Group 3
EEL 4914
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Initial Project Documentation:

Plan Bee

Commercial Beehive "Health" Tracking Solution

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Group 3

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We would like to thank Steven Eisele at Pollination.US Inc.
for fully sponsoring our senior design project.

Project Narrative

It is commonly understood that Honey Bees are a vital component of the ecosystem: many flowering crops are reliant on bees for pollination. But, lesser known is the importance of honey bees on the agriculture industry. Honey-Bees are depended upon to pollinate more that 30% of food crops grown in the United States. As a result, pollination services has became a vital element to the agriculture industry. Accordingly, beekeepers, also known as apiarists, are extremely important to the ecosystem, the economy, and the national security of the nation. Honey Bee hives are stored in Bee yards which can be very difficult to maintain. Hives,which are kept in remote locations, may routinely suffer from colony collapse disorder, small hive beetle infestation , or Varroa mites: all of which could destroy a hive within a few days. These issues are among the most widespread problems that arise when trying to sustain multiple bee colonies. Although colony collapse has decreased within the last few years, it is one of the least understood causes of colony loss and is still a major problem facing apiarists today. Because of the unknown factors related to colony loss, it is important that the apiarists can view and manage the hive in efficient ways. Providing more data for these apiaries would help the apiarists maintain the health of each hive colony, therefore reducing the likelihood of colony collapse. Monitoring the bee's health and the honey output would help economically as well. Apiarists would spend less money on replacing bees and would be able to estimate their honey output much more accurately. Small hive beetles and Varroa mites are a much more specific problem, as well as more dangerous. According to the USDA, "Varroa mites were the number one stressor for operations with five or more colonies during all quarters of 2016." [1] Finding a way to detect these predators and prevent them from destroying the hive would be extremely helpful for apiaries.

Given the need for an overall hive tracking solution, Project Bee attempts to solve the noted issues by monitoring the states of each colony and presenting said data in a practical manner. This includes tracking location, weight, temperature, and even the internal sounds of each hive. Food and medication will also be tracked. Such a hive tracking system must also be low cost so that it can be produced for many hives, durable for the outside weather conditions, and discrete so that it doesn't get in the way of day-to-day operation. When possible, the data should also be transmitted wirelessly, or aggregated and sent to a phone when the beekeeper enters a yard. These solutions, may also notify the beekeeper about thefts and predators.

Location monitoring of each hive will most likely be monitored with GPS. This is a first choice for Project Bee because of the low cost and easy setup. Accurate location pinpointing would help decrease theft risks as well as help streamline new colony placement. A set of colonies will become a "Yard" as well - and this is something we must accomplish using software and bluetooth, which will be later discussed.

Weight is another important aspect of hive control. Knowing the weight of each hive would help predict honey output as well as if the population in each hive was increasing or decreasing. If a hive isn't producing the amount of honey it should be, that is cause for concern. Honey loss would be an important indicator of something happening with the bees that could be unhealthy for them, and this problem could be fixed before it's too late. Weight could be measured for each hive using Load-cells or possibly while the various sound the bee make could be recorded a microphone or vibration sensors. From the internal sound of the hive one may be able to measure the total density of the bees or the state of the colony. Both sensors pair together in detecting the general condition of the hive.

Each device should have identification tags to label each hive. This would provide a technology that would help with recording and monitoring the amount of food and medication supplied to each hive. RFID tags would be extremely useful and inexpensive for Project Bee to use. This would be a low-cost way to implement technology into apiaries. Data would also be more organized and easier to access than before.

Predator detection would help apiaries on a large scale. Preventing the spreading of insects that destroy bee colonies would save many hives. One way to do this would be to use pheromone sensors. Pheromone sensors could sense specific pheromones of insects and the apiarists would be able to detect when these animals are in the area or invading their hives. This would prevent systematic losses of hives. The sensor that can detect the most complex molecules and their concentrations is the SAW sensor. This sensor would be Project Bee's preferred sensor to use given it is within the budget.

Combining all these systems into one systems is a priority. PCBs would be an effective way of integrating each technology into one final system. PCBs are extremely cheap and generally compact all-in-one systems. Creating one final reproducible device that includes all of the necessary monitoring aspects is a priority of this project.

Project Bee is dedicated to improving the efficiency of apiaries, including improving honey output and preventing colony losses of any form. Pollination U.S. Incorporated has sponsored this project due to the need for an improved technological system. This system may even be useful for future production and could help restore bee colonies throughout the nation.

Requirement Specifications

Project Constraints	Description
Environment	The device, which is attached to the beehive hive, will be commonly located in remote locations. As such, the device will be exposed to extreme weather conditions. In order to protect the electronic components, the project will incorporate an IP67 weather resistant housing. This sort of casing will also help protect against shocks as well as any for of liquids, such as honey, which may leak into the electronics.
Communications	Another reason why the environment becomes a constraint is because of the remoteness of the area. The device will be left out in farms that are located very far from civilization including transmitting signals. Cell lines wouldn't all necessarily reach these locations and satellite signals would be too expensive. At such a far location, communication with the device could prove difficult for emergency cases. This constraint also ties in to the safety of the device since it could be attacked by wild animals such as bears, or it could get stolen.
Power	In order to power this device at such a remote distance it will gather electrical power through solar panels that will in turn charge a battery that will power the rest of the device. The device must use low-power in order to make the battery last for at least a year.
FCC Regulations	The device cannot be sold without FCC approval. Also since it is a wireless device then it has to work within a specific unlicensed frequency which varies from country to country.
Time	Since this is a summer course then we have a limited number of weeks as opposed to having the time of a full semester in order to finish the first part of this project.
Data-Rate	The data rate of the low power wide area network is limited by its range. Typically 25 kilobits per second is expected to reach a range of 12 kilometers. Latency issues should be considered when sending data.

Table 1:Project Constraints

Known Standards	Description
Long Range Wide Area Network (LoRa)-WAN	An open-sourced chirp-modulated wireless interface developed by Semtech. Because of its open source nature, this wireless stack provides the means to develop and deploy personal area network to transmit and receive data using the ISM radio band.
SigFox	A closed-source wireless interface developed by SigFox. While currently a leader in the LPWAN industry, the network requires a mobile operator to manage the generated traffic. This restricts rural uses where coverage may be little to none.
Bluetooth	Widely used medium range wireless network developed and maintained by the Bluetooth Special Interest Group. This standard permits device to device communication.
ZigBee	A low cost, low powered, wireless mesh networking standard. The standard was developed by the ZigBee Alliance, and is quickly becoming the de facto mesh networking standard. It is commonly referred to as IEEE 802.15.4.
SPI	Serial Peripheral Interface, the de facto method of IC communication on a pcb. The standard was developed by Motorola in the mid 1980s. It follows a master-slave relationship whereby multiple slaves are controlled using a slave-select line.
I2C	Inter-Integrated Circuit, is a multi-master, multi-slave serial bus developed in the 1980s by Philips. It is commonly used to connect low speed devices to microcontrollers across short distances.
RS232	Recommended Standard 232, is a serial communication standard used to govern the electrical and timing characteristics of packets between a computer and modem. The standard was developed in the 1960s.
RS485	Recommended Standard 485, is a serial communication standard which dictates the electrical characteristics of a driver and receiver.
JTAG	Joint Test Action Group, is a serial communication interface used for testing and debugging PCB after manufacture.

Table 2: Known Standards

House of Quality

		Low-power	Cost	Dimensions	Installation Time	Communication Range
		+	-	-	-	+
Cost	-	↑	↑↑	↑	↑	↓
Installation ease	+	↑	↓	↑	↑↑	↓
Up time	+	↑	↓	↑	↑	↓
Durability	+	↑	↓	↑	↓	↓

Figure 1: House of Quality

Initial System and Member Responsibilities

In this section we present the individual member responsibilities. This is followed by an overall project illustration and block diagrams describing the underlying workings of various components of the project. Because the PCB is a significant portion of the final product, elements of its design was divided amongst group members. This is also fitting as the group consist of only electric engineers. Given our ability to produce a working board within the scheduled time, we may seek to develop additional devices to expand the project footprint.

Project Illustration

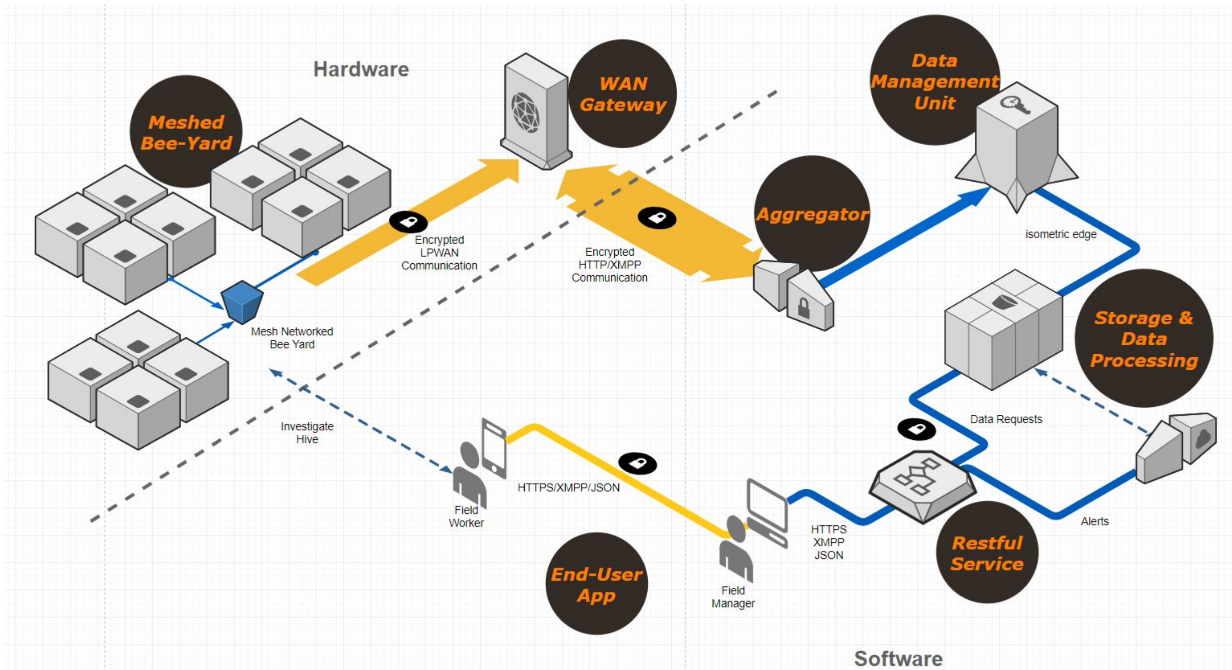

Figure 2: Project Illustration

Project Bee will be focused on the hardware portion, as defined in the illustration above. Accordingly, a private server will be used to emulate the entire software portion. This includes the web application aggregator and data management unit. Various cloud based tools will be researched for their feasibility, given the time constraint required to complete the design. While a PCB will be developed for the hardware tracking device, the WAN Gateway will be made using off the shelf modules which are compatible with a single-board-computer devices such as the Raspberry Pi. The gateway will also used wired ethernet to communicate with the internet. In an ideal scenario, a gateway may feature numerous ways of connecting to the internet, notably, cellular, wifi, satellite or one of the many IOT standards being deployed.

Hardware Block Diagram

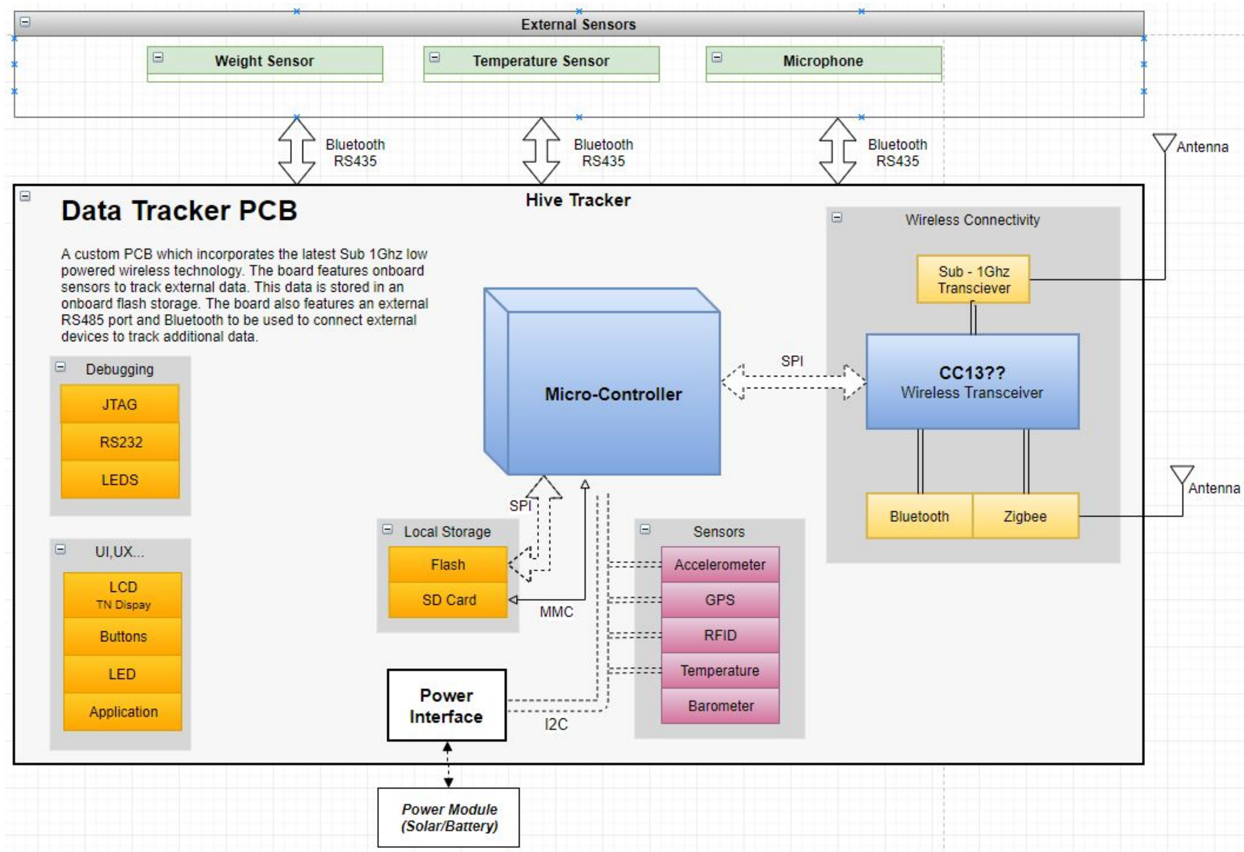

Figure 3: Data Tracker Block Diagram

Administrator: Yannick Roberts
Status: Researched
Additional Information:

The above diagram illustrates the target PCB design for the data-tracking unit. A standard Low Power Wide Area Network interface has not been selected as yet. The pros and cons of the current standards are being considered. While the LoRa stack does provide a viable method of deploying a custom network, their wireless transceivers are lacking important features such as bluetooth connectivity. Texas Instruments, on the other hand, do provide transceivers with built in microcontrollers and bluetooth and also support various LPWAN protocols such as Sigfox. The listed sensors will be incorporated into the board along with an internal storage device. A debugging interface will be necessary for testing the ICs on the PCB. Although the standards for interfacing amongst the ICs have not been confirmed, modern chips do provide libraries which abstracts the low-level communication protocols. As a result, a general application could be developed and tested on a test board and ported fairly easy to an arbitrary development board. A method for generating user feedback using either LEDs or an LCD display is also being considered. Bluetooth may be used to obtain data to a users phone.

Power Block Diagram

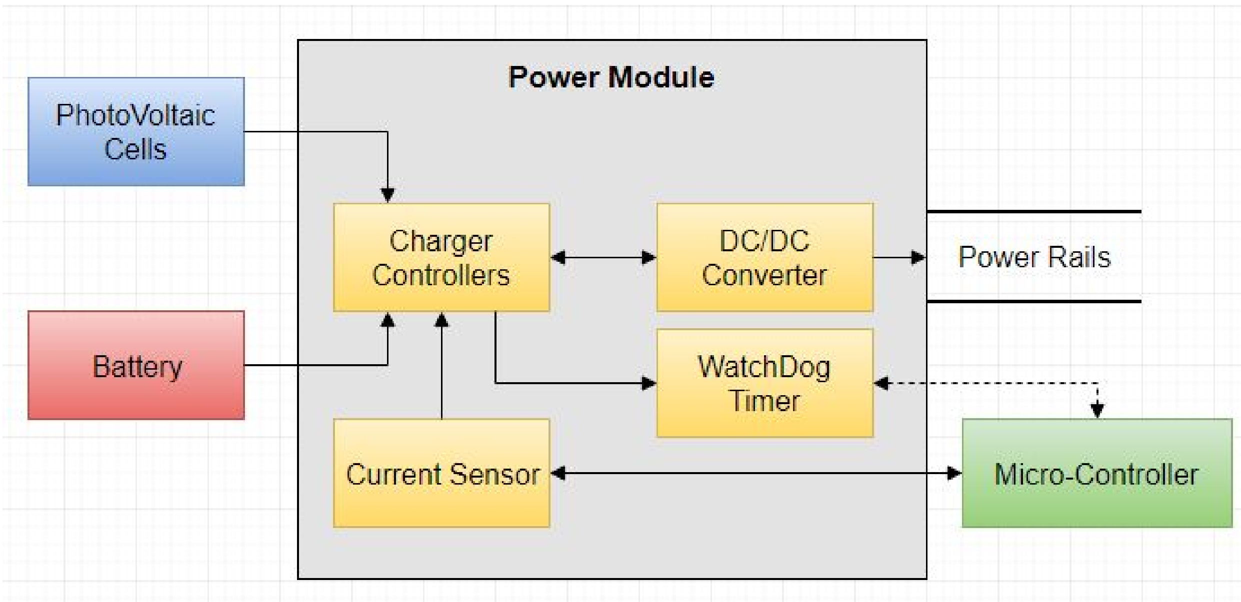

Figure 4: Power Module Block Diagram

Administrator: Giovanny Reyes
Status: Researched
Additional Information:

The above power module describes the implementation that is being considered in powering the device. Lithium iron phosphate batteries will be paired with photovoltaic cells to ensure the device and its supporting devices are powered. LiFePO4 batteries were chosen for their weather resistance qualities. A charge-controller will monitor the state of the state of the batter and react accordingly. A DC/DC converter will be used to convert the input voltage to a more appropriate value needed by the end device.

Software Block Diagram

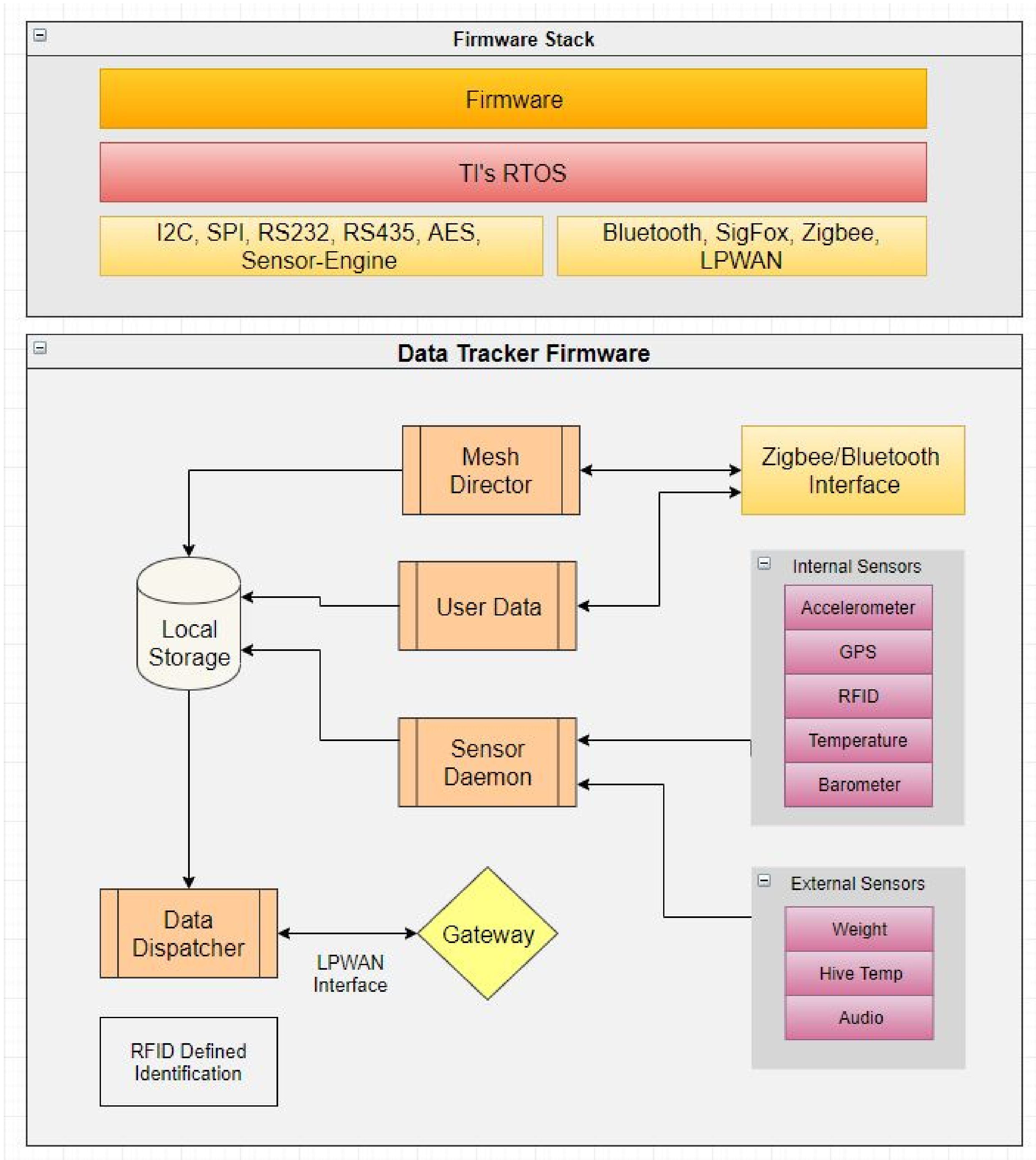

Figure 5: Firmware Block Diagram

Administrator: Yannick Roberts
Status: Researched
Additional Information:

Texas Instrument provides a real-time operating system made specifically for IOT type devices. It employs various algorithms for reading and storing sensor data. Coupled with its bluetooth and zigbee interface, using Texas Instruments IOT platforms may ease the software development process. The firmware block diagram illustrated above describe the different types of tracked data. Internal sensors are those sensors internal to the tracking device (External to the hive). External sensors are those within the hive. The bluetooth interface allows a user to connect to a hive using a phone, while the ZigBee interface allows that user to issue command to the entire yard at once. Data obtained from these data types are then dispatcher using the data dispatcher element to the gateway where it is translated to a TCP/IP packet and pushed to a web server.

Member Responsibilities

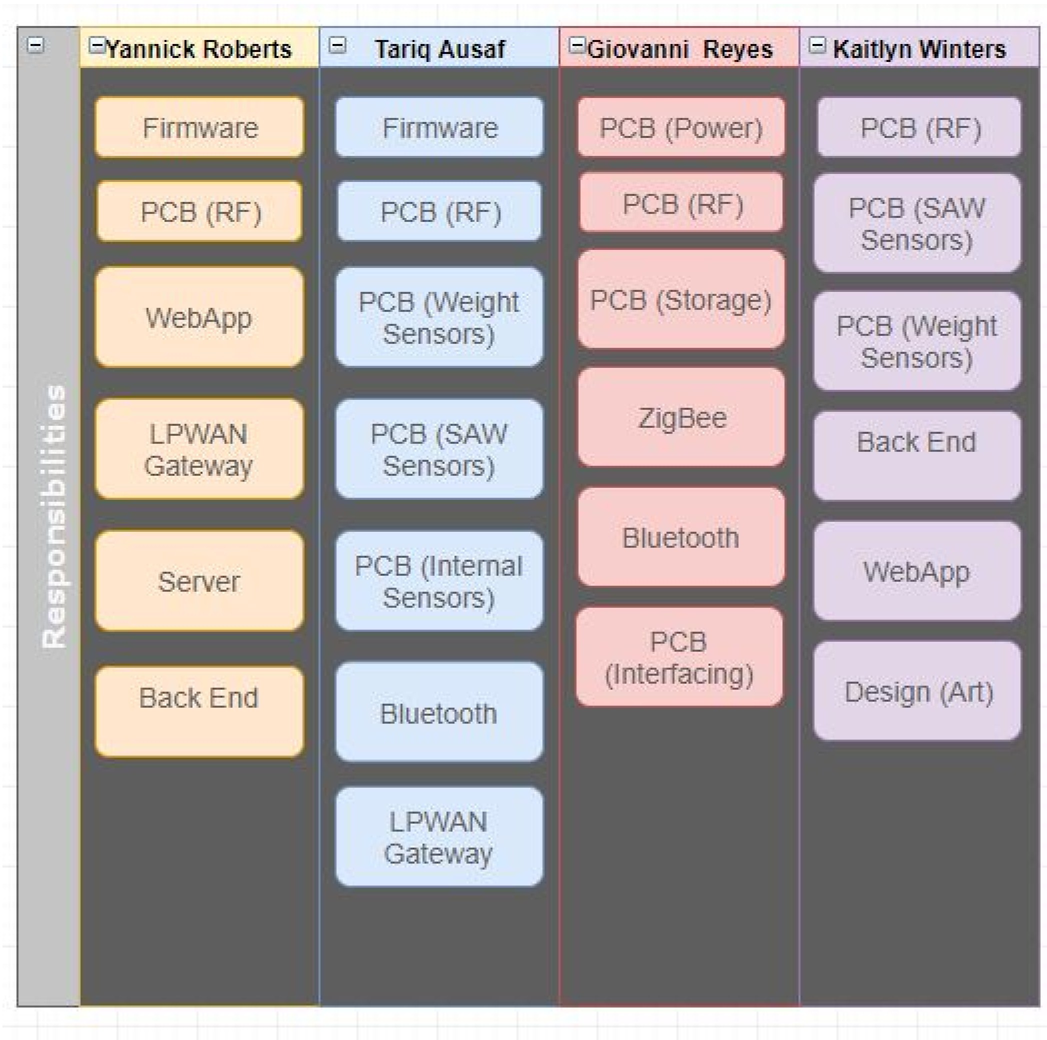

Figure 6: Responsibilities

Budget and Funding

In this section we present a preliminary project itemized budget. This budget includes projected costs for each technology we intend to integrate into our final device. It is important to note that these costs are preliminary, and will not necessarily be accurate until we finish the design and fabrication of the final device. As such, we have overestimated the technology and power requirements, and projected cost for some of the items in this budget, such as in the solar section. We have chosen to overestimate these costs so that when fallbacks occur we will stay under budget, so as not *surprise* our sponsor.

In order to meet the requirement specification of a reproducible unit cost of $70, for 5,000 units - the number of commercial beehives - we need to pay attention to the individual unit costs and unit cost breakpoints associated with suppliers that we choose to use.

Item/Description	Supplier	Part No	Unit	Projected (	Projected Sul
Solar Cells (6.15 W)	Adafruit	1525	3	$75.00	**$225.00**
High-Efficiency Synchronous Switch Mode Charger	Texas Instrum	BQ24650	3	$20.00	**$60.00**
LiFePO4 Batteries for Solar (1000 mAh)	Westinghou	N/A	3	$25.00	**$75.00**
Solar Panel Mount	Renogy	N/A	2	$15.00	**$30.00**
				** Miscellaneous Solar Costs	**$150.00**
Prototyping Microcontroller, incl. RF Comm. Chip	Texas Instrum	MCU: MSP-EXP430G2 Comm. Chip: CC1300x RF	2	$120	**$240**
Prototyping Sensor Kit for MSP430 MCUs	Texas Instrum	Multiple	2	$35.00	**$70.00**
Single-Strand 22 Ga Copper Wire (for ICs)	N/A	N/A	100'	$0.55	**$55.00**
Varied Basic Components Kit (Resistors, Capacitors, MOSFETs, Diodes, Op Amps, etc.)	N/A	N/A	4	$40.00	**$160.00**
Breadboard for Prototyping	N/A	N/A	4	$15.00	**$60.00**
				** Miscellaneous Prototyping Costs	**$200.00**
PCB Fabrication - Stage 1	Altium	N/A	2	$30.00	**$60.00**
PCB Fabrication - Stage 2	Altium	N/A	2	$30.00	**$60.00**
RF Comm Chip	Texas Instrum	CC1300:	4	$25.00	**$100.00**
				** Miscellaneous Sensors Costs	**$200**

Static IP Address Server S	N/A	N/A	1	$250.00	**$250**
				** Software Hosting / Development Costs	**$75**
Final PCB Packaging	N/A	N/A	2	$20.00	**$40.00**
Weatherproofing Enclosui	N/A	N/A	2	$30.00	**$60.00**

*** Projected** **$21**

***Table 4:** Projected Costs: *These are not the final costs, just the best estimate we can provide with the information we have at this time. As such, actual costs in these categories may vary.*
*** Miscellaneous Costs: we are using this to account for unforseen costs associated with incorporating these technologies. We have not fully estimated the power requirements and other items for our project, either, because it is not fully designed and fabricated yet.*

Our project is being sponsored in full by **Steven Eisele**, the acting President of **Pollination.US Inc**, a State-of-Florida registered commercial company. This sponsorship is contingent upon us fabricating a finished device to the marketing specifications listed in the third table of the Requirements Specifications section above. *In other words, he would like us to frame our generalized Internet-of-Things Tracking/Communications System for his commercial beehive tracking needs.*

Project Milestones

In this section we present a set of smaller, week-by-week deliverables that we can feasibly accomplish together, in order to make significant progress toward the end goal of completed our senior design project by November. Although our senior design presentation will not be until mid-December, we would like to have our project completed in sufficient time for ample testing; and in case we lag behind the agenda presented here, we will have scheduled time to recuperate. The current week is bolded to stand out, showcasing what we have accomplished thus far, and what we still have ahead of us. Two milestone-important weeks have been bolded and italicized; the first being the week we should have the project completed by, and the second being the week in which we are expecting to present our project.

Week No.	Dates	Project Milestone Deliverables
Week 1	5/13 - 5/19	Senior Design Group Formed, Senior Design Project Idea submitted on 5/18 @ 12 pm, Purchased Senior Design Books
Week 2	5/20 - 5/26	Retrieved TI MSP430 Microcontroller, Retrieved Sensors BoosterPack Plug-In Module

Week 3	5/27 - 6/3	Retrieved TI MSP430-EXP430G2 Microcontroller for con prototyping, Ordered TI CC1350 SimpleLink Ultra-Low Power Dual B Microcontroller
Week 4	**6/3 - 6/9**	**Current Week:** 10-Page Initial Project Documentation due 6/8 @ 12 pm, Initial work completed on temperature sensor
Week 5	6/10 - 6/16	First meeting with Dr. Lei Wei - 6/13 @ 2 pm, and Update Doc due 6/15 @ 12 pm, Get familiar working with the MSP430-EXP430G2, CC1350 Microcontroller, and the Sensors Module, Begin initial coding
Week 6	6/17 - 6/23	Begin estimating the parts we'll be actually needing for fu power requirements - *create parts list and budget* Setup CC1350 for Bluetooth Communication, Setup Sensors Module to track vibration from acceleromet humidity sensor, and temperature from temperature sensor Order Load Cells
Week 7	6/24 - 6/30	Begin looking into pheromone sensor using ASM, vibratio measure bee communications and density of the hive, Begin integrating Load Cells,
Week 8	7/1 - 7/7	60-Page Draft SD1 Documentation due 7/6 @ 12 pm
Week 9	7/8 - 7/14	Finish integrating load cell, Finish integrating vibration sensors, Integrate pheromone sensor using ASM Order all necessary parts, Begin PCB Design
Week 10	7/15 - 7/21	100-Page Draft SD1 Documentation due 7/20 @ 12 pm, Prototyping individual components with Breadboards
Week 11	7/22 - 7/28	Integrate pheromone sensor using ASM, Finish first PCB Design, Order first PCB
Week 12	7/29 - 8/4	120-Page Final SD1 Documentation due 7/28 @ 12 pm Get First PCB,

		Begin testing first PCB
Week 13	8/5 - 8/11	Break
Week 14	8/12 - 8/18	Break
Week 15	8/19 - 8/25	Finish testing first PCB, Redesign components for second PCB
Week 16	8/26 - 9/1	Redesign and integrate any new components into second P design, Order second PCB
Week 17	9/2 - 9/8	Begin testing second PCB
Week 18	9/9 - 9/15	
Week 19	9/16 - 9/22	Finish testing second PCB, If necessary, begin iteration for third (and final) PCB Desi testing done by first week of Nov.
Week 20	9/23 - 9/29	
Week 21	9/30 - 10/6	
Week 22	10/7 - 10/13	
Week 23	10/14 - 10/20	
Week 24	10/21 - 10/27	
Week 25	***10/28 - 11/3***	***Have Senior Design Project Completed***
Week 26	11/4 - 11/10	Applicable Field Testing Practice Demonstrations Practice Presentations
Week 27	11/11 - 11/17	
Week 28	11/18 - 11/24	
Week 29	11/25 - 12/1	
Week 30	12/2 - 12/8	
Week 31	***12/9 - 12/15***	***Senior Design Project Committee Presentations***

Table 5: Milestones

Citations

[1] https://ucnrs.org/role-honey-bees-ecosystem-pollination/

Yang, Sarah. "10.25.2006 - Pollinators Help One-Third of World's Crop Production, Says New Study." UC Berkeley, Office of Public Affairs, UC Berkeley, www.berkeley.edu/news/media/releases/2006/10/25_pollinator.shtml.