Mobile Data Harvester

Senior Design Project Proposal
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Overview

- Problem and Solution
- General System Overview
- In Depth System Description and Technical Components
- Challenges and Risks
- Marketing and Engineering Requirements
- Testing and Results
- Materials and Costs
- Timeline

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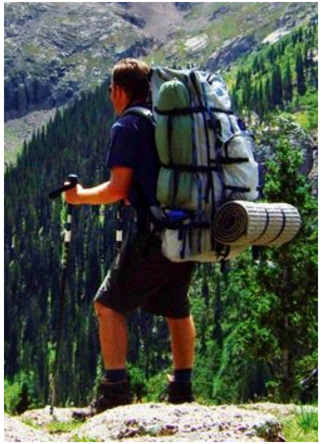
The Problem

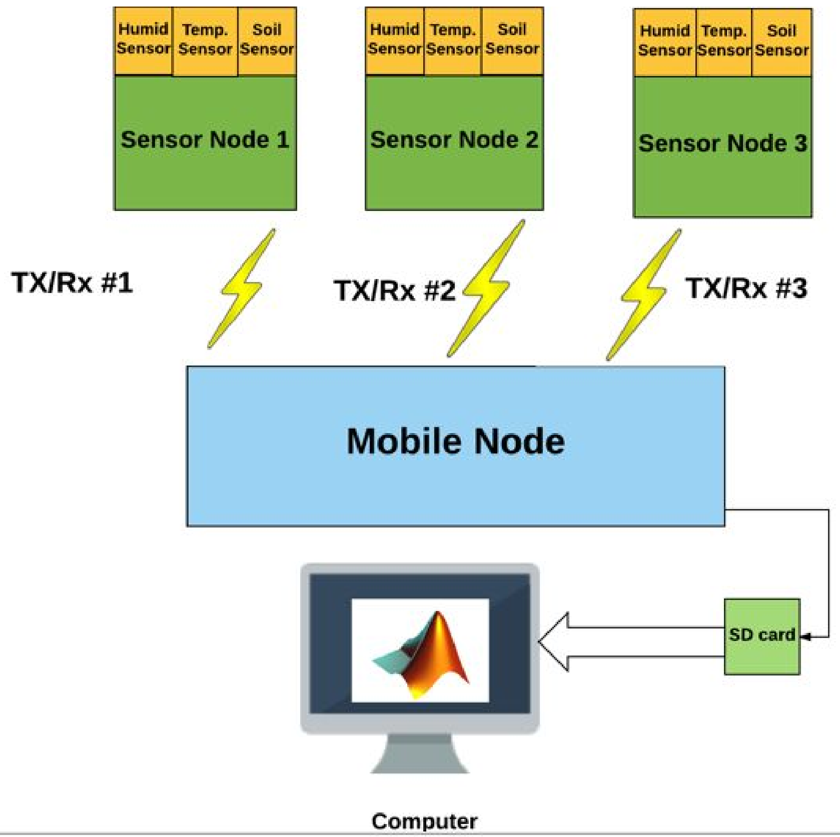
- Collecting environmental data is important for a number of reasons
  - Soil moisture to see if it's sustainable for crops
  - Temperature for examining the ecosystem in an area
- Sensors used for collecting data might be in far or remote locations
- It takes time to go by foot and can be dangerous to get to

The Solution

We developed a system that will allow the user to easily collect sensor data remotely, through the use of a mobile device that will connect to the sensors wirelessly.



System Overview



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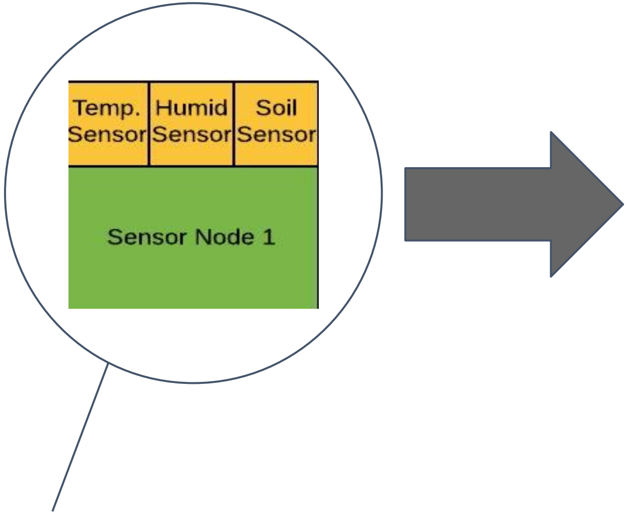
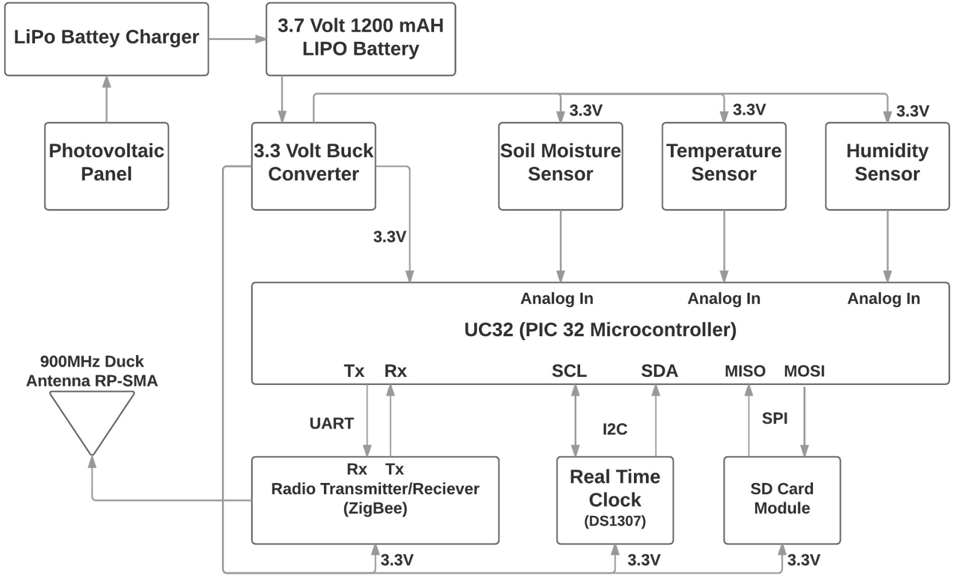
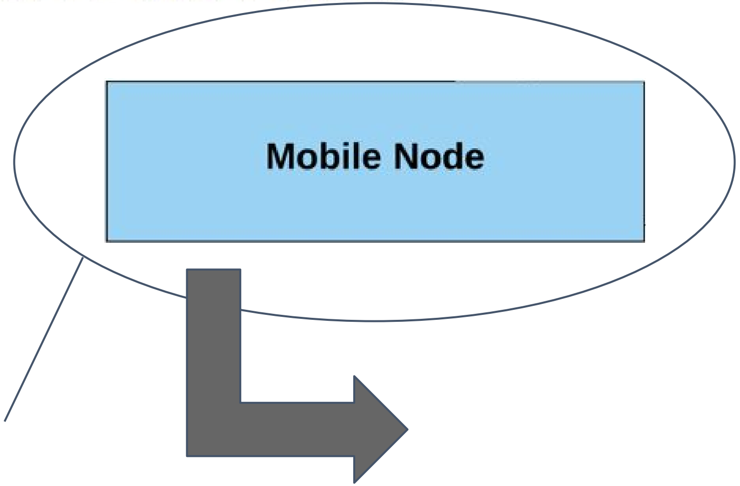
Hardware Design

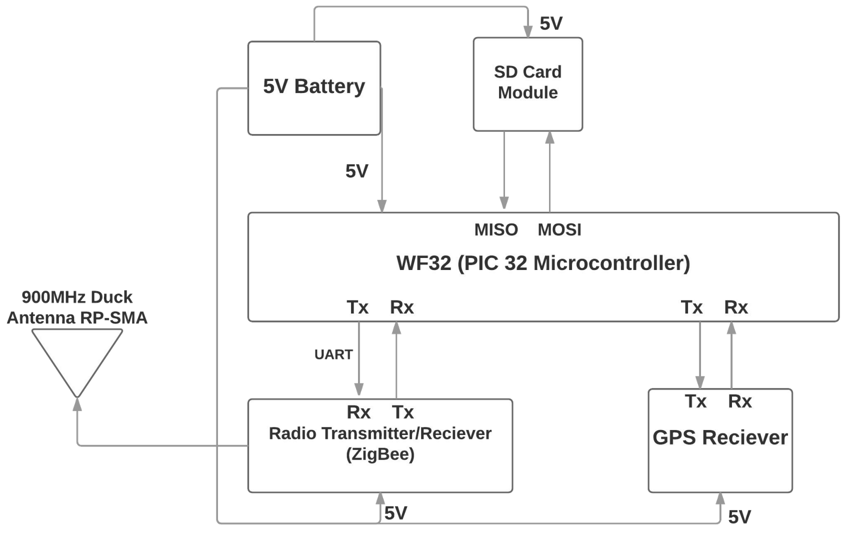




High- Level Diagram of Sensor Node

Hardware Design





High- Level Diagram of Mobile Node

Data Sample

MATLAB
The Language of Technical Computing

	A	B	C	D	E
1	Node_Number	Date_Time	Temperature	Soil_Moisture	Humidity
2	1	4/21/2017 17:35	29.125	66.6151	35
3	1	4/21/2017 18:05	21.75	45.7066	36
4	1	4/21/2017 18:35	22.75	39.7379	36.2999
5	1	4/21/2017 19:05	26.3125	38.4683	35.7999
6	1	4/21/2017 19:35	26.5625	37.8203	35
7	1	4/21/2017 20:05	25.5	37.2149	34
8	GPS Coord	38.343465	-122.594609	0	0
9	2	4/21/2017 20:35	23.125	37.7486	33.5999
10	2	4/21/2017 21:05	21	38.4864	33.7
11	2	4/21/2017 21:35	19.1875	39.1799	33.7999
12	2	4/21/2017 22:05	17.75	39.8167	34.2999
13	2	4/21/2017 22:35	16.5625	40.5953	35.2999
14	2	4/21/2017 23:05	15.625	41.1727	35.9
15	GPS Coord	38.34405	-122.593627	0	0
16	3	4/21/2017 23:35	14.8125	41.6583	36.2999
17	3	4/22/2017 0:05	14	42.5551	36.9
18	3	4/22/2017 0:35	13.3125	53.671	37.2999
19	3	4/22/2017 1:05	15.625	47.7884	47.2999
20	3	4/22/2017 1:35	16.625	46.1274	45.9
21	3	4/22/2017 2:05	15	45.8864	41.7
22	GPS Coord	38.344578	-122.594327	0	0

Packet Data Content/Excel Format

Challenges

- Keep mobile node small and light enough to be able to be mounted onto a UAV.
- Mobile node must be able to distinguish between the three sensor nodes.
- Mobile node needs to be able to inform the user when a sensor node is down.
- Keep the power consumption of the sensor nodes low enough so that they can be powered indefinitely via solar.
- Ensure that there will not be too much interference from the environment during communication.
- Making sure the data doesn't take too long to transfer from the sensor node to the mobile node.

Marketing Requirements

MR1. Guaranteed battery life up to 30 minutes for the mobile node on the UAV.
MR2. User will need an FAA license to operate the UAV.
MR3. Sensor nodes will support multiple sensors (soil, humidity, and temperature).
MR4. Can reach areas that are difficult to reach by foot. Up to a 90 meter radius.
MR5. Flag is initiated when a certain sensor is unresponsive.
MR6. User can receive data directly from the mobile node SD card.
MR7. Overall data information will be uploaded through a Matlab program displaying: node ID, sensor data, time, date, GPS coordinates.
MR8. Sensor node batteries do not need to be manually recharged or replaced.
MR9. Node will be placed in weatherproof casings to protect them from damage and will be durable enough to withstand outdoors conditions. eg rain, etc., (won't necessarily withstand tampering from wildlife such as bears, etc.).
MR10. Both sensor and mobile nodes (without the sensors) will cost under $60 per node.
MR11. Data accurate to three significant figures.
MR12. The system must be able to function over long periods of time without maintenance

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Engineering Requirements

ER1. 5 volts supplied by the power supply of the UAV to the mobile node.
ER2. Data will be transmitted and received up to 300 feet.
ER3. Data is transferred to the user's computer by use of an SD card.
ER4. Will use ZigBee wireless protocol for low power consumption (will have low data rate of 250 kbps).
ER5. Can support at least 3 sensors at a time on each sensor node.
ER6. Mobile node PCB will be 3x 3 so it can be placed easily on a medium to large sized UAV.
ER7. Mobile node will weigh no more than 5 ounces.
ER8. Sensor nodes will be powered by solar charged batteries.
ER9. Mobile node will use a GPS module to know when to receive data and also check to see if a sensor node is being unresponsive.
ER10. Each Xbee module will have attached 900 Mhz band rubber duck antenna (RPSMA connector).
ER11. The size of the data packet size must be restricted so that transmission doesn't take too long or the data takes up too much space in the sensor node's flash memory (around 32 bytes per data set).

ER4/ER5/ER6/MR3/MR9

Sensors

- All three sensor nodes will be using the same exact sensors and same number of sensors. In this project, each sensor node will have a temperature sensor, humidity sensor, and soil moisture sensor.

Sensors

Calibrating Temp Sensor

Comparing our soil moisture sensor
with a HydroSense II soil-water sensor

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ER4/ER5/ER6/MR3/MR9

Sensors

Long Term/ Power Tests

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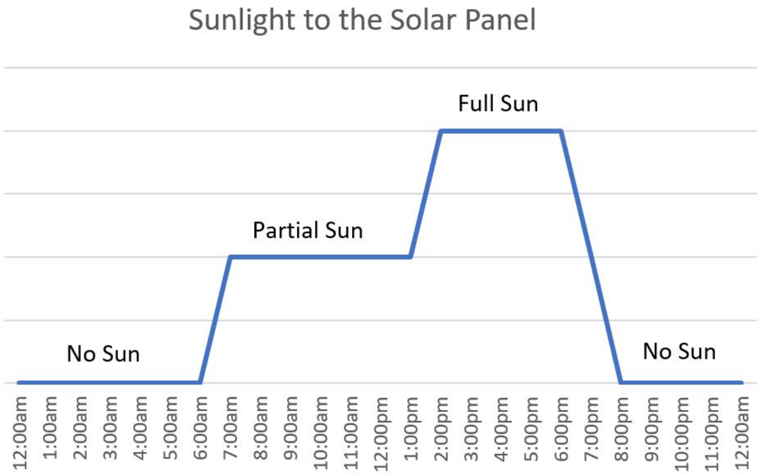
- The sensor node device uses 0.130 Amps to operate, while the solar panel produces about 0.500 Amps in sunlight.
- LiPo battery fully charges from solar panel in 6-8 hours in direct sunlight.
- LiPo battery lasts at least 8 hours without power from sun when fully charged



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Long Term/ Power Tests

- After completing the Sensor Nodes, We did a long term test to see how long they last last with a full charge.
- It collected data every 30 min recording a timestamp and data.
- Here our node ran for 20 hours without any corruption.

GoodLongRunTest - Notepad

File Edit Format View Help

```
3,2017/4/28 9:4:23,85.0,92.8565,52.7999d
3,2017/4/28 9:34:24,14.6875,94.8036,46.9999d
3,2017/4/28 10:4:25,15.5625,95.4006,46.9999d
3,2017/4/28 10:34:26,16.8125,95.7265,45.2999d
3,2017/4/28 11:4:27,17.6250,95.9353,35.2000d
3,2017/4/28 11:34:28,18.3750,96.1174,35.2999d
3,2017/4/28 12:4:29,19.6875,96.2091,35.0d
3,2017/4/28 12:34:30,21.0,96.2857,33.5000d
3,2017/4/28 13:4:31,21.8750,96.3087,25.6000d
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3,2017/4/28 14:4:33,27.1250,90.1107,14.1000d
3,2017/4/28 14:34:34,27.1250,86.6208,12.5000d
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3,2017/4/28 15:34:36,28.6250,84.5756,11.6999d
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3,2017/4/28 18:34:42,33.8125,90.6713,6.90000d
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3,2017/4/29 1:4:55,11.5625,97.5891,71.5000d
3,2017/4/29 1:34:56,10.7500,97.6489,80.5000d
3,2017/4/29 2:4:57,11.5000,97.7164,74.6999d
3,2017/4/29 2:34:58,10.3125,97.7285,75.9000d
3,2017/4/29 3:4:59,10.6250,97.7586,76.8000d
3,2017/4/29 3:35:0,11.0,97.8134,72.9999d
3,2017/4/29 4:5:1,10.5000,97.8219,73.3000d
3,2017/4/29 4:35:2,9.62500,97.8441,78.1999d
3,2017/4/29 5:5:3,9.31250,97.8215,80.3000d
```

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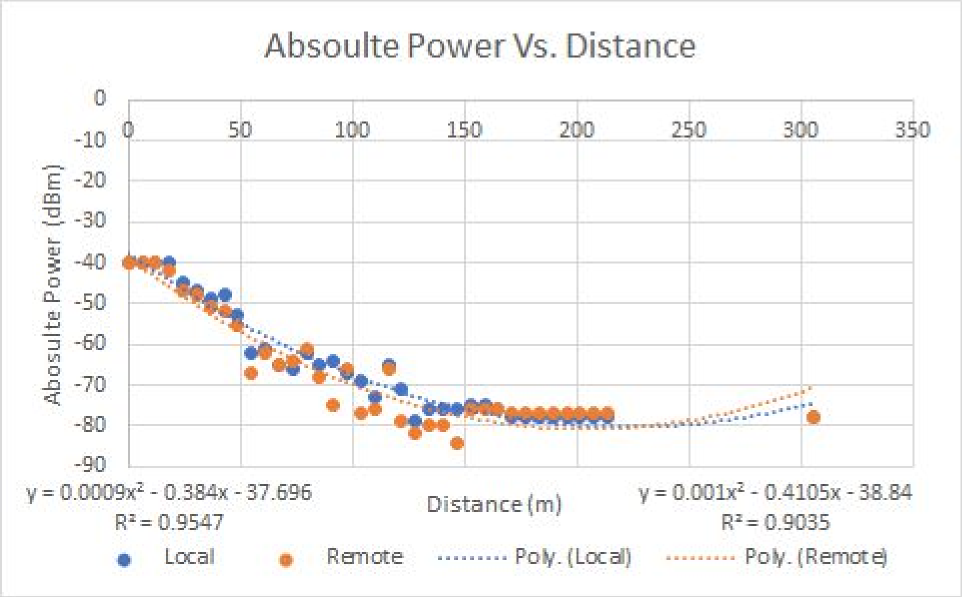
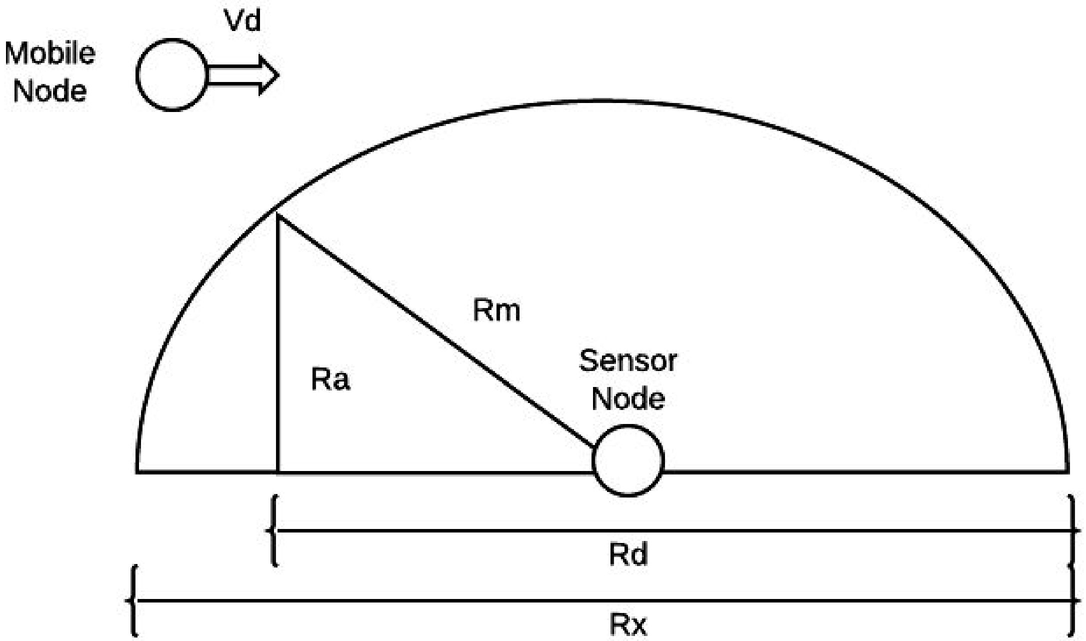
Long Range Test

- Here we measured the received signal strength between two nodes over distance and over time.
- We were able to go over 500 ft without losing signal. We could have gone further, but ran out of unobstructed space.



Transmission Time Simulation

- Here we simulate a worst case scenario
- A mobile node is on a UAV that does a fly by (as opposed to stopping at the location).
- This tests the minimum transmission time we will have.



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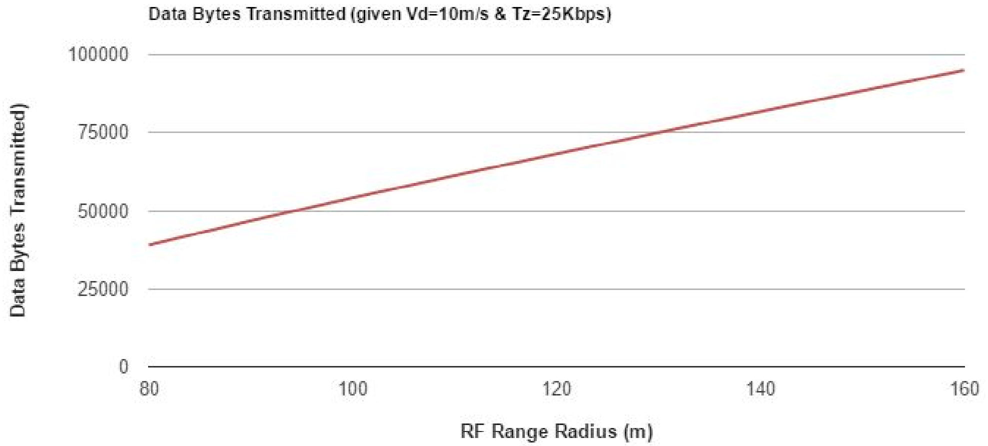
Transmission Time Simulation

10	UAV Speed m/s	25000	<--Zigbee Transmission rate				
Range Radius (m)		Flight Altitute			Contact Range	Contact Time	Data (byte)
80	6400	2500	3900	62.44997998	124.89996	12.489996	39031.23749
90	8100	2500	5600	74.83314774	149.6662955	14.96662955	46770.71733
100	10000	2500	7500	86.60254038	173.2050808	17.32050808	54126.58774
110	12100	2500	9600	97.97958971	195.9591794	19.59591794	61237.24357
120	14400	2500	11900	109.0871211	218.1742423	21.81742423	68179.45072
130	16900	2500	14400	120	240	24	75000
140	19600	2500	17100	130.7669683	261.5339366	26.15339366	81729.35519
150	22500	2500	20000	141.4213562	282.8427125	28.28427125	88388.34765
160	25600	2500	23100	151.9868415	303.9736831	30.39736831	94991.77596



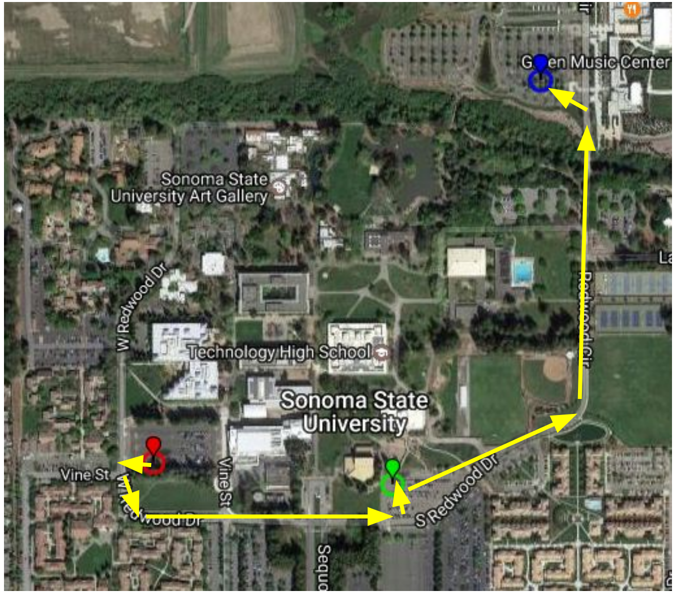
UAV Test

Early Prototype of Sensor Node

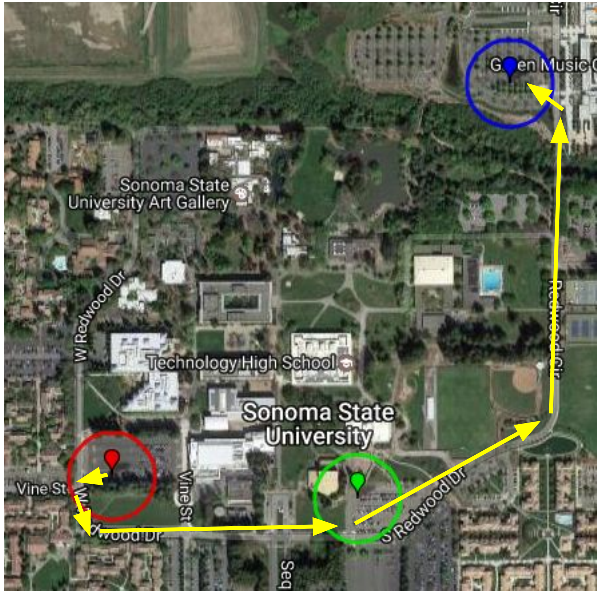
Flight Test	Height	Time Above Sensors
1	90 feet	5 minutes
2	50 feet	3 minutes
3	50 feet	1 minutes

Moving Mobile Node Test

MR4/MR6/MR11/ER3/ER9



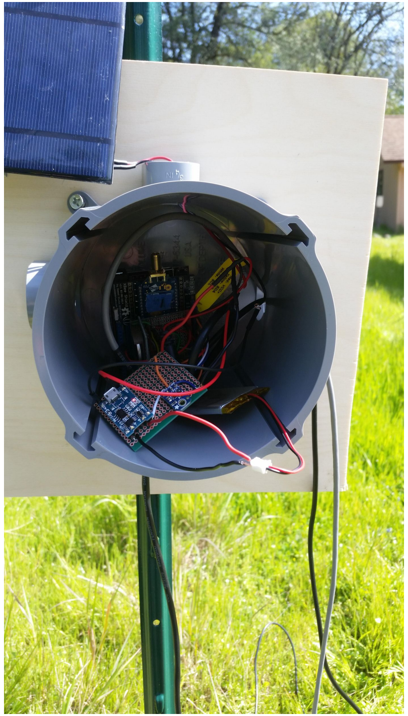
Sensor Node Locations with 50 ft. radius



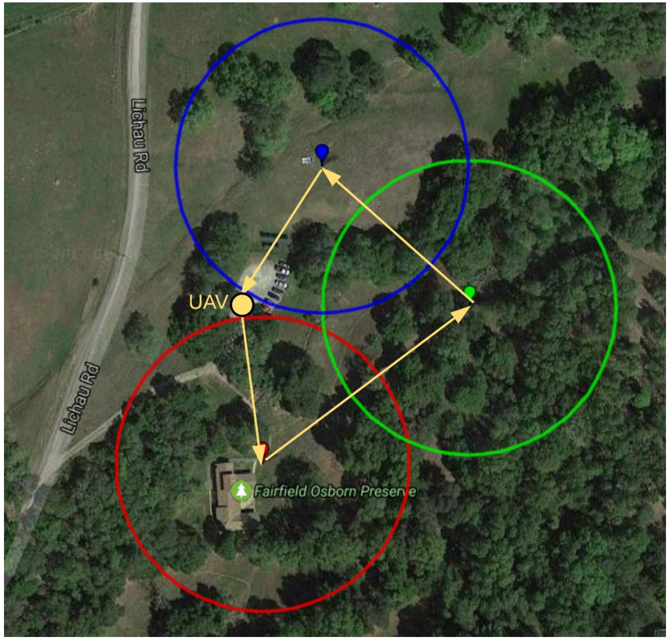
Sensor node locations with 200 ft. radius

Sensor Node - Complete

- After constructing each sensor node we placed them in a weatherproof PVC casing then hoisted up on a metal outdoors U-post. Both the sensor circuit and power circuit were able to fit in the casings.



Final Test



The flight path of the UAV along with the 200 ft GPS radius that the mobile node did the transmission in

	A	B	C	D	E
1	Node_Number	Date_Time	Temperature	Soil_Moisture	Humidity
2	1	4/21/2017 17:35	29.125	66.6151	35
3	1	4/21/2017 18:05	21.75	45.7066	36
4	1	4/21/2017 18:35	22.75	39.7379	36.2999
5	1	4/21/2017 19:05	26.3125	38.4683	35.7999
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7	1	4/21/2017 20:05	25.5	37.2149	34
8	GPS Coord	38.343465	-122.594609	0	0
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10	2	4/21/2017 21:05	21	38.4864	33.7
11	2	4/21/2017 21:35	19.1875	39.1799	33.7999
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14	2	4/21/2017 23:05	15.625	41.1727	35.9
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16	3	4/21/2017 23:35	14.8125	41.6583	36.2999
17	3	4/22/2017 0:05	14	42.5551	36.9
18	3	4/22/2017 0:35	13.3125	53.671	37.2999
19	3	4/22/2017 1:05	15.625	47.7884	47.2999
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21	3	4/22/2017 2:05	15	45.8864	41.7
22	GPS Coord	38.344578	-122.594327	0	0

Data from the test after being processed by our Matlab program.

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Estimated vs. Actual Budget

Estimated Budget of Parts: $633.31

Actual Cost of Parts: $991.00

*Some of the parts, such as the soil moisture sensors, were donated. Other parts were bought on sale for less. The budget does not include shipping.

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Schedule (Spring)

Project	Start Date	End Date	Days	%	Note	Alt Color
4.0 Winter Break Work	19-Dec	22-Jan	34	50%	All	gold
4.1 Start MatLab Program/ SD Card Initial system	19-Dec	22-Jan	34	0%	Taylor	green
4.2 Solar Power System/ GPS	19-Dec	22-Jan	34	0%	Josh	red
4.3 Xbee Configuration	19-Dec	22-Jan	34	0%	Abe	blue
4.4 Project Update #1	27-Jan	28-Jan	1	100%	All	purple
5.0 Implimentation	27-Jan	1-May	94	0%	All	gold
5.1.0 Zigbee Circuit	27-Jan	4-Mar	36	0%	Abe	blue
5.1.1 SD Circuit	27-Jan	4-Mar	36	0%	Taylor	green
5.1.2 Impliment Power System	27-Jan	4-Mar	36	0%	Josh	red
5.1.3 Project Update #2	3-Mar	4-Mar	1	100%	All	purple
5.2.0 Program Zigbee (MC)	4-Mar	18-Mar	14	0%	Abe	blue
5.2.1 Program SD Card (MC)	4-Mar	18-Mar	14	0%	Taylor	green
5.2.2 Program Clock (MC)	4-Mar	18-Mar	14	0%	Josh	red
5.2.3 Program Sensor Data (MC)	18-Mar	7-Apr	20	0%	Josh	red
5.2.4 Finish MatLab Program	18-Mar	7-Apr	20	0%	Taylor	green
5.2.5 Project Update #3	7-Apr	8-Apr	1	100%	All	purple
5.3 Final Testing/Debugging	7-Apr	1-May	24	0%	All	gold
6.0 Final Presentation Prep.	1-May	15-May	14	50%	All	gold
6.1 Final PowerPoint	3-May	13-May	10	50%	All	gold
6.2 Final Documentation	27-Jan	3-May	96	50%	All	gold
6.3 Final Presentation Practice	13-May	14-May	1	50%	All	gold

Taylor	Green
Josh	Red
Abe	Blue
All	Gold

4.0: Winter Break Work: Matlab program, SD card, power system, gps, Xbee configuration.
5.0: Implementation: circuit design and build, microcontroller programming, debugging.
6.0: Final Presentation Preparation: Powerpoint, final documentation, practice.

Lessons Learned

- Document everything.
- Project budget management.
- Sensor Calibration takes time and patience.
- How to power devices through a solar panel.
- How to manipulate a GPS module.
- How to make an idea into a product and understand the processes that go along with it.
- Collaborating with the SSU UAV committee required paperwork and separate meetings.
- Learning the importance of time management.
- Dealing with weather that prevents outside testing.

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Future Work

- Make the system completely autonomous.
- Make a network where each sensor node is connected together and sends the data to a central node when asked.
- Have the data from the sensor nodes display data in real time.
- Implement a data archiving system.
- More user friendly GPS coordinate set up.
- Change over from uC32 and WF32 boards to independent microcontrollers to further reduce size and cost of the nodes.

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A Special Thanks

- Our Faculty Advisors Dr. Chris Halle and Dr. Farid Farahmand for their help and support.
- Our Industry Advisor, Mr. Sean Headrick and Aerotestra for making our final test possible.
- The SSU SOURCE award for funding this project and making it possible.
- MESA coordinator, Dr. Carolyn Peruta, for donating soil moisture sensors for this project.
- Our intern, Micaela Bush of MESA, at Santa Rosa Junior College for helping us with necessary testing at the Pepperwood Preserve and project documentation.
- Suzanne Decoursey, reservations manager at the Fairfield Osborne Preserve, for letting us test this project at the preserve.
- Our friends and family for their support.

Questions/Comments

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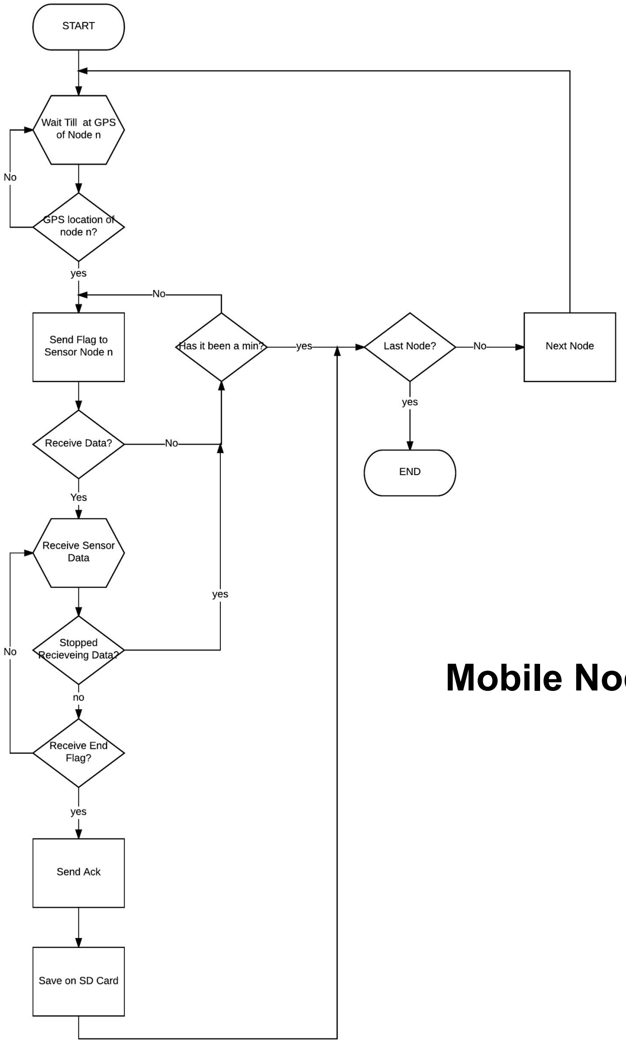
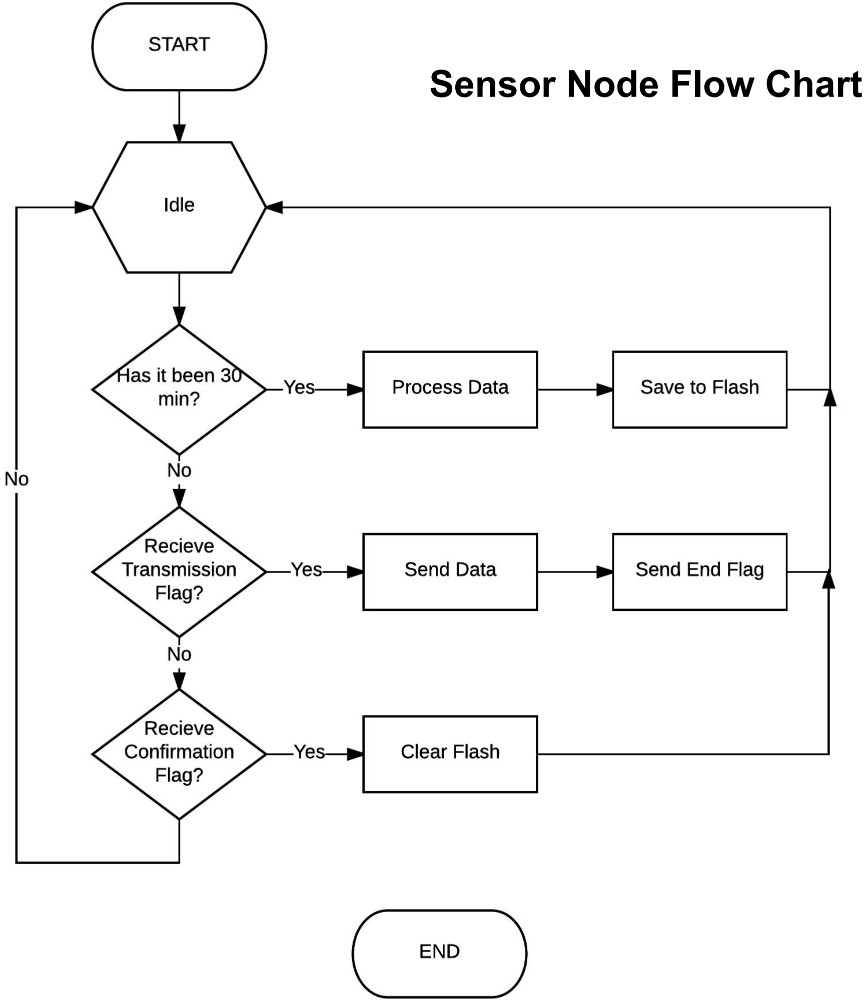
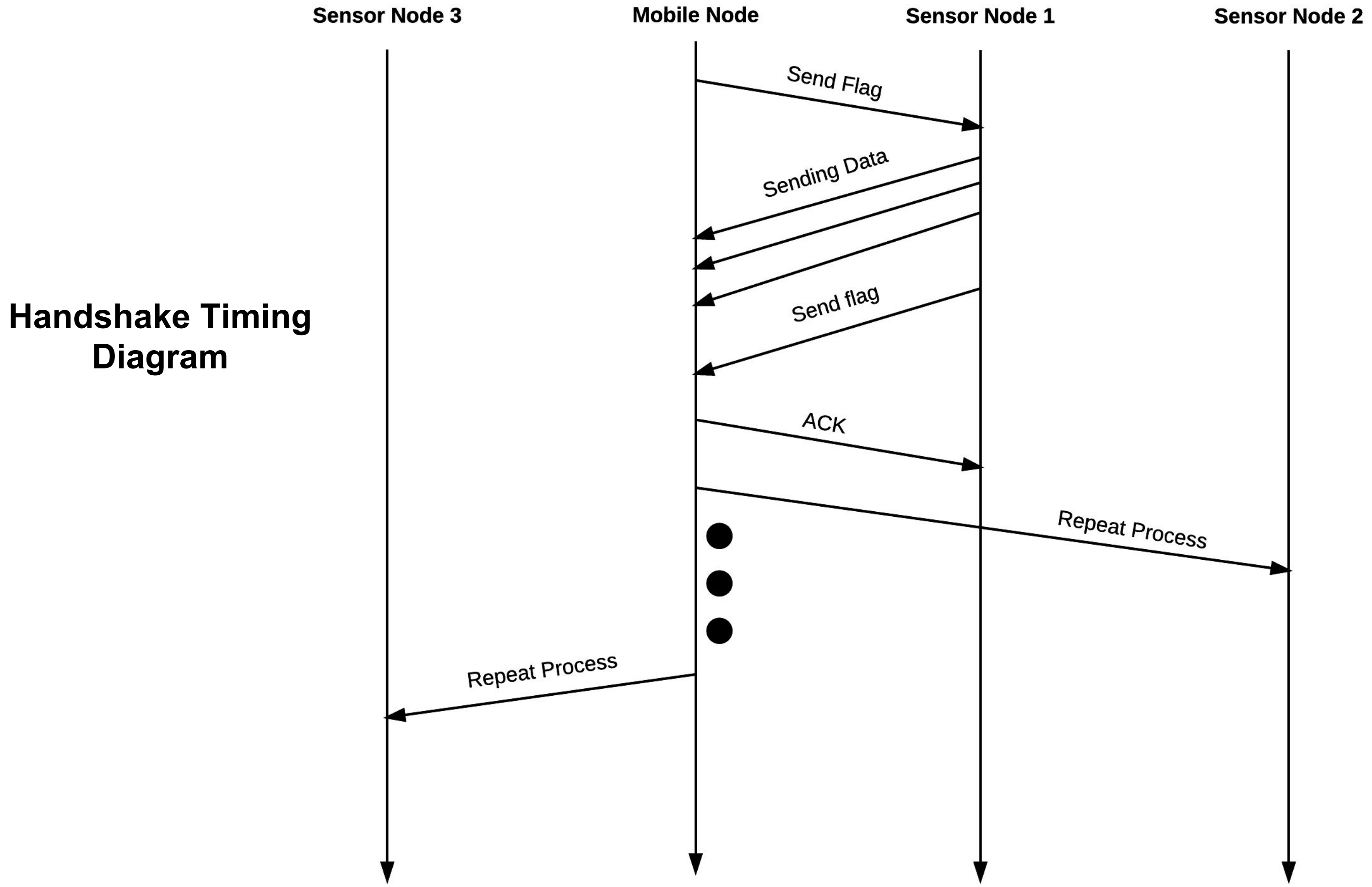


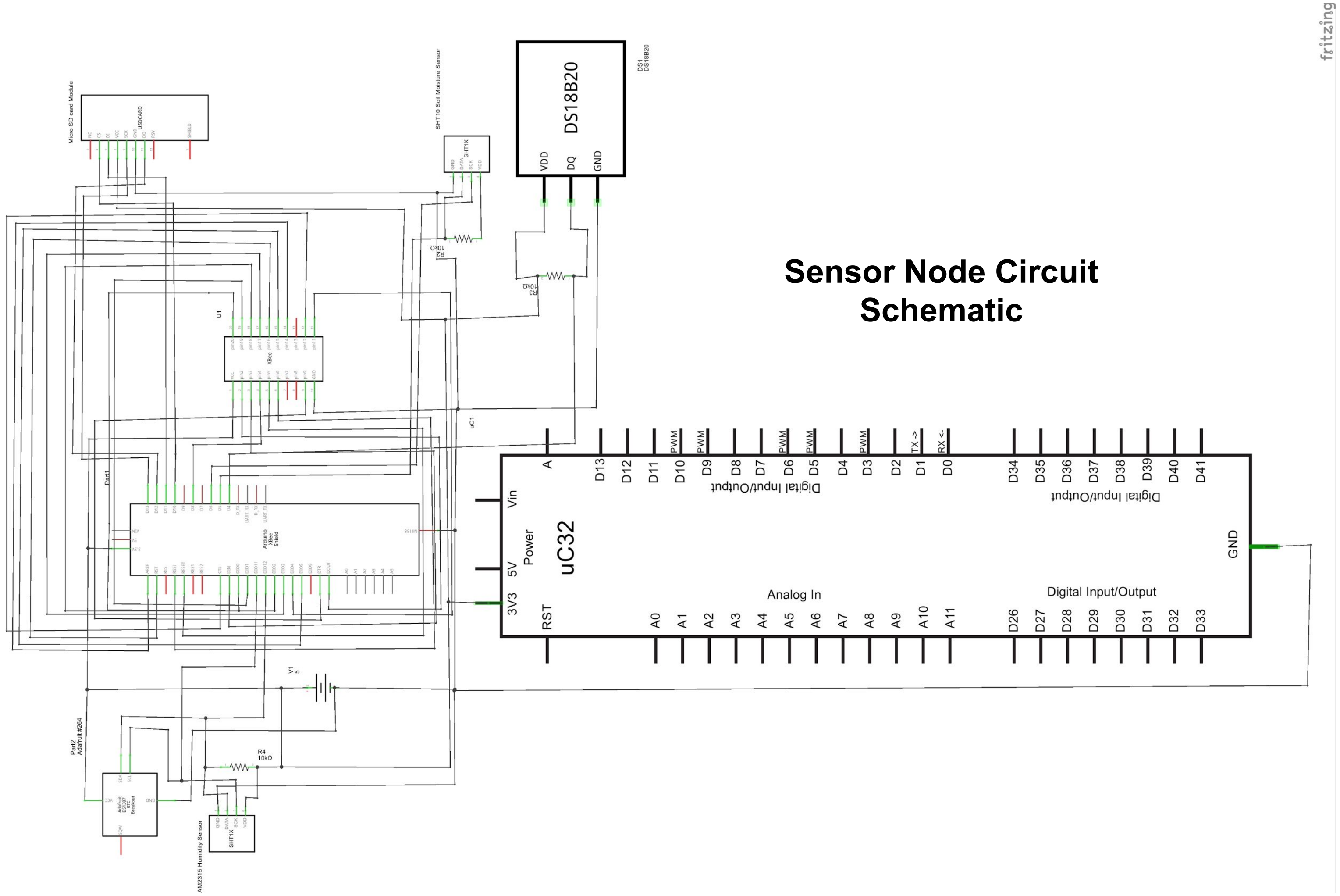
Mobile Node Flow Chart

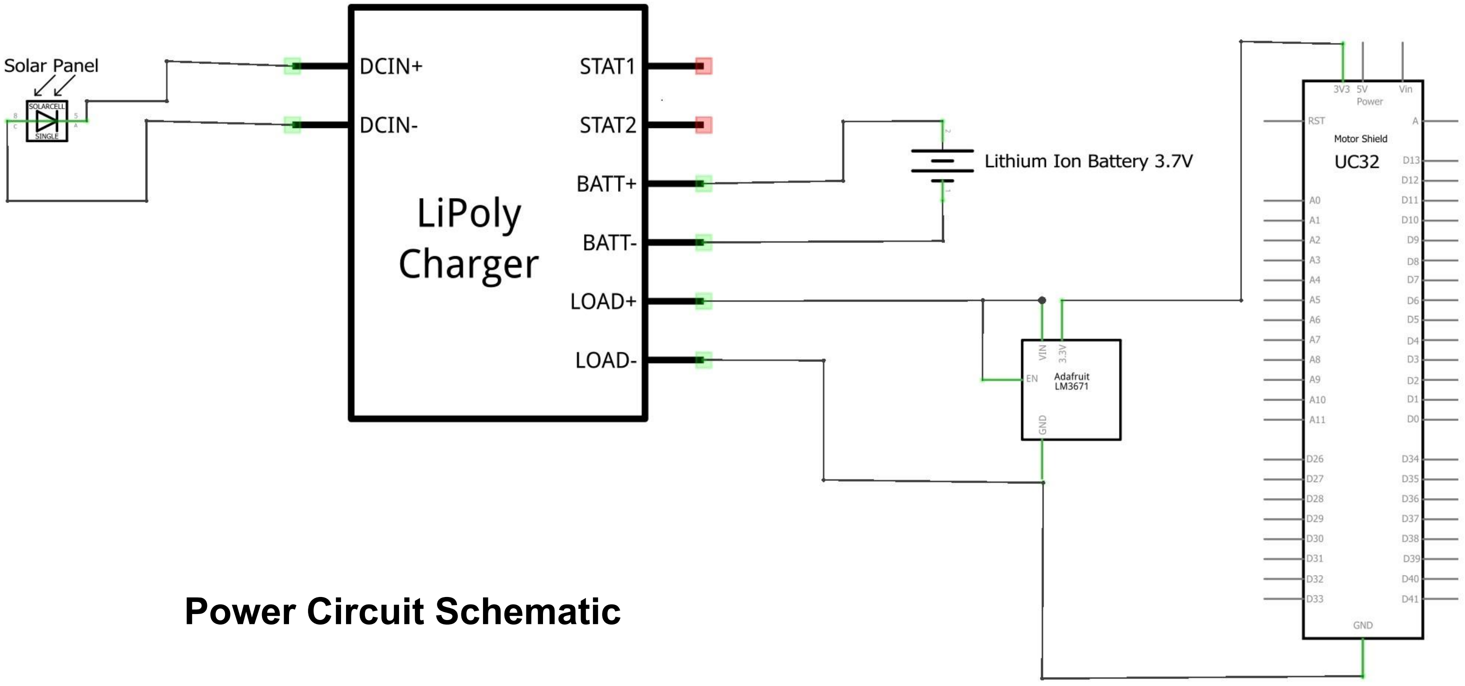
Sensor Node Flow Chart



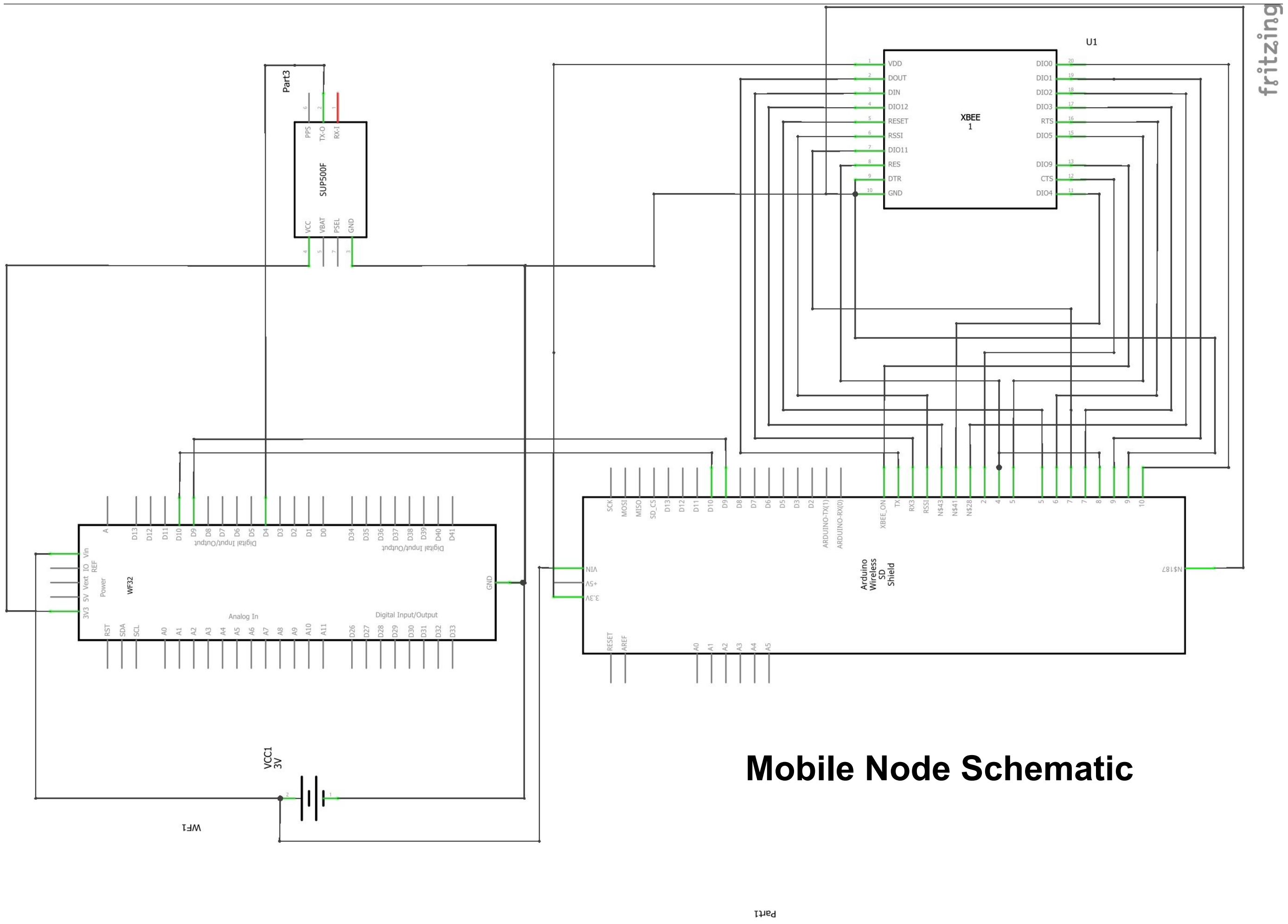

Handshake Timing Diagram
Sensor Node 3
Mobile Node
Sensor Node 1
Sensor Node 2
Send Flag
Sending Data
Send flag
ACK
Repeat Process
Repeat Process

Sensor Node Circuit Schematic





Power Circuit Schematic



Mobile Node Schematic

Calibration

- We stir our temperature probe in the ice bath while running the program until we reached freezing point temperature.

```
ROM = 28 8E C0 A9 8 0 0 DA
  Chip = DS18B20
  Data = 1 6 0 4B 46 7F FF A 10 F1  CRC=F1
  Temperature = 0.37 Celsius, 32.67 Fahrenheit
No more addresses.

ROM = 28 8E C0 A9 8 0 0 DA
```

Budget/Components

Quantity	Part	Price
3	3.7V 1200 mAH batteries	$10.00 each
3	Digilent chipKIT uC32	$30.00 each
1	Digilent chipKIT WF32	$70.00
4	Xbee S3 Pro Radio Module	$42.00 each
4	Xbee breakout boards	$3.00 each
3	Temperature Sensors	$10.00 each

Quantity	Part	Price
3	Soil Moisture Sensors	$50.00
3	Humidity Sensors	$30.00 each
3	Device casings for sensor nodes	$20.00 each
1	GPS Module	$16.50
3	Real Time Clock Module	$6.00 each
3	Solar Panels	$9.00 each
4	900MHz Duck Antennas	$6.36 each

Quantity	Part	Price
4	Xbee Shield	$12.00
4	16 GB micro SD card	$10.00 each
3	Micro SD card Module	$7.50
3	3.3V buck converter	$5.00 each
3	LiPo charger board	$6.00 each