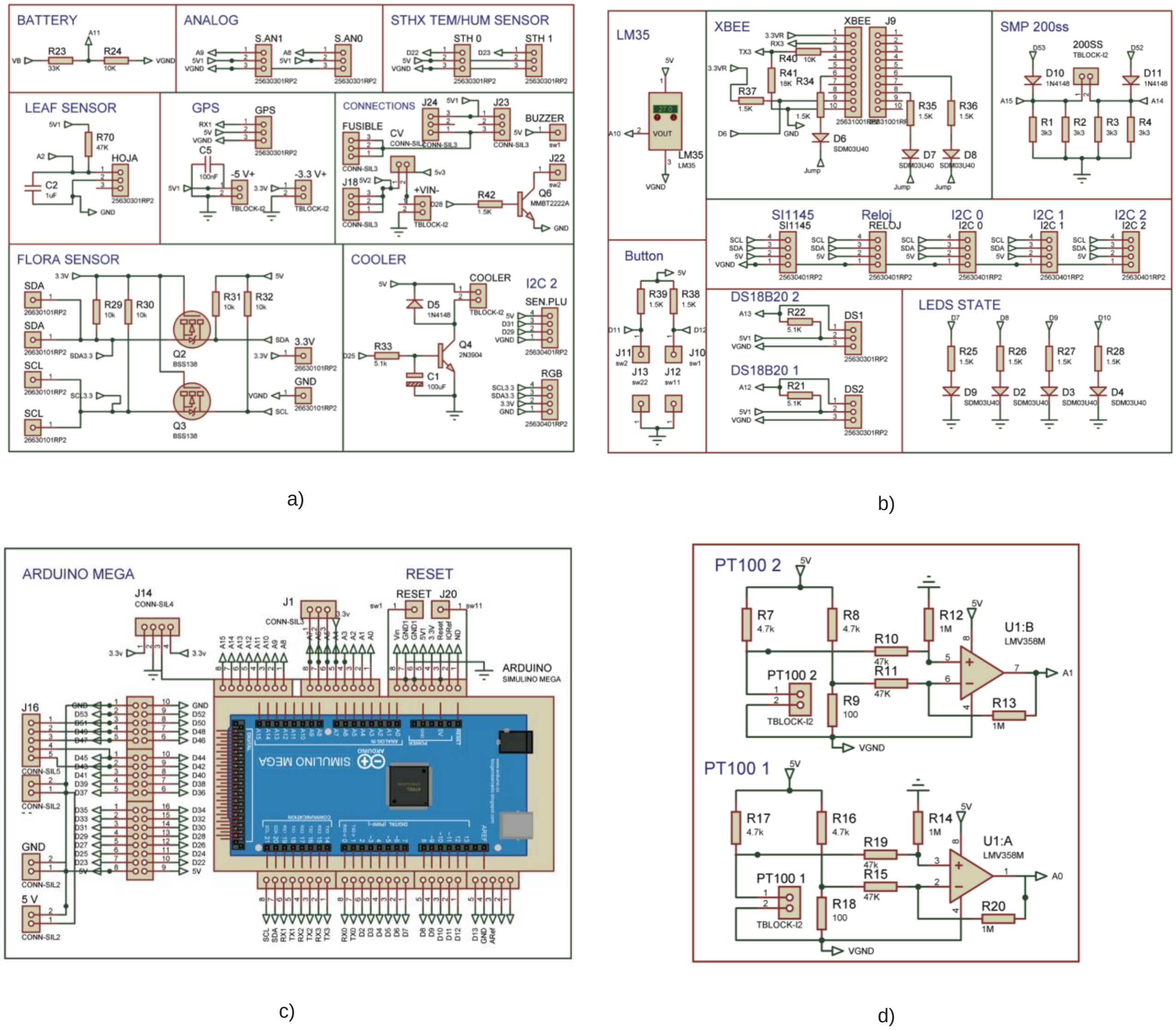


Figure 3. Schematic diagrams for the sensors simulated on Labcenter Electronics /Proteus: a) Schematic for battery voltage, air temperature/humidity, GPS, sunlight, fan-actuator; b) internal system temperature, Xbee, Soil Matric Potential SMP, I2C interfaces, and state led's; c) Microcontroller and used ports for control and d) conditioning for soil temperature sensor.

The Table 1 shows the descriptions and the manufacturer references for the used sensors on the system.

Table 1. Sensors and transducers used in the system.

No.	Description	Connection with microcontroller	Reference	Manufacturer Reference
1	GPS	Digital input with serial port	GP-20U7	(Sparkfun GPS, 2018)
2	Soil temperature	Digital input with I2C Communication	DS18B20	(DS18B20 datasheet, 2018)
3	Soil Matric Potential	Analog input with electronic conditioning	200ss	(Irrometer datasheet, 2018)
4	Air humidity/temperature	Digital input with I2C Communication	SHT10	(Sparkfun air T/H datadheet, 2018)

5	Sunlight sensor - UV	Analog input with electronic conditioning	ML-8511	(Sparkfun ML-8511, 2018)
6	Sunlight sensor - visible light	Digital input with I2C Communication and electronic conditioning	TSL2561	(Adafruit datasheet, 2018)
7	Internal temperature	Analog input	LM35	(TI datasheet, 2018)
8	Soil temperature Auxiliary	Analog input with electronic conditioning	PT100	(PT100 datasheet, 2018)

Autonomous power system

The supervision of crops allows the user to access and record information 24 hours a day, which implies the need for a continuous power system over the stations and over the collector node. The collector node usually makes use of the electrical network, on the other hand, the stations are implemented within the crop, without the possibility of connecting to the electrical network, for which it is necessary to add a conventional solar energy system, in which a panel solar power the “AgroSensor” and the battery charger that powers the system at night. The Figure 3 illustrates de general diagram for the energy subsystem, a sparkfun solar panel with the capable of 9 watts in the open sun with a peak power output around 6V at 1500mA power the system, the maximum power point tracking (MPPT) manage the energy from the panel to power the system, the 3.7 VDC 5000mAh battery and the Pololu Step-up converter which elevate the voltage from 3.3 VDC to 5 VDC. The MPPT based on LT3652 device has the ability to get the most possible power out of your solar panel or other photovoltaic device and into a rechargeable LiPo battery (Sparkfun MPPT, 2018). The size of the panel and battery capacity were obtained from the current consumption and the high/low times per acquisition. High sample frequency implies longer high times for acquisition and transmission, in other words more current consumption, the implemented stations have a high time around 10 seconds and low time around 10 minutes, with a sleep current consumption around 90mA and high current consumption around 200 mA, as shown the Figure 4a.

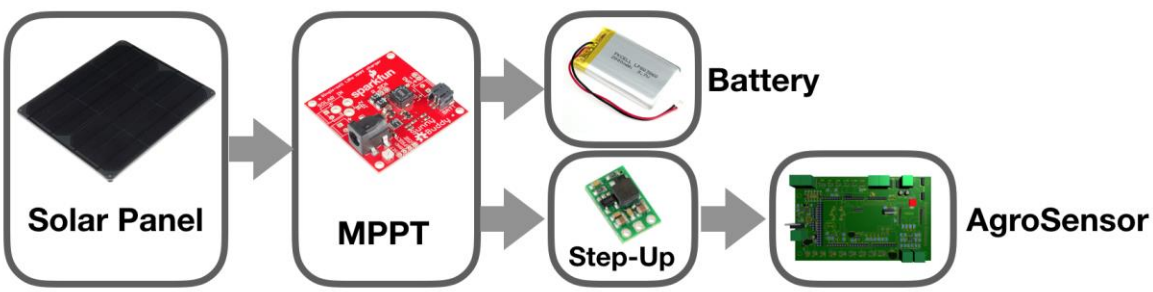
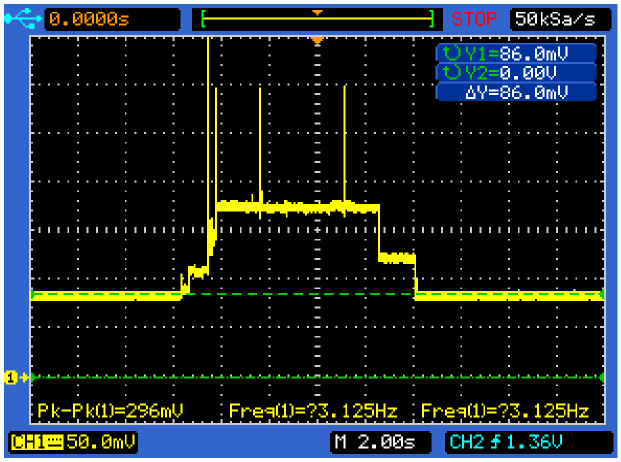
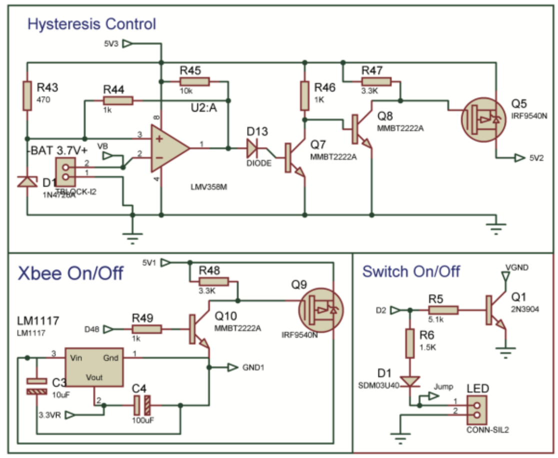


Figure 3. Energy system diagram for the stations.

The station starts by acquiring the data from sensors to send the information to the collector node and then jump to a low consumption mode: “sleep”. The Figure 4b illustrates the schematic diagram for the electronic circuit which manage the switching signal on each element to decrease the current consumption during the “sleep” mode. The Xbee, must operate with 3.3 VDC, however, the system works naturally with 5 VDC, therefore a circuit based on LM117 regulator and a mosfet IRFF95040N allows to switch the communication module in an efficient way. Another problem with the energy stage consists in the possible depth discharge of the battery in long periods of time of not sun. For this case a hysteresis control circuit was designed and implemented to disconnect the load from the battery when its voltage decreases under a defined umbral, allowing a load-power reconnection only when the battery voltage level reaches the upper umbral.



a)



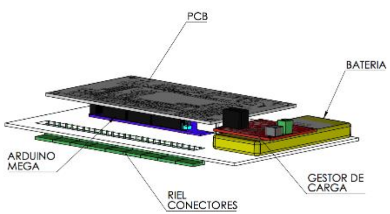
b)

Figure 4. System energy descriptions: a) current consumption equivalent in volts for each system cycle; b) schematic diagrams for the battery hysteresis charging control, Xbee switching and general switching simulated on Labcenter Electronics /Proteus

RESULTS

System Implementation

The Figure 5 presents the implementation steps from design consideration to the final installation of the station into a crop. The size and weight of main components of the station and the weather conditions defined the mechanical design on Solidworks for a posterior manufacturing in a 3D printer.



a)

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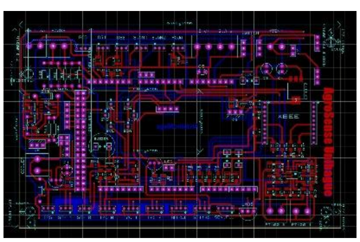
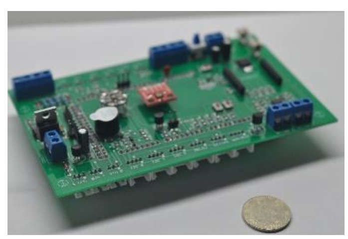


d)

e)



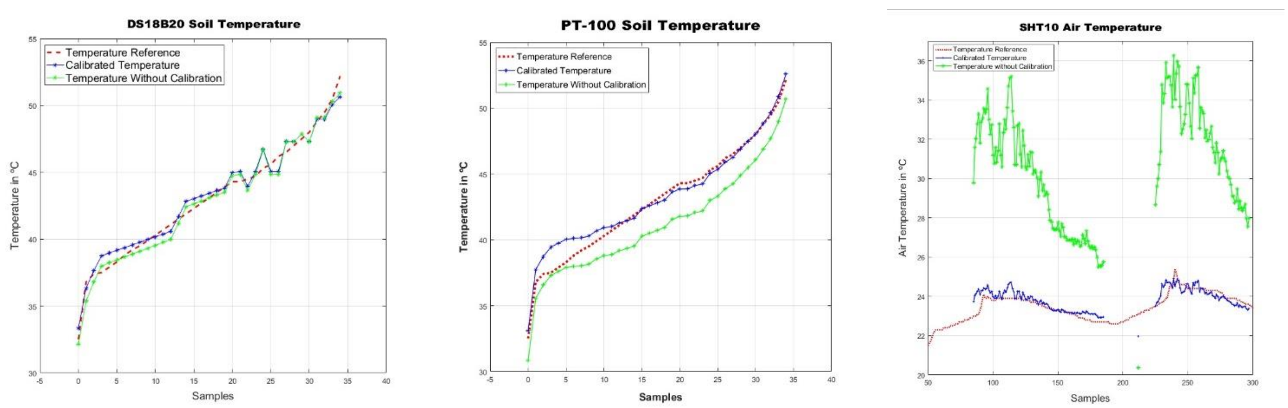
f)

Figure 5. Mechanical and electronical implementation of the system: a) Main internal components; b) 3D mechanical design; c) station working into a rice crop in Ibagué Tolima; d) Printed Circuit Board PCB station design; e) 3D board representation; and f) Final board implementation.

Electronical design started from desired variables, sensor selection and conditioning of electronic circuits to generate compatible signal with an Arduino Mega. Once the schematic of the system was successfully simulated on Proteus Isis the PCB was designed by using the Proteus Ares. Finally, the board was plotted and the electronic components were added by a soldering process.

Final acquired signals and instruments calibration

Once the system read, process and record the signals from the sensors into the crop and send it to the collector node, which upload the information to a web server, is necessary to validate the precision of the sensors. Some of the sensors are calibrated or manufactures provide calibration information and is not necessary to tune their parameters. However, in other cases is necessary to adjust some parameters to reduce the measurement error. Temperature sensors are the most sensible sensitive instruments to measurement error, so a calibration process was carried out, by a comparison with a reference instrument: Laboratory thermometer for soil and a weather station for air temperature. The Figure 6 shows a calibration results for temperature instruments.



a) b) c)

Figure 6. Data obtained for instruments calibration. a) Soil temperature, raw data, reference data and calibrated data; b) soil temperature using PT-100, raw data, reference data and calibrated data; and c) Air temperature, raw data, reference data and calibrated data.

Information received on the collector node can be processed according to the applications and needs, the data can be saved in a flat text file, uploaded to a web server, plotted in a graphical user interface, processed to send warnings and alerts (email, sms) in case of animalities or define a control decision on an actuator such as an irrigator. The Figure 7 illustrates an example of a data segment registered on the web server and visualized on ThingSpeak for air temperature, soil temperature, air humidity and soil Moisture. In this way is possible to know the specific needs from the crop based on a constant monitoring even from kilometers of distance from the crop.

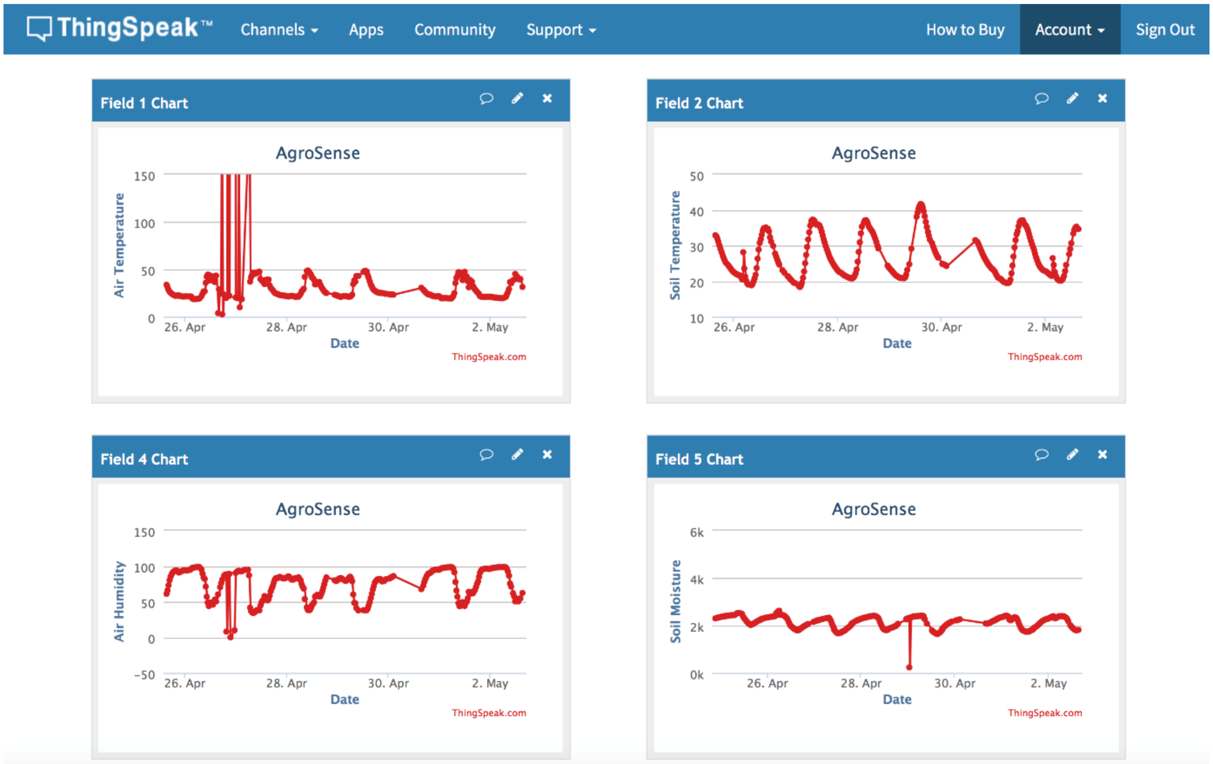


Figure 7. Final Data visualization on web site for four signals in time window of one week.

CONCLUSIONS

A supervision system for agrometeorological information of crops is proposed in this paper from the design to the implementation, and its effectiveness is tested via experimental data acquisition by using IoT remote connection. The stations implemented on crops have energetic autonomy, low cost (around 40% of the cost of commercially-available stations) and are a convenient tool to monitor the sunlight and temperature and humidity variables from soil and air into the crops. Moreover, the system can be migrated to indoor living, greenhouses, climate and forest monitoring.

The appropriation of technology facilitates and efficient response when solving problems related to crops. This information could be vital for a decision that define the performance of a crop, water management, poisons and fertilizers. Moreover, it reduces the cost of acquisition, installation and operation respect to the commercial options. In addition, thanks to the IoT and solar energy module, is possible to access and modify the system continuously in any moment from a remote connection.

ACKNOWLEDGEMENTS

This research is being developed with support of the Universidad de Ibagué projects No. 15-367-INT and 16-446-SEM. The results presented in this paper have been obtained with the assistance of students from the Research Hotbed on Instrumentation and Control (SI2C), Research Group D+TEC, Universidad de Ibagué, Ibagué-Colombia.

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