Small-Form-Factor Solar-Powered Self-Sustainable IoT Sensors with Long-Range Wireless Communication

DESIGN DOCUMENT

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Executive Summary

Development Standards & Practices Used

- C code Standards
- Well-Documented & Labelled circuit boards
- Clean PCB layout
- Software testing standards

Summary of Requirements

- Sensors will be programed to work with MCU and achieve measurement in a very low frequency
- Long-range wireless communication module will be programed to work with MCU and can transmit data 1 mile away
- Fully sustainable
- Lower power consumption
- Powered by solar cells
- Small design (pocket sized)

Applicable Courses from Iowa State University Curriculum

- EE 201 - Electronic circuits
- EE 230 - Electronic circuits and systems
- EE 330 - Integrated electronics
- EE 321 - Communication system
- EE 333 - Electronic System Design
- CprE 288 - Embedded Systems
- CprE 281 - Digital Logic
- CprE 185 - Introduction to Problem Solving

New Skills/Knowledge acquired that was not taught in courses

- Long Range wireless communication
- Arduino Programming

Table of Contents

List of figures/tables/symbols/definitions (This should be the similar to the project plan)

1 Introduction

1.1 Acknowledgement

We would like to thank Dr. Lu and Dr. Huang for helping us in this project. They gave us a very detailed guide for the whole design process and provided helpful suggestions.

1.2 Problem and Project Statement

Our project is Small-Form-Factor Solar-Powered Self-Sustainable IoT Sensors with Long-Range(LoRa) Wireless Communication. This project needs us to detect the light, humidity and temperature in an open field. Using long-range wireless communication module, we must transmit data to a LoRa gateway(approximately 1 mile away). After that, this data can be monitored by the users from a web browser or a smart phone app. The overall system is fully self-sustainable using solar power energy and with power optimization.

This project will help our client collect data on the presence of bacteria based on factors such as temperature, humidity, and presence of light.

1.3Operational Environment

This project will be used in an open field, so it should be waterproof and must be able to work under temperature ranges from 10~90 F.

1.4Requirements

- The sensors can collect data correctly
- The data can be transmitted through internet
- The product must be pocket sized
- The entire system needs to be fully self-sustainable
- The power consumption needs to be very low
- The end product needs to be waterproof
- The end product needs to work under cold and hot temperature

1.5Intended Users and Uses

Our intended user is our client, Dr. Lu. He should be able to keep the product in an open field and remotely collect data to assist in detecting bacteria.

1.6Assumptions and Limitations

Assumptions

- The environment it is placed in will have sunlight available
- The environment will not have obscene conditions (-50 degree weather/hurricanes/tornadoes)

Limitations

- The end product should be pocket size
- Lower power consumption

1.7 Expected End Product and Deliverables

At the end of this semester, we will produce a prototype that is comprised with all the sensors and the LoRa wireless communication module. We will then evaluate the power consumption of our device as well as begin custom PCB designs for the final product.

In the second semester, we will be working on the power optimization of the entire system and try to find a low-power MCU other than Arduino.

At the end, prototyping hardware with all the sensors, LoRa wireless module and power management circuits in the PCB level. The final product will be pocket size, fully self-sustainable by solar energy, and can work under specific weather conditions.

2. Specifications and Analysis

2.1 Proposed Design

The design we have come up with involves sensors being operated by an Arduino. This Arduino will also have access to a Long Range Wireless Module that can send data through the Internet. Figure 1 below outlines our design.

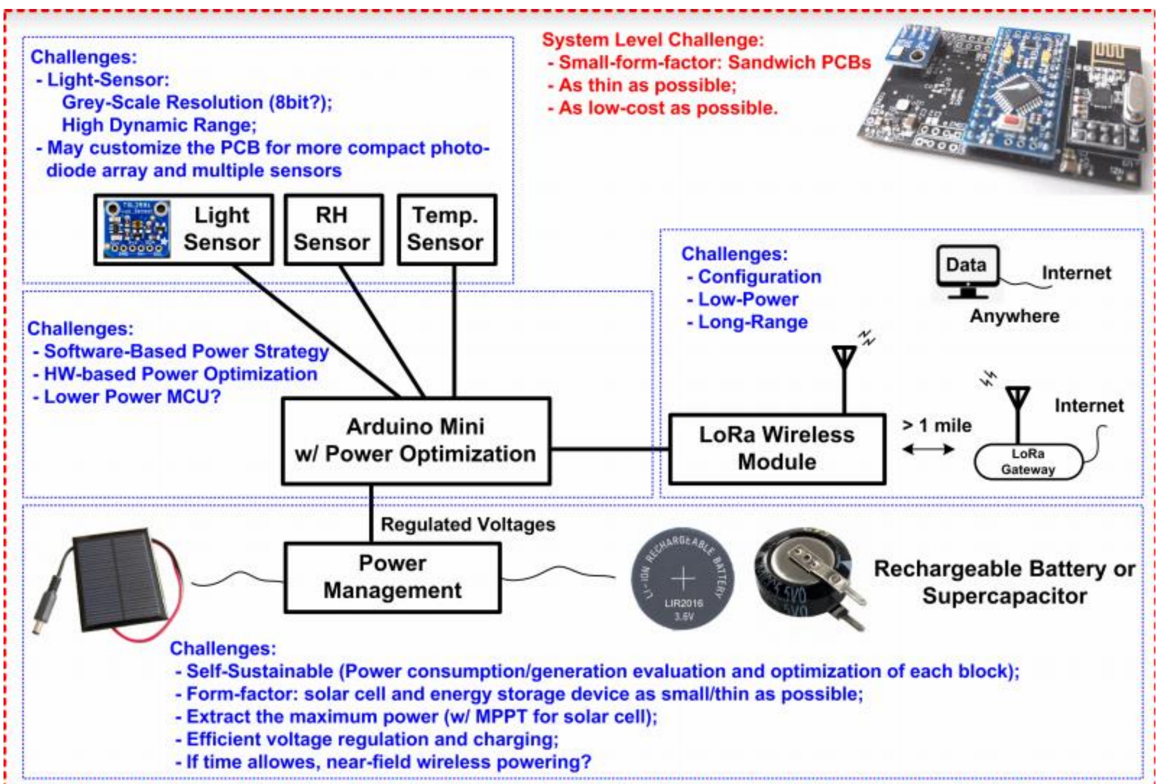


Fig. 1 - Proposed Design

2.2 DESIGN ANALYSIS

Our group was separated into three sub-groups, and each group has its own task. We have done the research on the required components for our project, and the order for the components has been placed. We think it is really efficient that we work for different parts of the project, and finally we can combine our work together.

2.3 DEVELOPMENT PROCESS

Our team is following the waterfall model. We have the requirements from our client and have designed what we think would be the best approach in solving the problem. We split into teams in order to divvy up the workload and will combine the work that each team has completed at the end.

2.4 DESIGN PLAN

Diagram:

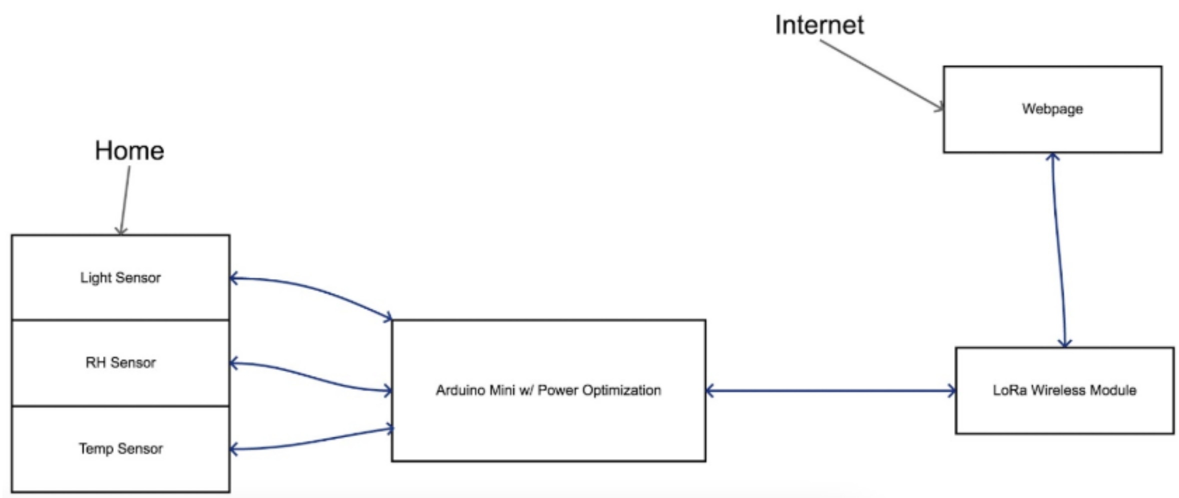


Fig. 2 - High Level Design

3. Statement of Work

3.1 PREVIOUS WORK AND LITERATURE

Our product is small-form-factor-powered self-sustainable IoT sensors with Long-Range Wireless Communication. We can find a lot of the same types of LORA wireless IoT products in the market. However, comparing with the normal LORA wireless IoT products, our product will have two advantages. First, our product can be completely powered by solar energy, which is very environmentally friendly and saves energy. Second, our product is designed so small that people do not need a large place to set up it.

3.2 Technology Considerations

There are a lot of off the market sensors available that we could use for this project, however a lot of them contain too much extra components that use more power and more ports on our Arduino than we can afford. Although the abstracted sensors are well-documented and easier to use, they will not work for our project.

We will have to find sensors that are solely the sensor without added components and build a custom PCB that can collect the correct data without unnecessary components.

3.3 Possible Risks And Risk Management

A risk that we have considered is the reliability of transmitting data. Our LoRa module specifications are at the limit of our desired range, so there could be times when data is not received due to being out of range. We have planned to combat this by investing in a different antenna than what came with the LoRa module. This will hopefully amplify the range enough to where it will work consistently.

Another risk is the light sensor ability to sense low levels of light. The light sensor will be sensing light generated from bacteria in the soil. Since we are unable to test our sensors in this environment, we are left to replicate the environment with what we know.

3.4 Project Proposed Milestones and Evaluation Criteria

Our main milestones are as follows:

- Semester 1
    - Complete component research and place order
    - Functional sensors
    - Functional LoRa module
    - Functional LoRa module with sensors
    - PCB design
- Semester 2
    - Complete component research and place order
    - Functional self-sustainability component
    - Update PCB design
    - Finalize and order PCB
    - Build and test full prototype

- Build final design

For component research, we will have to do extensive research to be sure that components do what we need and are compatible with our other components. To test the functionality of the components is to test they work in our desired way. Once we have confirmed they do, we can start adjusting them to work in the way our project desires. Testing them beforehand also gives a better understanding of the device.

3.5 Project Tracking Procedures

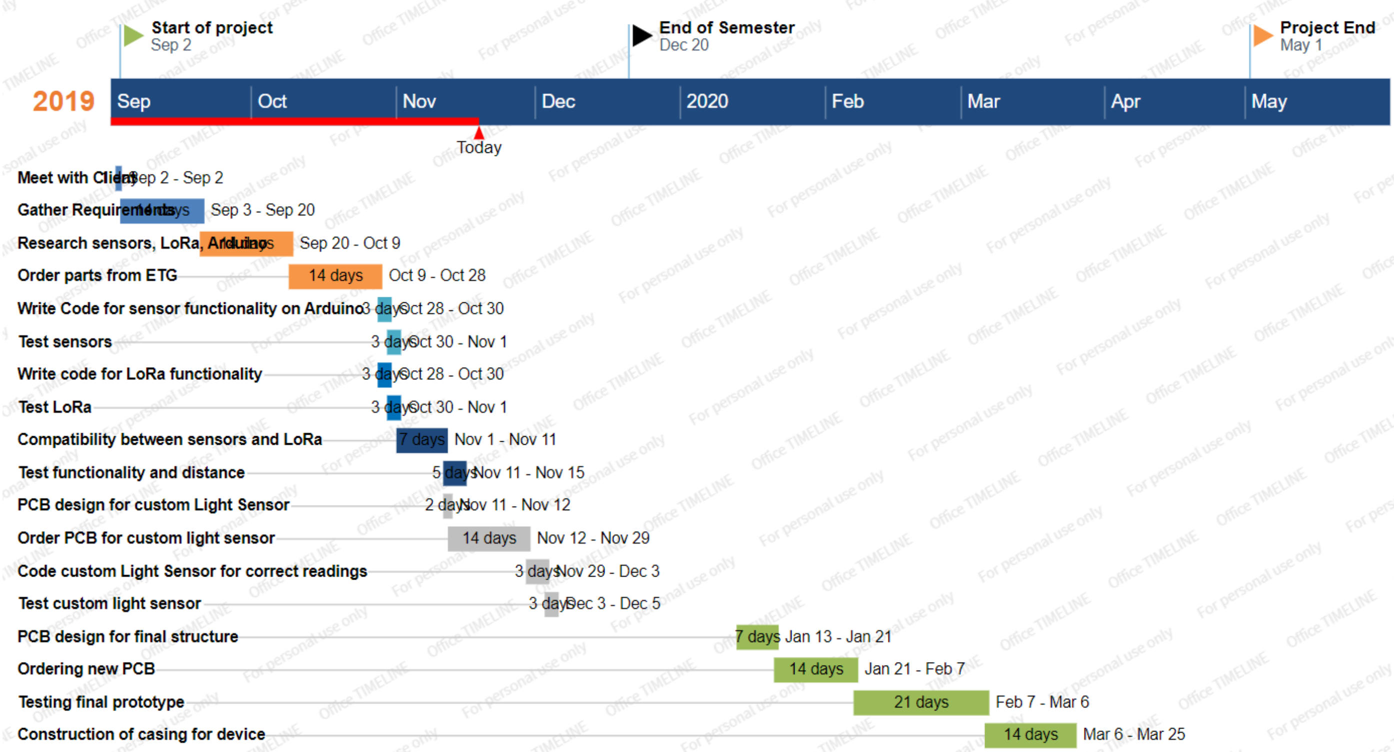
In our group, we have a simple way to track progress throughout the course of this and next semester. We have made a time table for our group project. In this way, our team has set a time table, so that we can compare every small goals with actual progress.

3.6 Expected Results and Validation

Our project has some basic expectations it has to meet. If we meet these expectations, we are confident it is working at a high level. These outcomes include: accurate sensor measurements, consistent data communication, and self sustainability.

4. Project Timeline, Estimated Resources, and Challenges

4.1 Project Timeline



In order to complete our project in 2 semesters, we have to complete a lot of the initial design steps in the first semester and begin constructing the device right away so that it leaves us time to test and make changes in the second semester.

The Gantt Chart provided above shows our proposed timeline. Most of the deliverables are in the first Semester by design. We want to get as much done as possible in the first Semester, because we believe there will be a lot of work to do in constructing the final version of our device as we have not taken power consumption into consideration yet. We have found it useful to assume ordering parts from the ETG will take around 2 weeks to deliver.

4.2 Feasibility Assessment

In real life, our project will be a detector in a black box that can record temperature and humidity of an open field and the illuminations coming off of bacteria. Foreseen challenges include not having a sensitive enough light sensor to pick up the emitted light, using too much power, and not having a long enough range on our wireless communication.

4.3 Personnel Effort Requirements

Task	Personnel effort	Time
Parts research	We have to do a lot of research to select the right parts for our project. Our parts need to be low power consumption to meet our requirements.	Calvin: 6 h Chuxin:6 h Qin: 6 h Lun: 6 h Yuchen: 8h Luke:8 h
Sensor testing	We check the data sheet to make sure how to connect with the breadboard, and then,set up the Arduino and write the code to function every sensor. We need to make sure all the data read from Arduino are correct.	Calvin:6 h Chuxin:6 h Qin:8 h Lun:8 h Yuchen:8 h Luke:6 h
Lora module testing	Lora module should be connected correctly and can transmit and receive the message properly. We first tried to transmit some simple words, after that, we tried to transmit the sensor data to the receiver port.	Calvin:10 h Chuxin:7 h Qin:6 h Lun: 8 h Yuchen:5 h Luke:5 h
Arduino coding	We have to write a clear and concise Arduino code of all the functions. All the code should be have proper functionality.	Calvin:8 h Chuxin: 10 h Qin:6 h Lun:4 h Yuchen:6 h Luke:5 h

4.4 Other Resource Requirements

One of our main resources has been Electronics Technology Group (ETG) here at Iowa State. They have not only helped us by supplying components, but also assisting with our understanding of certain design aspects of our project. For example, none of our team members have designed a PCB before, so ETG has supplied us with different resources to understand and design our own PCB.

4.5 Financial Requirements

The total will be less than $500, this will include all the sensors and customized PCB board. In the next semester, we also need to buy a solar energy panel and a case to protect our final product.

5. Testing and Implementation

Testing is an **extremely** important component of most projects, whether it involves a circuit, a process, or a software library

Although the tooling is usually significantly different, the testing process is typically quite similar regardless of CprE, EE, or SE themed project:

1. Define the needed types of tests (unit testing for modules, integrity testing for interfaces, user-study for functional and non-functional requirements)
2. Define the individual items to be tested
3. Define, design, and develop the actual test cases
4. Determine the anticipated test results for each test case 5. Perform the actual tests
6. Evaluate the actual test results
7. Make the necessary changes to the product being tested 8. Perform any necessary retesting
9. Document the entire testing process and its results

Include Functional and Non-Functional Testing, Modeling and Simulations, challenges you've determined.

Modules that need to be tested include the Temperature/Humidity sensor, the light sensor, the LoRa module, and how the sensors and the LoRa work with each other.

Our testing through all of these components includes setting up our sensors to an Arduino and running the code that we've written. We use the Arduino IDE to help debug if necessary, otherwise we look at the behavior of the sensors and LoRa and revise the code to achieve the required functionality.

5.1 Interface Specifications

All of our tests are being done on the Arduino IDE and the code is being mounted directly onto an Arduino so there is not much interfacing necessary.

5.2 Hardware and software

We use the Arduino IDE to help code on the Arduino Uno. This software is meant for writing C code on Arduinos especially. It includes necessary libraries for most Arduino hardware and makes it simple to import libraries for commonly used hardware modules.

The only other hardware used in testing is a breadboard and wires in order to link the sensors to the Arduino.

5.3 Functional Testing

Examples include unit, integration, system, acceptance testing

5.4 Non-Functional Testing

Testing for performance, security, usability, compatibility

5.5 Process

– Explain how each method indicated in Section 2 was tested

– Flow diagram of the process if applicable (should be for most projects)

5.6 Results

– List and explain any and all results obtained so far during the testing phase

- – Include failures and successes
- – Explain what you learned and how you are planning to change it as you progress with your project
- – If you are including figures, please include captions and cite it in the text

  • This part will likely need to be refined in your 492 semester where the majority of the implementation and testing work will take place

-**Modeling and Simulation**: This could be logic analyzation, waveform outputs, block testing. 3D model renders, modeling graphs.

-List the **implementation Issues and Challenges**.

6. Closing Material

6.1 Conclusion

Summarize the work you have done so far. Briefly re-iterate your goals. Then, re-iterate the best plan of action (or solution) to achieving your goals and indicate why this surpasses all other possible solutions tested.

6.2 References

This will likely be different than in project plan, since these will be technical references versus related work / market survey references. Do professional citation style(ex. IEEE).

6.3 Appendices

Any additional information that would be helpful to the evaluation of your design document.

If you have any large graphs, tables, or similar that does not directly pertain to the problem but helps support it, include that here. This would also be a good area to include hardware/software manuals used. May include CAD files, circuit schematics, layout etc. PCB testing issues etc. Software bugs etc.