(Sensor suite) Product Design Specification

Team 20
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ECE 412 Capstone Project Development
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5 February 2021
Version 1.0

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Executive Summary:

The Sensor Suite is a network of low power, wireless motes that measure the environmental data within the network, and displays this data to the user in a meaningful way. The environmental data acquisition will include sensors like temperature, humidity, CO_2, wind speed, etc. We are creating this device because the agriculture industry depends on optimal weather conditions for the best quality in their plants or livestock which amounts to an increase in profits, although this device can be used in other industries. By interpreting the data, growers can alleviate risks that may affect their yields. The user will manage the Sensor Suite through setup, maintenance, and data interpretation. Management entails the deployment of new motes and a base station, recharging of old motes, and responding to environmental changes based on data presented to the user via visual dashboard.

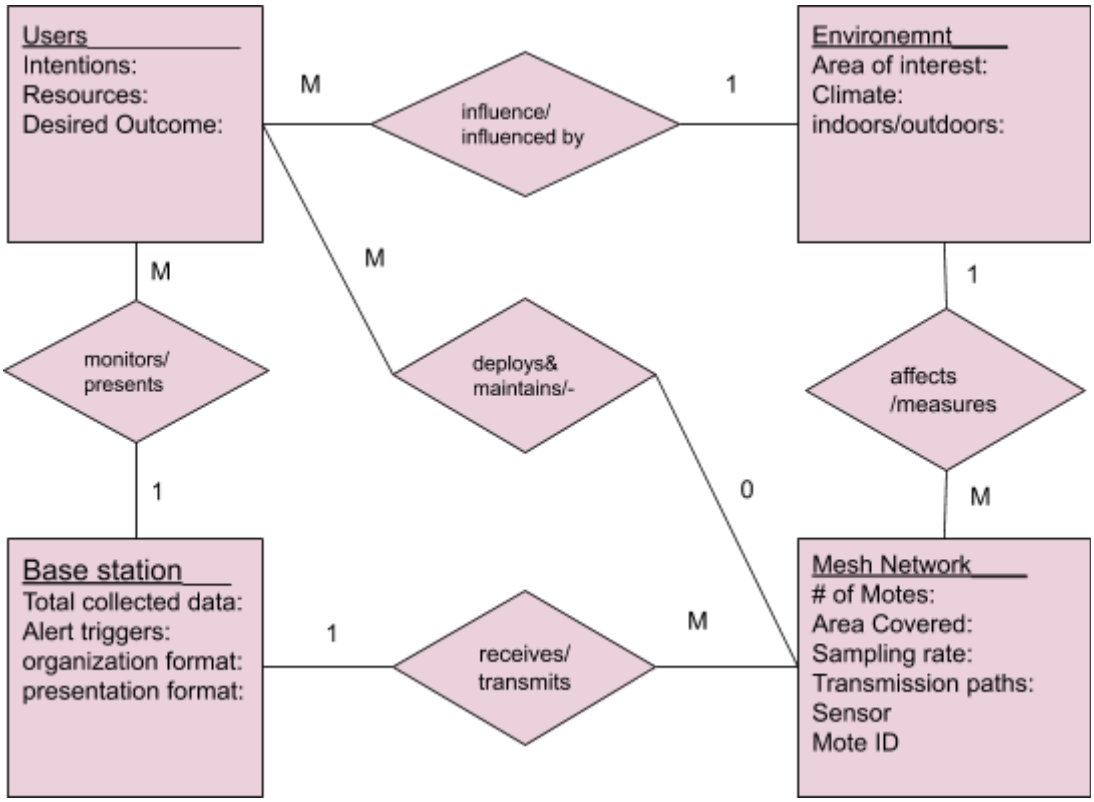


Figure (1): Concept of Operations Model

Setup:

Deployment of the motes must cover the area of interest with at most 150 feet of spacing between each mote being 2 meters above the surface, and at least 1 mote being within 150 feet of the base station. Each mote must have visible sensors free from obstructions, particulates, and contaminates to ensure recording of accurate measurements. A 2.4 GHz WiFi connection must be provided to the base station using a transmission control protocol (TCP).

Maintenance

Each mote will have a battery that will need to be recharged once depleted.

Use

The base station will have an interface that enables the user to view data gathered in the last 24 hours, view data gathered through its history and view selective sensor data from each mote. Based on data gathered, the user must correct any significant changes in the environment within a mote(s) to promote desired behavior (for example: promote crop yield).

Market Analysis:

The largest viable market is the agriculture industry where atmospheric data can be used to better help the growth of plants or livestock, this includes people in farming, aquafarming, forestry, ranching, etc. In terms of market competition we found a couple weather monitoring systems that measure lots of atmospheric data and also log it wirelessly, but are costly starting at $1,500 dollars. A competitor is OnSet's HOBOnet field monitoring system, which is solar powered, has rechargeable batteries, and has an app that collects data through a wireless mesh network. This system is also restrictive in its use and focused primarily on farming.

Figure (2): Physical Model Representation of the Mesh Network

Our project, in comparison, will differ by aiming to be much more flexible as it can also be used for data aggregation for climate research, and can be used to create live meteorology maps that track multiple atmospheric metrics simultaneously to create an incredibly verbose atmospheric analysis of a region at a high resolution. Additionally, this system can be used to monitor facilities that have many machines or complex pipe systems. Consequently, use more types of sensors to reflect the flexible implementations it supports, while being able to perform more complex analysis on the front end. Sensors per mote are chosen by the customer and added at time of assembly. This can reduce customer expense by not paying for sensors they don't need. In summary, our design is low power, has a more compact housing, and scales price with customer needs

Stakeholders

Stakeholders		
Name	Organization	Contribution
Dr. David Burnett	ECE Department	To be determined
Outside sponsors	OnePointOne	To be determined

Requirements & specifications

Project Requirements		
Must	Should	May
Use a low voltage power supply (12V or less).	Be in a low power state when not in use.	Be solar powered.
Be able to wirelessly communicate data every 10 mins within a maximum range of at least 150 ft between any given two motes.	Use SmartMesh IP.	Be able to adjust individual sample rates for each mote independently, and allow over the air programming (OTAP).
Have IP65 rated housing.	Have IP67 rated housing.	Be the size of a Puck or similar.
Measure temperature and humidity, light intensity, acceleration and wind speed.	Measure CO2 gas and O2 gas, and detect water contact.	Measure other environmental or relevant data.
Display collected data over the last 24 hours, which updates every 10 minutes, and permanently logs data.	Be able to present data using maps or diagrams, adding mean and standard deviation parameters.	

Must be able to support at least 5 motes	Must be able to support at least 100 motes	Must be able to support at least 1000+
Maximum power consumption of each mote must not exceed the peak power operation of all components used +20%.		

Deliverables

Hardware:

- Power optimized Mote prototype made using PCB layout
- Durable and weatherproof Mote housing.

Firmware:

- Frontend software and GUI: software that will manage as well as receive and store data from a mesh network. Moreover, a User interface that will display collected data as well as allowing the user to observe mote status.

Documentation:

- Complete documentation
- Bill of materials
- System schematic & functional diagram
- Design files for any custom mechanical components or PCBs
- Operations guide

Initial Product Designs

The system architecture has three core modules: sensor mote - the collection of data via sensors, mesh network - the transportation of the data via wireless communication, and base station - the presentation & storage of this data via the front-end software. The sensor motes and the mesh network have to balance power consumption and compatibility. We have two possible architectures for the mote, one is where the sensors feed directly into the wireless module(master mode) and the other is that the sensors feed into a separate microcontroller that then feeds into the wireless module (slave mode). This architecture is largely possible because of the Smartmesh networking system which automates and simplifies the setup and maintenance of a mesh network, using their low power LTP wireless modules.

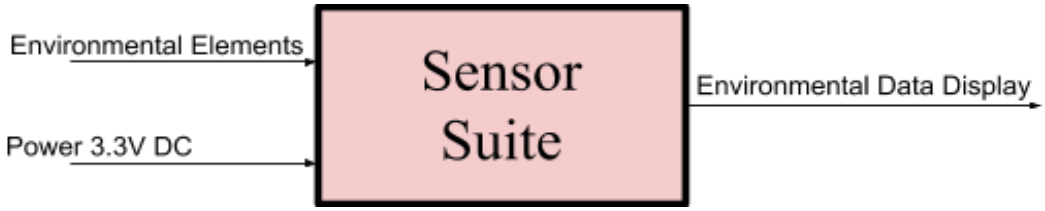


Figure (4): Level 0 Block Diagram

Module	Sensor Suite
Inputs	Power: 3.3V DC Environmental Elements: Measured by various sensors. Temperature, -40°C to 85° C Humidity, 10% to 90% RH Wind Speed, 0 to 60 mph Acceleration, -5000 to 5000 g Light Intensity, 0.1 to 40,000 LUX
Outputs	Environmental Data Display: Graphical representation.
Functionality	Displays environmental data based on measurements sampled from sensors.

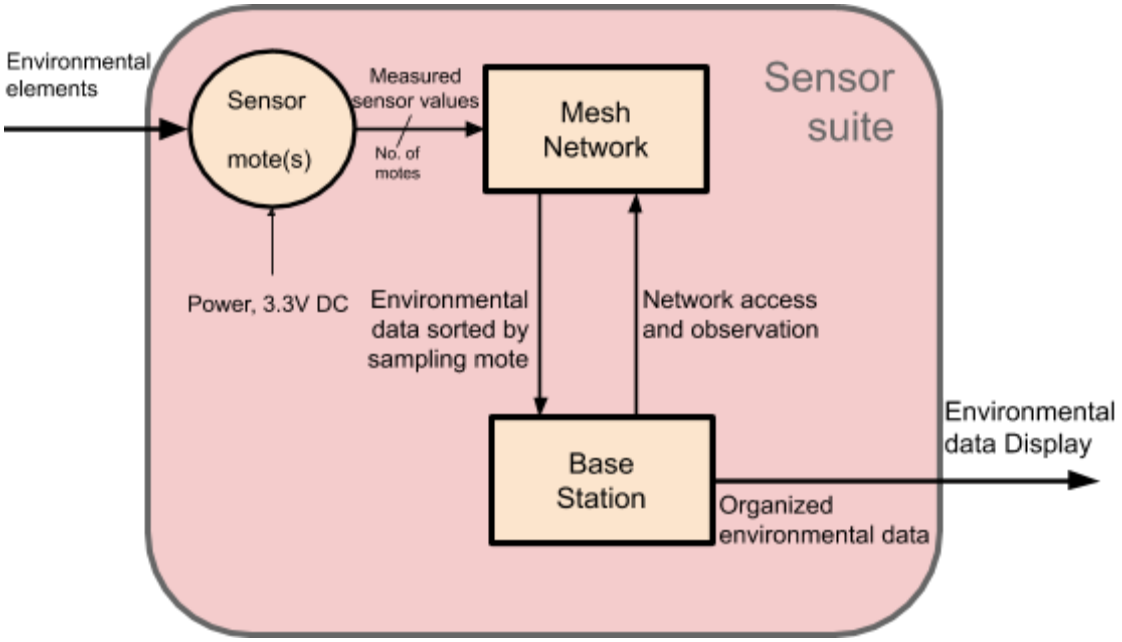


Figure (5): Level 1 Block Diagram

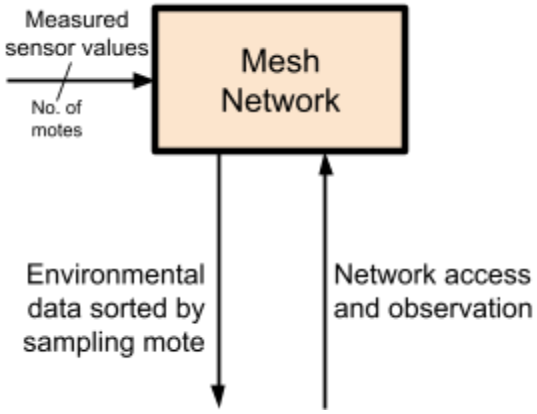


Figure (6) Level 1 Block Diagram (Mesh Network)

Module	Mesh Network
Inputs	Measured sensor values: Measured values from each sensor on the Sensor Mote.
Outputs	Environmental Data: Serial packets of measured sensor values with corresponding mote ID.
Functionality	Provides a path for measured data from Sensor Mote(s) to Base Station.

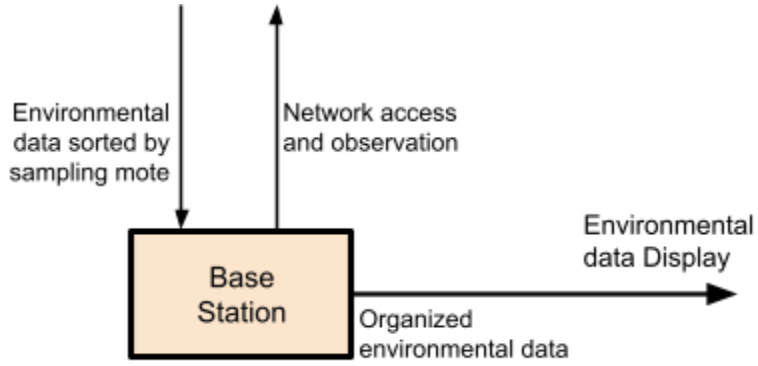


Figure (7) Level 1 Block Diagram (Base Station)

Module	Base Station
Inputs	Environmental Data
Outputs	Organized Environmental data display.
Functionality	Provide environmental data to visual display.

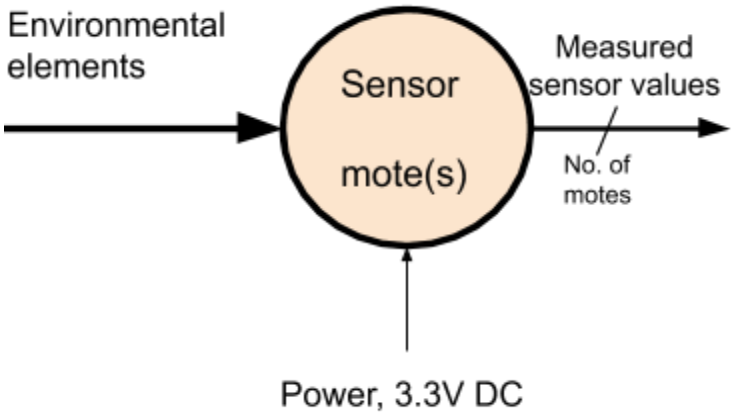


Figure (8) Level 1 Block Diagram (Sensor Mote)

Module	Sensor Mote(s)
Inputs	Power: 3.3V Environmental elements: Measured by various sensors
Outputs	Sensor Data indexed with corresponding Mote ID
Functionality	Provide environmental data to visual display.

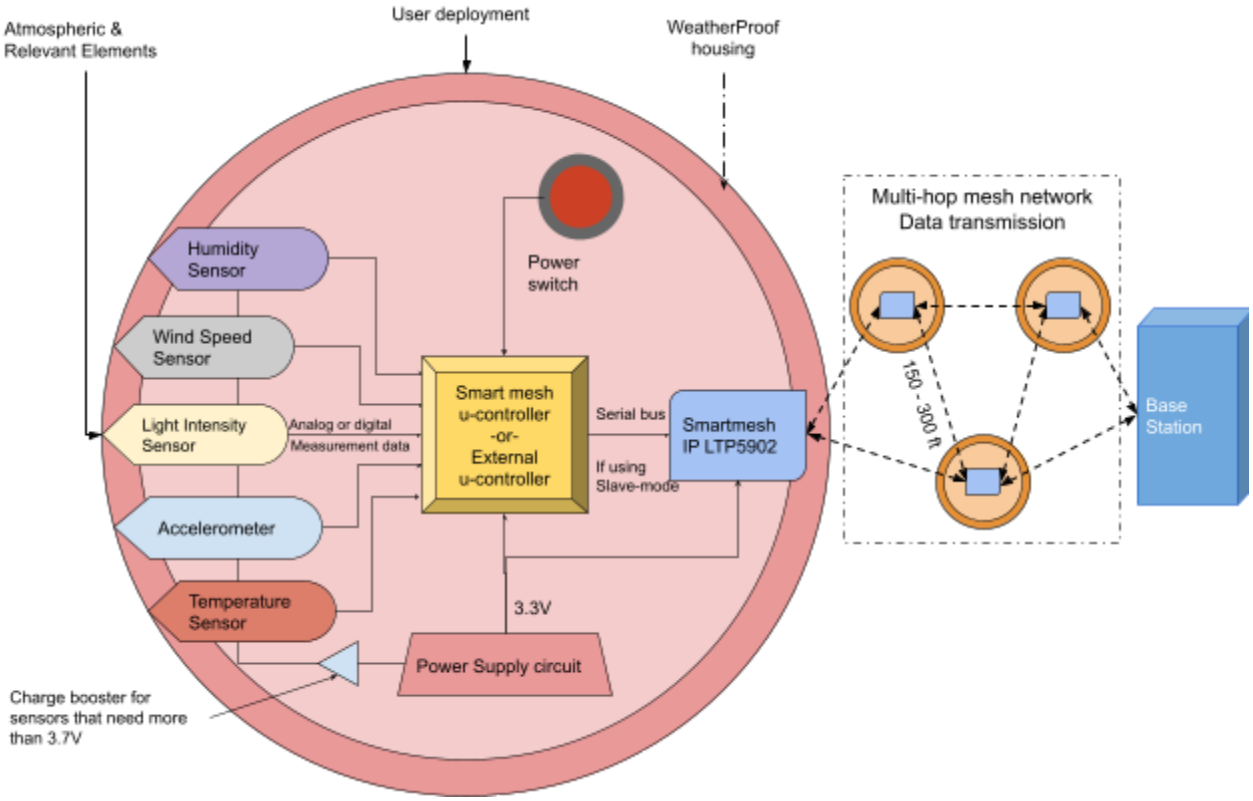


Figure (9): Level 2 Design Diagram - Mote and Mesh Network

Design Specifications

Sensor Mote

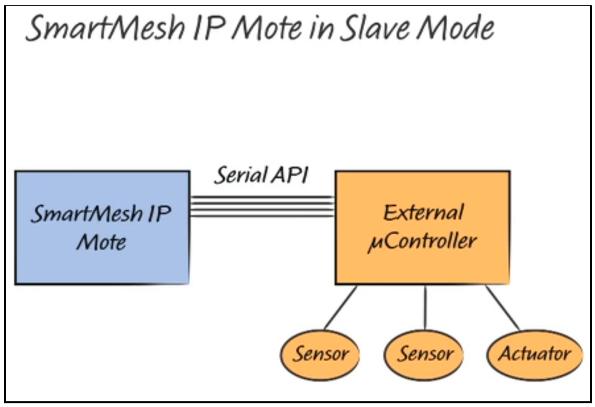
Processor:

- SmartMesh IP - LTP 5902 module: used to transmit data gathered by the microcontroller (slave mode), but may be used as the primary microcontroller (master mode) if possible to simplify the build and management of the mote.

- Texas instruments - MSP432P401: communicate with the sensors to measure relevant data and transfer the data over to the wireless module via SPI in order for the wireless module to transmit the data over the mesh network.

Mechanical Design: An IP65 rated housing for the Sensor Motes and the Base Station.
Firmware:

- Smart mesh software and libraries will be used to make full use of the LTP5902 modules integrated into the design of the motes. Modified Smartmesh python code will be loaded onto the LTP5902 module
- External microcontroller will be loaded with C code using code composer studio



Development Environment: C++ and Python. Arduino programming language is advised against due to lack of capabilities with desired features such as switching between low power state operation and wake up operation. However, it may be used for quick prototype testing of components like sensors.

Sensor	Sensor range			Normal Operating Current	Peak Power (mW)
	Min	Increment	Max		
Light Intensity- OPT3001	0.1 LUX	+/- 0.1 LUX	40,000 LUX	1.8µA	0.006
Temperature - MAX302	-40°C	+/- 0.1°C	85°C	67µA	0.2
Humidity- HIH8120	10% RH	+/- 2 RH	90% RH	650µA	21
Acceleration - ADXL362	-5000 g	+/- 2 g	5000 g	2µA	0.004
Wind speed- Wind sensor (REV.C)	0 mph	NA	60 mph	40mA	200
Controller	Normal Operating Conditions				Peak Power (mW)
LTP5902	1.3mAh at 3.3V				43
MSP432	80µA/MHz at 3.3V				12.5 (at max clock)

*Peak power values are overestimated.
The total power consumption of these core components is 277 mW.

Operating Conditions (Mote):

	MIN	MAX
Voltage	3.3V	3.3V
Temperature	-40°C	85°C
Humidity	10% RH	90% RH
Optimal Placement(off Ground)	2 m	-

Base Station

Smart mesh API:

- Smartmesh IP software solutions shall be used to monitor networks, receive and organize for better accessibility and long term storage.
- May be used to control motes sampling through over-the-air programing (OTAP)

Front-end GUI:

- The Base station may have a GUI and be capable of complex data analysis and live data graphing

Project Management Plan

Budget: Pending with outside Sponsors.

Team and development process:
Members, tasks, strengths:

- **Brandon:** Github/Documentation, Microcontroller, Sensor coding/Integration/Testing
  - Skills: programming, soldering
- **Yikun:** Microcontroller, Sensor coding/Integration/Testing
  - Skills: hardware debugging
- **Yudi:** PCB design, SmartMesh Software
  - Skills: programming and software integration
- **Yousef**: SmartMesh IP Integration & Housing Design & visual dashboard design
  - Skills: programing and debugging, circuit design
- **Calvin**: Schematic design/PCB Layout, SmartMesh IP Network, Documentation
  - Skills: THT soldering, PCB CAD, troubleshooting, circuit design

***Yikun and Yudi are positioned in China at the moment. So there are difficulties collaborating on hardware development.**

Collaboration:

- The main collaboration tools we are going to use are Github projects and Google drive.
- Some tasks may include collaboration depending on the complexity of the task.

Design methodology:

- We are using scrum as a design methodology, we are currently doing weekly standup meetings with our sponsor.

Schedule: The schedule plan was uploaded as a separate Microsoft Projects file along with this document.

Sponsor approval

***IMPORTANT* This document is still under review and is pending approval.**