Sensor Web

DESIGN DOCUMENT

Team Number: Dec 1713

Client: Dr. Geiger

Team Members & Roles:

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1 Introduction

1.1 Project statement

Our project is to make a network of nodes to relay sensor data and relay that data to a webpage for a user to interface with. Each node will collect information on temperature, pressure, soil moisture etc. This information is sent to a "home" node with 3G cellular enabled, and be able to upload data to an off-site web application. The data can then be interpreted by the user. The field hardware will be designed to last up to 8 months on a battery. The modules will be cheap and biodegradable so that there is no need for collection.

1.2 Purpose

In the immediate future, this project will benefit farmers. These cheap, wireless nodes will be able to send data about the moisture in the soil, temperature, and anything else that a sensor can gather. With this information the farmer can know which areas of their farm need to be watered or why crops may be performing better in some areas rather than others. In the future, this project could be used in military settings and these nodes could send information about the motion of people or if a tank was passing by.

1.3 Goals

Our goal is to create network of nodes that can relay sensor data. These sensors will be able to send the data no matter the configuration of the sensors, whether they are in a straight line or clustered together. As a stretch goal, one of these sensors will be a hygroscopic, 3D printed, compostable sensor. These nodes will be wirelessly sending the information and will then be sent up to the cloud through a 3g module. A website will then display this information for the user in an informative and simple interface.

2 Deliverables

At the conclusion of this project we expect to have at a minimum of three nodes, each with two sensors that can relay information to each other. These nodes could be in any configuration and still be able to send all of the information. We will have one 3G module that will receive all of this information. The data will be sent to a webpage that can display the data that was received by the 3G sensor.

3 Design

Our group broke the project down into three parts. The first are the leaf nodes that extend out in the field. The second is the home node that fetches data from the nodes and relays it to the server. The last part is the website which takes the data and presents it in an intuitive way.

The design for the leaf nodes is to have a low power/low cost module that is equipped with many sensor such as temperature, pressure and moisture sensor. The data is read from these peripherals and transmitted to the home node each day at a given time. When the system is not transmitting it will be in a low power mode until it is called upon by the home node. These nodes should be disposable.

The home node is designed to send out a signal to all of the leaf nodes and requesting information one leaf node at a time. When the leaf node wakes up, it will transmit its data which could be passed along multiple leaf nodes until reaching the home node. The home node will record this data and call upon the next leaf node's data. This process will continue until all the leaf nodes have been called. After the data is collected, it is then packaged into the JSON format and uploaded to the server over 3G communication. This module will be equipped with more robust batteries as it will require more power than the leaf nodes.

The web server will interpret the incoming data from the home node and display the values at each leaf node location. When leaf nodes are placed in the field each is given a name and the location is recorded with GPS coordinates. This information is provided in a lookup table for the programmers to use for data mapping. A heat diagram will show the fields data in an easy to read format. If a leaf node is unresponsive for a certain duration the program can interpret it as dead and notify the owner for a replacement.

3.1 System specifications

The system will be using a few microcontrollers, primarily Arduinos. These Arduinos will be used in the wireless node part of the project and control all of the processing going through the wireless communication. Arduinos do not have long range radio capabilities so NRF24l01+ modules will be used for the radio communication. These radio modules can work directly with Arduinos to transmit and receive sensor data to other Arduinos on the network within the range of 500ft. In order to make the home node get connected to the web server, a SIM module can be used to send the data for the long distance communication.

3.1.1 Non-functional

Spreadsheets of data collected from testing 3D print materials will be submitted. CAD drawings of the hydroscopic probe along with annotated drawings will be submitted as well. Both of these non-functional documentation relates to the sensors attached to each leaf node.

3.1.2 Functional

- The system shall include a parent node with wireless capabilities to receive data and send it to a remote server.
- The system shall include child nodes with short range wireless capabilities to send data to the parent node.
- The system shall include a server to receive data from the parent nodes.
- The system shall include a web interface to display the collected data to the user.
- The system shall provide an informative project-focussed website to outline methods and processes used to complete the system.

3.1.3 Standards

Our project does not currently possess any practices that would be considered unethical by organizations such as IEEE, ABET or others. Our goal is to help society and more specifically farmers by increasing their crop yield with the information that they receive from the sensors. Standards can be beneficial so other students could pick up and continue our project. It also allows for the students currently working on the project to understand industry standards defined by IEEE and ABET.

- The System shall follow the standard REST protocols (POST and GET) in the web application.
- The System shall follow javadoc in the implementation of the microcontroller for the 3G node.
- The System will follow I2C protocols for some of the hardware operations.

3.2 PROPOSED DESIGN/METHOD

Our team has decided on approaching this project by dividing into three pairs. We have a rather large group, and dividing the group into their specialties for the project will be the most efficient.

The first team, Khoi Cao and Terver, is tasked with designing a home node. Its primary purpose is to receive radio signals from the leaf nodes, and make a POST request to the web-app with a 3G connection. It will combine the data to deliver a single payload via JSON, where the web-app can parse the data into relevant sets.

The second team, Tim and Steven, is tasked with designing a leaf node. The purpose of this leaf node is to use sensors and collect information from the soil. The current plan is each leaf node will have two sensors that measure soil moisture levels and air temperature. This data is then relayed through the network of leaf nodes to the home node, and delivered to the web app by the home node.

The third team, Ian and Gregory, is tasked with creating a web-application that the home node can communicate with. The web-application should be capable of receiving data, storing it in a database, and displaying that data to the appropriate user. The application's purpose is to help a farmer understand the conditions in their field, and whether or not irrigation is required.

3.3 DESIGN ANALYSIS

The leaf node group is working on communication using the short range radio transceivers. They were able to successfully send data using them. They observed that with the long range transceivers there was some unsuccessful sending and receiving. This should not be an issue as the radios will transmit more than once and send confirmation messages between each other. The software for this communication is stable and working. This group is also working on the hydroscopic sensor. A 3D model was created for 3D printing (see figure 1 and figure 2). For the testing phase, the material has been cut into squares with leads on either end. Soil will be brought in and dehydrated to natural levels (see figure 4: for process of soil testing). Water volume ratios will then be added to the dehydrated dirt to simulate wet soil at different ranges. The sensor will then be placed in environments similar to those tested to see how the properties of the material react to the moisture levels. The experimenters would like to have a predictable resistance model for the probe to accurately interpret the moisture content of the soil (see figure 3 for material water testing results).

The home node group has tried to generate an http post with JSON format utilizing the Arduino JSON API library. The layout of output data has been verified on JSONlint.com for the compatibility with the standard input from the web server.. Also, we have made a small prototype with Arduino and 3G module for long-range data transmission. The configuration was successful to send out some sorts of data chunk over the SMS and GPRS. The process of fetching and relaying data to the web has been still in progress. There is a need to spend a considerable amount of time to integrate the JSON output with the AT opcode command to use the 3G instead.

The web application has been moving fairly well. The web team is able to build an application into a jar, which can be deployed on any linux machine. Currently, the space provided to the team is from ETG, and are struggling with the firewall. The team has a domain “sensorweb.ece.iastate.edu” but currently can not access it publically. Through local testing, the team has a REST api that the home node will be able to send JSON to. The app will retain the last 4 requests, whether or not it was valid JSON, and what the text was.

4 Testing/Development

4.1 Interface specifications

Discuss any hardware/software interfacing that you are working on for your project. This section is decided by team advisor/client.

The leaf nodes should be able to send data between each other using radio signals. This means that interfacing between the Arduino and the NRF24l01+ modules will need to be seamless. The leaf nodes should be capable of interfacing the hardware of at least two leaf nodes. This interfacing will be done with an Arduino microcontroller and eventually just an Atmega328P chip on a PCB.

Our home node should be able to make POST requests using a 3G connection. Users should be able to view the application from any web browser via HTTP or HTTPS.

4.2 Hardware/software

Indicate any hardware and/or software used in the testing phase. Provide brief, simple introductions for each to explain the usefulness of each.

Software:

Postman: A program that can create web requests manually, and allows us to verify that our application is working as intended.

JUnit: Unit tests will be imperative when our web app gets more complicated. Tests will be run before packaging the JAR, which will help prevent errors.

JSONLint: check the JSON format for the data layout sent from the home node.

Hardware:

Arduino: The leaf node group is using Arduinos to test receiving sensor data and transmitting/receiving data from the NRF24l01+. The Arduinos will be helpful for testing as they have the same microcontroller that will be used in the final revision of the leaf node.

NRF24l01+ : These are small and inexpensive wireless modules that integrate well with Arduinos. The testing of these modules will assist in getting the wireless mesh network completed so the Arduino will be capable of handing off information.

Fona 3G cellular: provided by Adafruit, this item is guaranteed to integrate well with Arduino and Raspberry. It includes the SIM5320 module that supports most of US carriers and allows to send and receive GPRS data (TCP/IP and HTTP post) with AT command interface. This module will help establish a continuous connection between the home node and the server over the long distance.

4.3 Process

Soil Moisture Testing:

This process will be used for testing our hydroscopic sensor prototype. The goal is to determine if the sensor will give reasonably accurate readings, a separate test will be needed to test the resilience of the biodegradable material. Prof. Kaleita described a method where the sensor would be suspended in a container, probably glass. We would then layer appropriate soil around it, as to not disturb the sensor. From there, we would add water somewhere between the field capacity and the permanent wilting threshold of the soil, and monitor the readings. After the fact, we will remove the soils from the container and air-dry it completely, and compare our readings. See Figure 4 for more information.

Software Testing:

Our web-application is very close to being hosted on a publicly accessible URL. Through local testing we were able to see our testing URL working correctly with Postman. After the system is hosted, we will be able to send POST requests to it and see the data from anywhere.

Hardware Testing:

The rest of the testing has not been completed yet as the groups have just received their hardware from ETG.

5 Results

5.1 Home Node Testing Results

The group tested the 3G module to ensure proper communication with the Arduino (microcontroller) and that it was able to send and receive sensor data. Initially, the Arduino was unable to read data from the 3G module. Our group was able to test and fix this issue by reading the output on the the Arduino receive pin. The group connected the 3G module to the computer using a micro USB to test the 3G module but we were unable to establish a communication between the computer and the Arduino. The problem was resolved by activating the 3G module sim card and fixing the soldering job on the 3G module pins.

5.2 Sensor Testing Results

Although the sensor testing result is not finalized, the sensor test values will be compared to known values to determine the accuracy of the sensors. If the sensor results are off by a predetermined value, then modifications would be made to the sensors to compensate for a wide margin of error. The microcontroller's output and input will be used to relay sensor data and will be tested to ensure the right data is being transmitted and received. Our group will also learn more about the characteristics of the biodegradable material in order to enhance the specification of the project.

5.3 web testing

In the web testing, data is sent to the web site (sensorweb) and the data sent has to be in JSON format. In the testing procedure, a JSON format data and a data which is not in JSON format is sent to the web to verify if the web can detect the format type. The web is able to detect the format of the sent data. Web testing results can be seen in the Appendix section Figure 5.

6 Conclusions

Our first hardware group had to determine what sort of communication would be best between the leaf-nodes and the home-node. From there, they had to decide on which hardware satisfied their needs. In the end, we have decided on radio signals as our form of communication, with JSON strings as the format. Radio signals were chosen, because the hardware required to send and receive the signals, is incredibly cheap. Also, radio signals are incredibly easy to produce, and manipulate, which makes sending and receiving data incredibly easy.

Our second hardware group had to decide on a method of sending the data of all connected leaf-nodes up to a remote server. For this, they decided to use 3G as the method, and JSON strings as the format. 3G was chosen as the method of sending information to the remote server, because, once again, the hardware required is easy to acquire and manipulate. The long range capabilities of 3G also make it desireable, as our home-nodes will likely be out in the middle of a field, with no access to WiFi or Ethernet.

Our software team has been working to establish a web interface and endpoint for the home-nodes to contact. We have decided to use Java Spring Boot as our server framework, and have been working on getting an API up and running. Java Spring Boot was chosen, because it makes creating API endpoints almost effortless. JSON was chosen as the format of communication for all groups, because JSON is very simple to write and it can represent both arrays and objects. This allows for very complex data to be transferred easily using just a string.

Our end goal is to have a web of leaf-nodes that wirelessly send sensor data to a more robust home-node. The home-node would construct a JSON from the data of all the leaf-nodes, and send it to the remote end-point using 3G. Users will then be able to view the data from their nodes using the graphical user interface which our software team will provide.

7 References

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8 Appendices

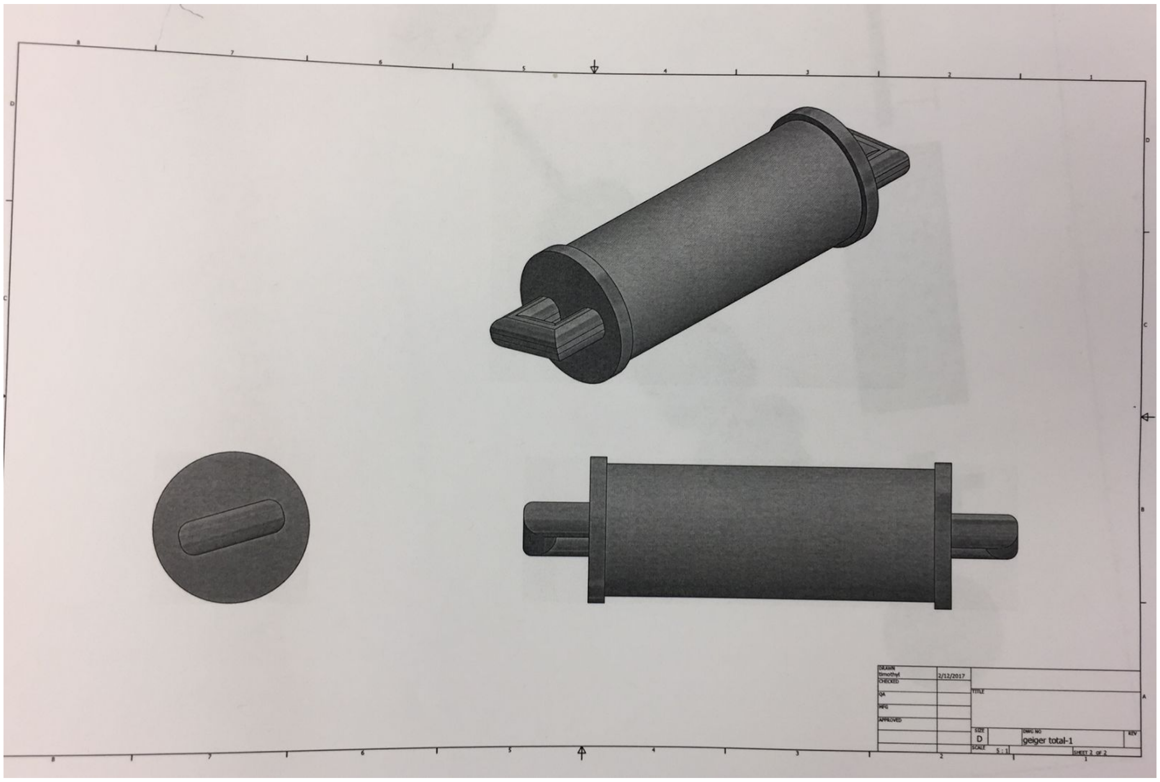


Figure 1: CAD Drawing of Hydroscopic Sensor

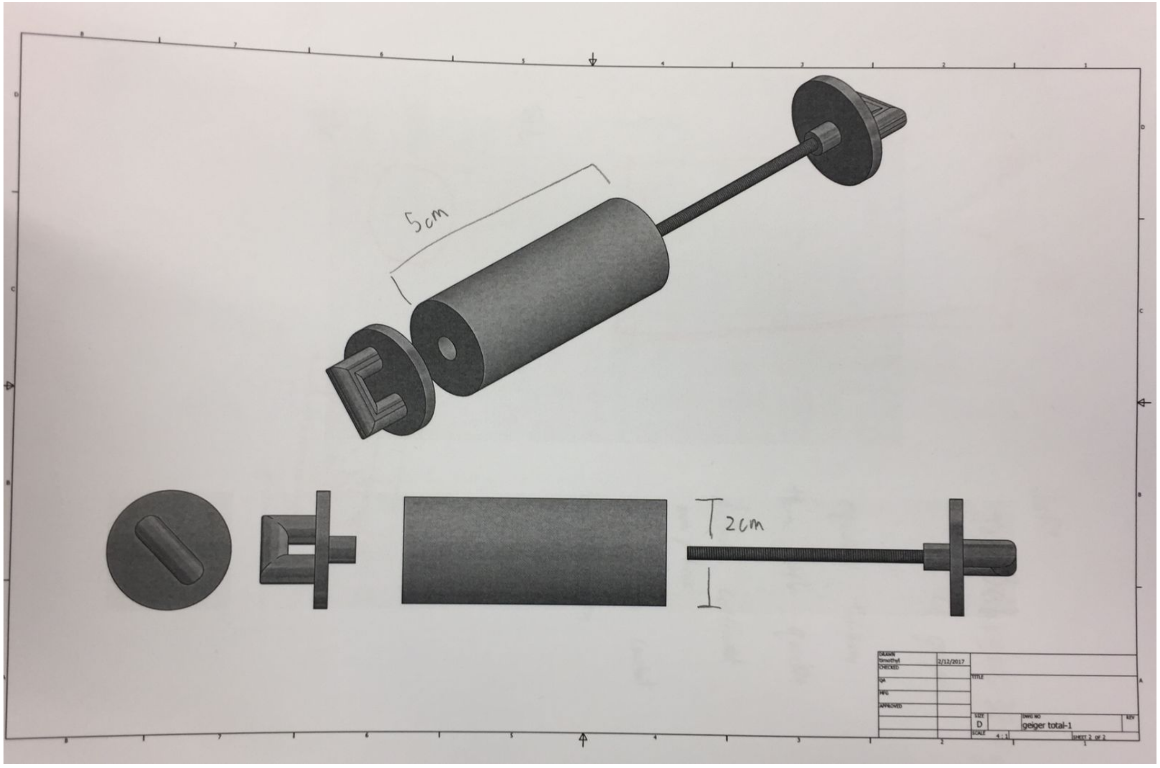
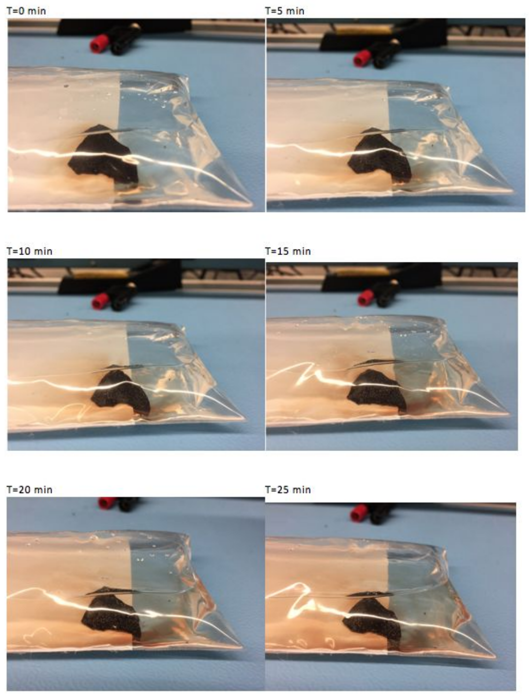


Figure2: CAD Extruded Drawing of Hydroscopic Sensor



Distance between Probes	Soaked Blood (MΩ)	Dry Blood (MΩ)
1mm	0.22	21
1mm	0.23	15
1mm	0.19	24.8
1mm	0.28	16.2
1mm	0.24	11.2
1mm	1.3	17
1mm	0.24	12.6
1mm	0.32	14.7
1mm	0.31	19.5
1mm	0.26	17.3
1mm	0.26	12.8
	Avg	Avg
	0.35	16.55454545

Figure 3: Confidential Material Water Testing. Resistance wet/dry chart.

Soil Moisture Test Procedure

1. Place soil in bin maximizing surface area. Bake soil in oven for *var1* hours to evaporate all water.
2. Measure soil to *var2* g mass, dump into mixing container. Measure graduated cylinder to *var3* ml of water. Dump into mixing container. (able to calculate volume ratios using known densities.)
3. Mix till homogeneous solution.
4. Place probe in testing jar. Fill with soil. Cap for anti-evaporation.
5. Micro controller will read sensor data *var4* times per *var5*. Data is then written to a .txt file over serial communication. (will be delimited so can easily dissect and plot at any time during the test cycle)

*would like to have multiple jars running at the different volume ratio
*can adjust surface area of sensor to accelerate decay

Figure 4: Processor for Testing Soil Moisture Sensor.

Figure 5: Web Testing Results