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Smart GPS System

EEL 4915 - Senior Design II

Group B/14

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1 Executive Summary

As the world has become a more traitorous place for both children and adults alike, the need for systems which can send alerts of irregularities and ensure the safety of who may be incapable of caring for themselves has dramatically increase. This issue, most glaringly obvious in day cares, nursing homes, and hospitals is one this project's attempt to address. To that end this senior design project seeks to design a tracking system which will alert caretakers, whether they are parents, teachers, nurses, or baby sitters to the whereabouts of someone who may have gotten lost while in their care. The objective of this project as a result is to design a GPS tracking device which, when worn by a person with the potential for being unable to defend or care for themselves if lost, will reduce the time needed to find said person. Because one of the most terrifying situations imaginable is being unable to find a person once they are lost, the objective of the project is to eliminate that issue by finding the person before they have had time to venture too far from an area of safety.

From a more technical aspect the goals and objective of this project are to gain a better understanding of the technologies with which wireless communication can be employed to not only track objects but transmit data as well. In order to address the tracking aspects of this project not only are GPS devices used within the structure of the system but RFID detection systems as well. Because there are a variety of methods which with to transmit information wirelessly, RF transmission was selected as it lends itself nicely to sending information long distance will also providing an excellent illustration of one of the most fundamental modes of communication. Lastly, to ensure that an understanding of the most popular social mediums are understood the development of a smartphone application, which will be accessed via the internet, is also found within the thresholds of the project to allow the end user to track those cared for from a device which has an ever increasing hold on the hearts and minds of society as a whole.

2 Project Description

2.1 Motivation

The reason we chose to work on this project is because, initially, we wanted to work on a project that could actually be useful in a real life application, something meaningful that could be beneficial. This project appealed to us because it fulfills that usefulness that we were looking for since it can be used to help keep helpless people safe, such as in the case of small children or mentally handicapped people wandering off unsupervised without anyone noticing. These accidents happen more often than we think possible and a lot of the time they do not have a happy ending.

In a study that was published in the journal *Pediatrics* in November 2012, a survey of parents of 1,218 children who have autism spectrum disorders, revealed that half of the parents reported their child had wandered off or attempted to wander off at least once after the age of 4. These numbers are alarming, considering that many of those reported incidents involved some sort of injury that could have resulted in death. Of the missing reports that involved a close call situation, drowning (24%) and traffic injury (65%) were the most common incidents. The places children wandered off from the most are their homes (74%), stores (40%), and schools (29%).

Unfortunately, there have been cases where the children were found too late. When the study was published in November, 22 wandering-related death cases had been identified, where a large number of the children had wandered off from their home. Lori McIlwain, co-founder of the parent advocacy group National Autism Association, said that 9 out of 10 wandering-related deaths she had identified were due to drowning. She stated that wandering poses a significant risk for many children and adults with autism, Alzheimer's, and other disorders.

Knowing the reality of what these children and their family go through on a daily basis is a powerful motivation to work on this project. We feel that we can use our skills and knowledge to design a product that can be beneficial in restoring much needed peace of mind to the families of people with disorders and at the same time help in keeping these people safe in places that should be safe havens to them, such as their home.

Another motivating factor, albeit not as powerful as the one already stated, is the challenges this project offers us. This project will require knowledge from many different aspects of electrical and computer engineering and will put to the test our skills as soon-to-be engineers and as team players. Throughout the project, we will make use of different areas of engineering such as communications theory, microcontroller implementation, digital signal processing, and a fair amount of coding, all of which are areas that have been covered in our engineering education.

2.2 Goals and Objectives

Our target audiences for the Smart GPS System are parents with small children, families of relatives that suffer from mental disorders, such as autism and Alzheimer's disease, and cannot be left unsupervised; daycares that need to keep track of the children under their care, or hospitals with mental illness patients.

Our goal is to build a light weight and easy to use wireless GPS tracking system with low power consumption that can be easily carried by even a child. This system could be used as an added safety measure to prevent certain individuals from wandering off and possibly getting lost when left unsupervised. It will include a tracking device embedded on a clothing item, such as a wristband or a watch, which can be worn by the individual. This device will be used to send warning signals to the base station and track the person in case they leave the perimeter of a specific stationary area.

The way this will work is by having the device send a signal to a base station alerting that the device has left the perimeter. In turn, the base station will send alerts to a mobile phone with several choices on how to proceed. One of these choices will be to start tracking the device via GPS, in which case the base station will signal the device for its location. The tracking device worn by the individual will start sending its GPS coordinates to the base station to be relayed to the user.

2.3 Requirements and Specifications

As a product targeted to individuals that need supervision, this device will be designed with the intent of being worn on the person without falling off and to withstand rough conditions such as heavy vibration. The main objective of the Smart GPS System is to be able to track an individual wearing a GPS device within a specified range in a wide array of environments. The system requirements and specifications are as follows:

- The base station will consist of a microcontroller unit in a stationary location.
- It shall have the ability to communicate with the GPS device wirelessly and to send/receive signals from a maximum distance of at least 1 mile in an urban setting.
- The base station shall be able to establish a connection with the user application using the TCP/IP stack and shall also be able to transfer or receive information related to the GPS device.
- The RFID system will act as the alarm system if the GPS device leaves the perimeter by alerting the base station as soon as it happens.
- The base station will handle two-way communication happening with the GPS device's MCU and with the user application simultaneously.
- The base station will alert the user when the GPS device has left the location by sending a signal to the phone application.
- The phone application will interact with the user and ask if they would like to track the device.
- The phone application will then send a signal back to the base station with the user's response for further action.

- The GPS device will be designed to last at least 5 hours in active mode and 30 hours in standby mode. Active mode is when it is in tracking mode while stand-by mode is its normal state.
- The GPS device will include a microcontroller unit to monitor power consumption and to communication with the base station.
- The goal is to have the GPS boot up in the range of 12.5 minutes the first time it is turned on.
- The GPS device will be designed with a rechargeable battery and a power jack to allow it to charge from an external source.
- The GPS tracking device will not exceed the size of an iPhone.
- The user application shall have a graphical user interface (GUI) to interact with the user.
- The user will be able to login to their account and see the saved information regarding the person they are monitoring.
- The user will be able to modify the information about the person being monitored through the user application.
- The user application will be able to send requests to the GPS tracking device via the MCU at the base station.

3 Research

3.1 Existing Technology and Products

GPS tracking devices are becoming more readily available in the market. GPS offers the capability of tracking almost anything from phones and vehicles to animals and people and this is why they are appealing to the customer, it gives people an extra sense of security knowing that they have the ability to locate whatever it is they want to keep secure. Looking through different GPS products, we found several that are similar to what we are working on, one of the products in particular is very similar to what we are trying to achieve. This product is called PocketFinder, a wireless device that uses GPS to monitor and transmit information back to the PocketFinder Network via the AT&T cellular network. The person doing the monitoring can then view the information by accessing the network via the internet, a web-enabled mobile phone, or from the Android/iPhone mobile applications.

This product was designed for constant monitoring. It is capable of monitoring locations as well as speeds and can send alerts to e-mail or cellular phone, depending on the choices the user makes. It allows you to create optional Zones that will notify you when the device enters or exits that zone or you can also create Speed Limits that will notify you when the device calculates a speed faster than the set limit. Some of the other features it includes are:

- Ability to manage multiple devices
- Exact location data – within 10 feet of the person being located
- Ability to set the power options for long battery life – choose how often it updates locations

- Allows you to view up to 60 days of map history
- Device is circular, small and light – 1.4 ounces and about 2 inches in diameter
- Waterproof and shockproof – designed to work in extremely hot or cold conditions

PocketFinder is really similar to our project in that they both use GPS to monitor a wireless device and use a notification system to send alerts and messages to a mobile phone. However, there are some differences that distinguish our project from PocketFinder. The Smart GPS System is meant to be used as a short-range emergency tracking device, for example, in cases where small children or mental illness patients have left a perimeter that is being monitored and it is imperative to find them right away. In order to do this, our project uses an RFID system to know exactly when they leave the perimeter and alert the base station, allowing for faster response. The RFID system uses a reader and a passive tag to exchange radio frequencies at short distances; this makes it more accurate than GPS when monitoring a perimeter and allows for less power consumption since it saves the GPS from being active all the time. Another difference is the use of cellular network by PocketFinder. Using cellular data requires a monthly fee that adds up over time and can get expensive, the Smart GPS System will work with Wi-Fi and radio frequencies to transmit signal which are meant to replace the need for cellular data and thus make it more affordable.

3.2 Outdoor Tracking System

3.2.1 LS20031
Among all GPS Modules, The LS20031 GPS Module, shown in Figure 1, is one the commonly used in the market. Besides the reasonably price, it comes with its antenna and cables required for its respective connections. One of the advantages of using this GPS Module is its size. It is about 30 mm square, which meet the size requirements for the tracking device being built. The price is about 64 dollar, and Sparkfun Electronics makes it.
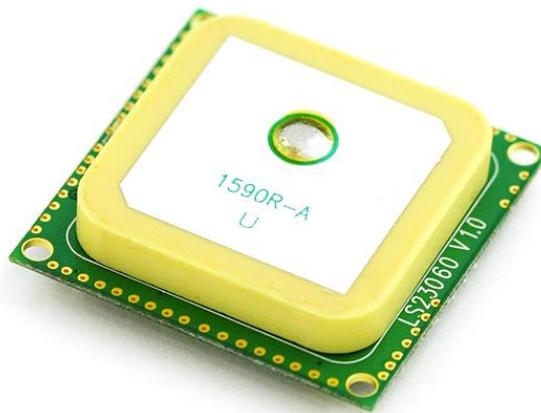
Figure 1: LS20031 GPS Module

3.2.1.1 Connections

The LS20031 GPS Module has 5 connections.

- Enable: This signal operates under active high.
- Transmit data and receive data: A standard serial protocol (UARTs)
- Supply voltage
- Ground

3.2.1.2 Outputs

The LS20031 implements a subset of the NMEA 183. It defaults to binary mode at a high baud rate at 4800 baud, 1 stop bit and no parity. Its default outputs are GSA, GSV, and RMC. Depending of the processor used, a certain type of output will be better to implement that the others

The GSA message lists the active satellites, those that are being used by the GPS receiver at the moment. It also includes dilution of precision information, which is an indication of how good or poor the current satellite geometry is. When the satellites are all in a line, or clumped together, then the dilution of precision is high (poor). When the satellites are spread throughout the sky then the dilution of precision is low (good). Figure 2 below shows the output of the GSA: [2]

```
$GPGSA,A,3,04,05,,09,12,,,24,,,,,,2.5,1.3,2.1*39

Where:
    GSA         Satellite status
    A           Auto selection of 2D or 3D fix (M = manual)
    3           3D fix - values include: 1 = no fix
                                         2 = 2D fix
                                         3 = 3D fix
    04,05...    PRNs of satellites used for fix (space for 12)
    2.5         PDOP (dilution of precision)
    1.3         Horizontal dilution of precision (HDOP)
    2.1         Vertical dilution of precision (VDOP)
    *39         the checksum data, always begins with *
```

Figure 2: GSA Output

GSV: The GSV message lists the satellites that are in view, giving information about their signal strength and their position in the sky. Using the GSV message software can make a sky plot so that the user can see where the satellites are and understand the dilution of precision better. Figure 3 below shows the output of GSV:

```
$GPGSV,2,1,08,01,40,083,46,02,17,308,41,12,07,344,39,14,22,228,45*75

Where:
      GSV            Satellites in view
      2              Number of sentences for full data
      1              sentence 1 of 2
      08             Number of satellites in view

      01             Satellite PRN number
      40             Elevation, degrees
      083            Azimuth, degrees
      46             SNR - higher is better
           for up to 4 satellites per sentence
      *75            the checksum data, always begins with *
```

Figure 3: GSV Ouput

RMC: NMEA has its own version of essential GPS PVT (position, velocity, time) data. It is called RMC, The Recommended Minimum. Figure 4 below shows the output of RMC:

```
$GPRMC,123519,A,4807.038,N,01131.000,E,022.4,084.4,230394,003.1,W*6A

Where:
      RMC            Recommended Minimum sentence C
      123519         Fix taken at 12:35:19 UTC
      A              Status A=active or V=Void.
      4807.038,N     Latitude 48 deg 07.038' N
      01131.000,E    Longitude 11 deg 31.000' E
      022.4          Speed over the ground in knots
      084.4          Track angle in degrees True
      230394         Date - 23rd of March 1994
      003.1,W        Magnetic Variation
      *6A            The checksum data, always begins with *
```

Figure 4: RMC Output

3.2.1.3 First Time Set Up

From the GPS Satellites, the LS20031 calculates a valid position on the earth. This process takes about 12.5 minutes when the module has not been used for the first time or when the module has been a long time since was last used. Otherwise, the module will save the data in memory through a capacitor so when power is reapplied the module can find its location in faster time.

3.2.1.4 Antenna

The antenna being used by the module is a built in patch antenna. It is a type of antenna with a low profile and it is specially design to be mounted in a flat surface. This antenna has problem in getting signals from the satellites in the horizon. Special situations such as weather conditions or being indoors can affect the performance of the antenna and can take up to 5 minutes to get a lock. The most sensitive orientation for this antenna is pointing to the sky. It is also needed an active external GPS antenna, and has to be suitable for a 3 volts module.

3.2.1.5 Power Supply

The supply voltage tolerance for this GPS module change between ranges of 3.2 to 3.6 volts. According to its specifications, this module is very sensitive to values below 3.2 volts. Also, the normal operating current is 45mA, but it is important to keep in mind that the current jumps a lot during the startup process. It could go from 75mA to about 90mA peak. On the other hand, the current draw drops to about 0.4mA when the Module is not operating. Because of these characteristics, there are some terminal regulators that have to be considered. In addition, a rechargeable battery is required which required the implementation of a charge controller. According with the specifications of the project, size is an important requirement for the device. All components have to meet their specifications required in small sizes possible.

3.2.1.6 Charge Controller

A charge controller is an important part on energy based electrical systems. It will be important in limiting the flow in electric current from the batteries, and preventing overvoltage. Because charge controllers prevent heavy current flow that cause fire or explosion of the battery, the device will be safer. In addition, a charge controller power electronics while using the least amount of energy making them efficiently and safety in transferring energy. Thus, the project will meet requirements about performance and safety risk. In addition, the device will be mobile, so a rechargeable battery will be used which mean that an integrated charge controller circuitry has to be implemented.

When charging a battery, the initial stages until the battery voltage rises to the float voltage is a constant-source mode. The controller switches to constant-voltage mode until the current decrease to a minimum charge (Signifying a full charge), when the battery reaches the float voltage. By using the standard CC/CV algorithms, a close estimate of the charge time of a lithium-ion battery can be obtained. Dividing the battery capacity in ampere-hours by the constant-current mode charge current in amperes and multiplying that quantity by the charge time. In spite of the fact that is possible to use a voltmeter, a standalone microcontroller, and implement a PID controller in code to regulate the pulse width modulated signal to the transistor gate, dedicated charge ICs are available at relatively low cost. It seems to be a good choice to build our project without having to increase the number of connections and the size of the GPS Tracking device. Actually, there are ICs with a USB connection as the DC supply voltage.

For instance, the BQ-24193, a battery charge management and system power path management device, by Texas Instruments. In addition, it can be set up over the I^2C bus eliminating the need for additional line in the design. An advantage of using this particular device is that it's low maintenance and easy to set up. According to the datasheet, this device completes and initiates a charging cycle without software control. It is completely independent. Furthermore it starts in a pre-conditioning phase before moving to constant current and eventually to constant voltage. Finally it provides programmable thresholds for the minimum current in the CV phase, as well as over-voltage/over-current protection.

The MSP430G2553 has an input voltage between 1.8 and 3.6 Volts. Since this charge is used to charge 3.7 Volts batteries, a voltage divider has to be implemented to meet the

power requirements for the GPS module, and microcontroller. In addition, the board incorporates a status LED, charging circuits, external LED footprint, selectable solder jumper and various holes for your own connectors. As is said before, the USB port allows the user to connect to the computer power supply. There is also a 'SYS OUT', which allows the user to connect the charging circuit directly to the batteries so it will not be necessary to disconnect the charger each time you want to use it.

3.2.1.7 Rechargeable Batteries

The most widely used mechanism for energy storage in a wide range of applications is when the battery stores energy in the electrochemical form. The primary battery converts the chemical energy into the electrical energy. The battery after discharge is discarded because the electrochemical reaction in the primary battery is nonreversible. For this reason, the primary battery finds its applications where high energy density for one time use is needed.

The secondary battery is also known as the rechargeable battery. The electrochemical reaction in the secondary battery is reversible. This type of battery converts the chemical energy into electrical energy in the discharge mode. After the primary battery is discharge, the battery is recharge again by injecting direct current from an external source. In the charge mode, it converts the electrical energy into chemical energy. In both the charge and the discharge modes, a small fraction of energy is converted into heat, which is dissipated to the surrounding medium. For the GPS device, the fraction of energy that is converted in to heat is so small that is neglected.

There is some important information and facts about the battery that will help us to decide what the right battery for our project is. First, the cell stores electrochemical energy at low electrical potentials, typically a few volts. The battery is made of numerous electrochemical cells connected in a series-parallel combination to obtain the desired operating voltage and current. The cell capacity, denoted by C, is measured in Ampere-hours (Ah), meaning it can deliver C amperes for one hour or C/n amperes for n hours. The higher the battery voltage, the higher the number of cells required in series. The battery rating is stated in terms of the average voltage during discharge and the Ah capacity it can deliver before the voltage drops below the specified limit. The product of the voltage and the Ah forms the Wh energy rating it can deliver to a load from the fully charged condition. The battery charge and discharge rates are stated in unit of its capacity in Ah. For example, charging a 100 Ah battery at C/10 rate means charging at 10 A rate. Discharging that battery at C/2 rate means draining 50 A, at which rate the battery will be fully discharged in 2 hours.

Even though rechargeable batteries are more expensive, they can be used many times and last for long time. Also rechargeable batteries   protect the environment, conserve resources, and prevent waste. Those are desirable characteristics that the project should have. There are some options that will fit the project requirements like long battery life, power consumption, and safety. For instance, using a nickel cadmium battery (NiCd) would be a good choice because of the reasonable prices and the advantage of getting standards sizes. In addition, these batteries have low internal resistance, rapid charge typically two hours (in some case as low as 10 to 15 minutes), long life cycles. However,

there are some drawbacks about this battery. The NiCd has some memory issues that will limit the recharge life of the battery and it is heavier than other choices in batteries.

The Nickel-Metal Hydride Batteries (NiMH) use hydride instead of cadmium, and the capacity is three times as the NiCd with fewer memory issues. Also, it is lighter that the NiCd but has fewer lifecycles, short run time, and a voltage drop at near discharged levels. However, the mobile device being used requires having a lighter weight to it be easily carried around.

Lithium-ion technology is a relative late development, which offers three times the energy density over that of lead-acid. Such large improvement in the energy density comes from lithium's low atomic weight of 6.9 versus 207 for lead. Moreover, the lithium-ion has higher cell voltage of 3.5 versus 2.0 for lead-acid and 1.2 for other electrochemistry. This requires fewer cells in series for a given battery voltage, thus reducing the manufacturing cost. On the negative side, the lithium electrode reacts with any liquid electrolyte. Every time when the cell is discharged and then charged, the lithium is stripped away, a free metal surface is exposed to the electrolyte and a new film is formed. To compensate, the cell uses thick electrodes, adding into the cost. Or else, the life would be shortened. For this reason, it is more expensive.

Li-ion batteries tend to have one of the highest cost per-watt ratios, much higher than lead-acid chemistries in operation, the lithium-ion electrochemistry is susceptible to damage from overcharging or other faults in the battery charge control. Therefore, it requires a more sophisticated charging technique with mandatory protection against overcharging. In addition, it is essential to build protection circuitry into the battery pack so that thermal dissipation does not cause the battery to light on fire and/or explode. Lithium is also highly reactive with water so care must always be taken to not overexpose these batteries to water.

All rechargeable lithium batteries use lithium ions to store the energy by the migration of these ions from the cathode to the anode. During discharge the anode undergoes an oxidation reaction, which frees electrons to conduct current (do work) in an external circuit while the cathode undergoes a reduction reaction (gaining of electrons). The cathode is made up of a lithium-metal-oxide and the anode is made of graphite (porous carbon). Some common cathodes used in Li-ion batteries are: lithium-cobalt, lithium manganese, lithium phosphate, and lithium-nickel manganese-cobalt. The different cathodes offer differing levels of safety, specific energy, lifetime, and cost. Those are important characteristics to for our project. Most of these Li-ion batteries use a liquid electrolyte to carry charge between the anode and cathode, but some use a polymer with a gelled electrolyte. These lithium-polymer batteries offer a slight advantage to liquid electrolyte types by the fact that there is no need for a rigid case, and thus can be made smaller, lighter, and more flexible. Lithium Polymer is simply a lithium battery with solid polymer electrolytes. Its structure consists of a film of metallic lithium bonded to a thin layer of solid polymer electrolyte. Which is a negative aspect since Metallic lithium is highly reactive and flammable, thus very unsafe. It is usually put on mineral oil for that reason, but that would just be too unpractical for the project. In addition the solid polymer enhances the cell's specific energy by acting as both the electrolyte and the

separator. Moreover, the metal in solid electrolyte reacts less than it does with liquid electrolyte.

The Lithium ion (Li-Ion) battery seems to be the best choice not just because it is recyclable but comes in different shapes. All the issues related with memory effect are not a problem anymore, so this battery can be recharged before it is completely discharged without affecting the energy capacity. In addition, Lithium ion batteries are smaller, lighter and provide more energy that the other ones describe above. The main disadvantage of this battery is that it is not response well with high temperatures. Li-Ion sometimes erupts or explodes in high heat, hot cars, or direct sunlight. That could be a problem because tracking a person over summer temperatures would cause the device to heat.

Lithium-ion charging is similar to the lead-acid charging system, except for the higher voltage per cell in lithium-ions and the float charge stage which is a very delicate charging phase for lithium-ions since they cannot accept overcharge unlike lead-acid which offer some flexibility.

 The first stage in the process is a constant current stage. Here the voltage rises to a pre-determined level and then a constant charging voltage of about 4.4V is applied to the battery. A lithium-ion cell (nominal cell voltage 3.7V) has about 4.2V when fully charged with a tolerance of +/− 50mV per cell. Higher voltages could increase the capacity, but the resulting cell oxidation would reduce service life. In addition it would be unsafe if charged beyond 4.20V per cell. When this level is reached, charging should terminate, because Li-ion batteries only take what it can absorb, any extra charge causes stress. If not used for a while, the Li-ion will self-discharge and will need to be topped off often to keep the battery at full capacity. Figure 5 and Figure 6 shown below best illustrate this process.

Figure 5: Li Ion Charging Proccess

Li-ion is fully charged when the current drops to a predetermined level or levels out at the end of Stage 2. In lieu of trickle charge, some chargers apply a topping charge when the voltage drops to 4.05V/cell (Stage 4).

Lithium-ion batteries can be charged much faster than can lead-acid batteries. This means that a Li-ion can be charged in about one or two hours. Lithium-ion batteries are about 97 to 99% efficient in charging and stay relatively cool during the charge process. If a Li-ion battery is overcharged, then the production of CO_2 will begin and raise the pressure in the cell. If this pressure gets high enough, the cell will burst and vent out a flame and/or explode. Over discharging lithium-ion batteries is also not advised. If the cell voltage falls much below 3.0 V then the battery might become permanently dead so protection circuitry tries to shut off all current output when the cell voltage reaches around 3 V. In Figure 6, we describe Capacity as a function of charge voltage on a lithium-ion battery.
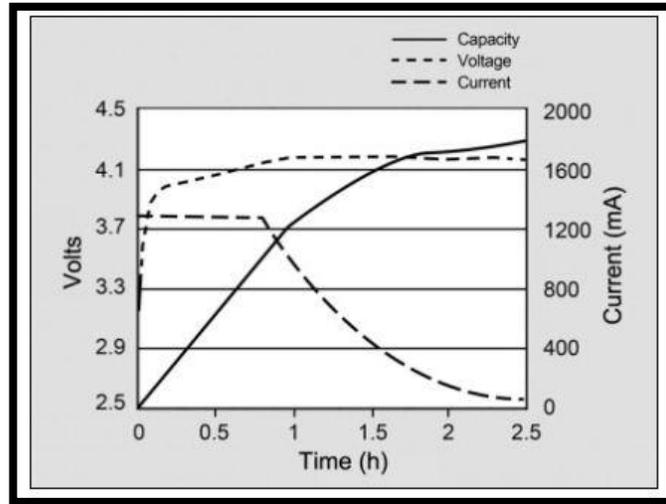

Figure 6: Li Ion Characteristics Charging Process

Keeping away from full charge has benefits, and some manufacturers set the charge threshold lower on purpose to extend battery life and prevent hazardous response from the battery. Table 1 below best illustrates the estimated capacities when charged to different voltage thresholds with and without saturation charge. It describes the typical charge characteristics of Lithium-Ion.

Charge V/cell	Capacity at cut-off voltage	Charge time	Capacity with full saturation
3.8	60%	120min	65%
3.90	70%	135min	76%
4.00	75%	150min	85%
4.10	80%	165min	87%
4.20	85%	180min	100%

Table 1: Typical Charge Characteristics of Lithium-Ion

Adding full saturation at the set voltage boosts the capacity by about 10 percent, but it adds stress due to high voltage.

3.2.1.8 Linear Regulators

A linear regulator is a system used to maintain a steady voltage. One of the purposes of the linear regulator is to extend the battery life and most importantly minimize MSP430G2553 power consumption. As the different loads vary, the resistance of the regulator varies in agreement resulting in a constant output voltage. This is due to the linear regulator is made to act like a variable resistor. In comparison, a switching regulator works different. It uses an active device that switches on and off to maintain an average value of output voltage. Efficiency is limited and the input voltage must be high enough to always allow the active device to drop some voltage.

As part of GPS tracking device design for the power supply it will be considered a linear regulator that will be regulating voltage between the source and the regulated load, a series regulator, or may place the regulating device in parallel with the load, shunt regulator. Integrated circuit regulators are very common because linear voltage regulators are common elements of many devices. For the purposes of this project it will consider the TPS780xx linear regulator to building a 3.3 V power supply. Below are some key features of the TPS780xx family that are being considered:

- Adjustable or fixed output voltages ranging from 1.22 V to 5.25 V. Fixed output voltages easily modified using factory EPROM programming.
- VSET pin toggles between two factory preset voltage levels
- Low dropout: 250-mV (typical) at 150-mA
- 3-percent typical accuracy over load/line/temperature
- Thermal shutdown and over current protection
- Low total quiescent current: 500-nA
- 150-mA low dropout regulator with pin-selectable dual level output

LP2950CZ –3.3 Regulator: This voltage regulator is designed to maintain a constant voltage between 3.2 to 3.6 volts, and it has been used in previous projects with great results. It is 3 terminal sizes and has the following specifications shown in Table 2.

3.3V Versions (Note 17)										
Output Voltage	T_J = 25°C	3.3	3.317	3.3	3.317		3.3	3.333		V max
			3.284		3.284			3.267		V min
	−25°C ≤ T_J ≤ 85°C	3.3		3.3		3.333	3.3		3.350	V max
						3.267			3.251	V min
	Full Operating Temperature Range	3.3	3.340	3.3		3.340	3.3		3.366	V max
			3.260			3.260			3.234	V min
Output Voltage	100µA ≤ I_L ≤ 100mA	3.3	3.350	3.3		3.346	3.3		3.379	V max
	T_J ≤ T_{JMAX}		3.251			3.254			3.221	V min

Table 2: LP2950CZ –3.3 Regulator Characteristics

TPS780xx: This regulator, with selectable dual level output voltage, is an ultra-low power and low dropout device. One of the characteristics of this regulator is that allows us to dynamically shift to a lower voltage when the microprocessor is in sleep mode. This can significantly extend the battery life even if the MSP430G2553 is operated at 8MHz when active and placed into low power mode when it is not active. The MSP430G2553 has operating currents at 2.13 μA and 1.3 μA, when the inputs voltages are 3.3 and 2.2 Volts respectively

For the GPS tracking device a battery-powered system will be considered. The battery will be series with the TPS780xx. In addition, the TPS780xx series is designed to be compatible with the MPS430g2553. The TPS78001 characteristics are shown on Figure 7.

	TPS78001
Vin (Min) (V)	2.2
Vin (Max) (V)	5.5
Output Options	Adjustable, Fixed
Iout (Max) (A)	0.15
Iq (Typ) (mA)	0.0005
Pin/Package	5SOT, 6SON
Vout (Min) (V)	1.22
Vout (Max) (V)	5.25
Vdo (Typ) (mV)	200
Noise (uVrms)	88
Additional Features	Enable
Approx. Price (US$)	0.35 | 1ku
Fixed Output Options (V)	
Accuracy (%)	3

Figure 7: TPS780xx series Characteristics

LM1117 LOW DROPOUT VOLTAGE REGULATOR IC 3.3V: This voltage regulator works fine as well with the only different that it needs a 10uF cap on the input and output. It will cause an increase on the size of the tracking device. For the GPS module used on the known position, size is not a problem. Depending on the actual performance of this regulator, it might be used in the project. Table 3 shows these voltage regulator characteristics.

Symbol	Parameter	Conditions	Min (Note 5)	Typ (Note 4)	Max (Note 5)	Units
V_{REF}	Reference Voltage	LM1117-ADJ				
		I_{OUT} = 10mA, V_{IN}-V_{OUT} = 2V, T_J = 25˚C	1.238	1.250	1.262	V
		10mA ≤ I_{OUT} ≤ 800mA, 1.4V ≤ V_{IN}-V_{OUT} ≤ 10V	1.225	1.250	1.270	V
V_{OUT}	Output Voltage	LM1117-1.8				
		I_{OUT} = 10mA, V_{IN} = 3.8V, T_J = 25˚C	1.782	1.800	1.818	V
		0 ≤ I_{OUT} ≤ 800mA, 3.2V ≤ V_{IN} ≤ 10V	1.746	1.800	1.854	V
		LM1117-2.5				
		I_{OUT} = 10mA, V_{IN} = 4.5V, T_J = 25˚C	2.475	2.500	2.525	V
		0 ≤ I_{OUT} ≤ 800mA, 3.9V ≤ V_{IN} ≤ 10V	2.450	2.500	2.550	V
		LM1117-2.85				
		I_{OUT} = 10mA, V_{IN} = 4.85V, T_J = 25˚C	2.820	2.850	2.880	V
		0 ≤ I_{OUT} ≤ 800mA, 4.25V ≤ V_{IN} ≤ 10V	2.790	2.850	2.910	V
		0 ≤ I_{OUT} ≤ 500mA, V_{IN} = 4.10V	2.790	2.850	2.910	V

Table 3: LM1117 Low Dropout Voltages Characteristics

3.2.1.9 Switching Regulators

First it is necessary to understand which types of solid states devices are available in the market, and how they function as well. Some of the more commonly used devices are as follows:

- Bipolar junction transistor (BJT).
- Metal-oxide semiconducting field effect transistor (MOSFET).
- Insulated gate bipolar transistor (IGBT).
- Silicon controlled rectifier (SCR), also known as the Thyristors.
- Gate turn off Thyristors (GTO).

The choice of these semiconductor-switching devices solely depends on specific applications; power, voltage, current, and the frequency required for the system. A common feature between these semiconductor devices is that all are three-terminal devices as demonstrated in their regularly used circuit symbols.

The two-power terminal 1 and 0 are connected in the main power circuit, and the control terminal G is connected to the controller. In general working operations, power terminal 1 is usually at higher voltage than power terminal 0. This is optional and its selection is arbitrary depending of the user. Terminal G however, is known as the gate terminal and it is connected to the auxiliary control circuit or in other words the controller.

These semiconductor devices are primarily used for switching power on and off as required. In the absence of the control signal at the gate terminal, the semiconductor device resistance between its two-power terminal is large thus the semiconductor behaves like an open switch. In the other hand when a control signal is present or applied at the gate terminal then, the device resistance decreases approaching zero thus, making the device behave like a closed switch. The semiconductor device in the closed switch state lets the current flow freely through its body and travel through the circuit.

The voltage and the current ratings of these semiconductor-switching devices available for purchase vary a lot. Some specifications and characteristics of each are listed on Table 4:

Device	Voltage Rating (Volts)	Current Rating (Amps)	Remark
BJT	1500	200	Requires large current signal to turn on
IGBT	1200	100	Combines the advantages of BJT, MOSFET and GTO
MOSFET	1000	100	Higher switching speed
SCR	6000	3000	Once turned on, requires heavy turn-off circuit

Table 4: Semicondunctor Switching devices Characteristics

The Switch is triggered periodically on and off by a sequence of control signals at the gate terminal of appropriate frequency. This control signal at the gate terminal may be of rectangular or other wave shape, and is generated by a separate firing circuit or triggering circuit. Even though this triggering circuit has a different identity, function, and many different features, it is usually integrated in the main power electronic component assemblage. Stand-alone renewable energy power systems use the DC to DC converter for battery charging and discharging.

Switching regulators are another alternative in regulating the voltage because they offer design flexibility and higher power conversion efficiency. A buck regulator, which is used to reduce DC voltage to a lower DC voltage, could be implemented in our design. One of the advantages of using a buck regulator is that the power loss related in very little, so the GPS device will be more efficient. A Flyback regulator is also a good choice because is the most versatile of all topologies. This type of regulator allows us to create one or more output voltage for our design. If later on, a new feature is implemented in the GPS device that requires a third load with a negative input voltage, a flyback regulator would produce it. A flyback regulator will make GPS device more versatile and easy to supply voltage to new loads. The conversion efficiency for this regulator is very high.

In conclusion, to design a GPS tracking device battery-power system, it should be pay close attention to the proper operating voltage of GPS module, the transmitter, the microcontroller, LCD character display. Also, it has to be considered the operating conditions of the all components in the tracking device, as well as the chemistry of the batteries that best suits the main characteristics of our project.

3.2.2 Microcontrollers for GPS
Microcontrollers are small-scale computers on a chip circuit, which contains a processor core, a memory, and an array of General Purpose Input/output pins. Because of their bound structure, these devices are used in embedded system design, frequently to control a system, where the output are signals to external device and the inputs are generally external sensor data. Microcontrollers range in their amount of General purpose Inputs/output pins, chip communications modules, clock speeds, the size of their

accessible memory. Additionally, a lot of microcontrollers have an array of programmable timers, which can be operated in scenarios where accuracy in time is needed. In fact, about 55% of all CPUs sold in the world are 8-bit microcontroller making those devices very popular in the market.

One drawback of microcontroller is memory size. The MSP430G2553 offers 512B while other microcontrollers offer better size than that. For instance, the Arduino UNO offers 2MB. Even though it is possible to interface an external memory device with a microcontroller, it will be a speed vs. size compromise. The speeds of protocols like I2C or SPI are usually much slower than the microcontroller's internal memory. For instance, fast I2C operates at 400 KHz therefore instructions like fetch might take only a couple of cycles from internal memory, the microcontrollers might idle for many cycles before data is ready to be used.

Additionally, one of biggest limitation of microcontrollers is speed. Most microcontrollers run in the order of tens of Mega Hertz. Microcontrollers just cannot process the data quickly enough in cases where high throughput is required. Thus the number of instructions required may vary from tens to hundreds depending on the nature of the processing algorithm. However, this issue may not be a problem on the tracking device because the data received from the GPS does not have to be processed a higher speed. Also, microcontrollers are operated a one clock cycle per basic instruction because they use a RISC architecture. When an array of instructions for more complex instruction is needed, a clock speeds in Giga Hertz range is required. However, any interrupt might be enough for the system to lag because of interrupts based nature of microcontrollers.

Microcontrollers are better in tasks that do not require extensive bit crunching. They are good for doing simple analysis on sensor data, controlling various types of displays, and matching input conditions to outputs. Those are characteristics required for our project. In addition, microcontrollers are attractive to the market because of their low cost. Most embedded applications are simple enough that they do not require a microprocessor for the job, so microcontrollers are very appealing as they are suited for simple task, and keep production cost down. Nowadays, it is common to see systems with multiple microcontrollers communicating with each when more intensive applications are needed.

There is a variety in deciding which microcontroller to use. Each company seems to have some advantages and disadvantages depending on the type of microcontroller and its applications. One of the choices that have been presented at UCF is the Texas Instrument MSP430. The MSP430 is low cost and power microcontroller. Additionally, some choices in low power and low cost like the PIC18 series of microcontrollers from Microchip including the PIC18F45K22 could suit our needs. The ATmega168 and ATmega328 Microcontrollers from Atmel also could be good choices. In the following sections, a discussion that summarizes different characteristics of each of the above microcontrollers and how they can be useful in the GPS project is presented.

Microchip PIC18 Series: This 8-bit microcontroller will be also a good choice. One of the advantages of using this microchip is its reduced instruction set architecture and compatibility with C/C++ code and optimization for a C compiler. Unlike the MSP430, PIC18 microcontroller has great documentation such as tutorials, videos, and workshops

that are very helpful in getting familiar with the software used for this microcontroller. The PIC18F45K22 microcontroller in their PIC18F series is could be a good choice because it has a 32KB of programmable flash memory, a operating voltage up to 5.5 Volts, an ADC with 28 10-bit channels, 1.5 KB of internal RAM, and a max CPU frequency of 64MHz. In addition, the package has large input/output lines of 24 inputs/35 output lines and 40 pins. This chip operates at an extremely low power draw utilizing power-saving technology when the chip is idle. Cost is not an issue with this microcontroller. Its price is under $5, but a complete code development platform is needed at significant price.

Arduino Uno: This is a development package that runs off a wiring-base language similar to C++, and is based on the 8-bit ATmega328 microchip. Arduino Uno functions are more accessible for beginners because it is meant as an electronic solution for those who might not be familiar with embedded design. Since its release, hobbyists have used Arduino extensively. There are variety libraries, and tons of information in terms of code for support.

Atmel ATmegaXX8 Series: There are several reasons why this microcontroller could be implemented in the GPS project. This chip uses the RISC architecture and a low power draw level. This chip has a max clock speed of 20 MHz, an 8-bit AVR CPU, pin size of 32, 23 I/O pins, 10-bit ADC, an 8-channel, and an operating voltage of 1.8 to 5.5 programmable flash memory over 16 KB. The software used is AVR Studio 5, an IDE that allows the coding of assemble and C/C++ projects within any windows platform. The software used is free and can be found online.

Texas Instruments MSP430 Series: The MSP430 has a variety of microcontrollers, which allow flexibility on specifications, pin sizes, ADCs, form factors, and wide array of flash and SRAM memory sizes. All chips from their Value Line have low power draw and a clock speed of 16 MHz. Most likely the one that will be used in the project is MSP430G2553, which has up to 20 I/O pins, 8-10 bit ADC channels, and a 16 KB flash memory size. The microcontroller operates at supply voltage of up to 3.6 Volts. The software used for the MSP430 is Code Composer Studio. This software is free of cost can programmed using C/C++ programming languages. This microcontroller and development board can be obtained at no cost.

The MSP430G2553 is a surprisingly flexible microcontroller. In addition to its obvious advantage over the competition in regard to power consumption, it has several other features, which make it the preferred choice. Firstly, the clock system, the MSP430G2553 features three clock signals: The Master clock, the Sub-main clock, and the Auxiliary clock. All clocks are independent of each other, and can be the clock source for the various modules on board. The clock module block diagram is shown below in Figure 8.
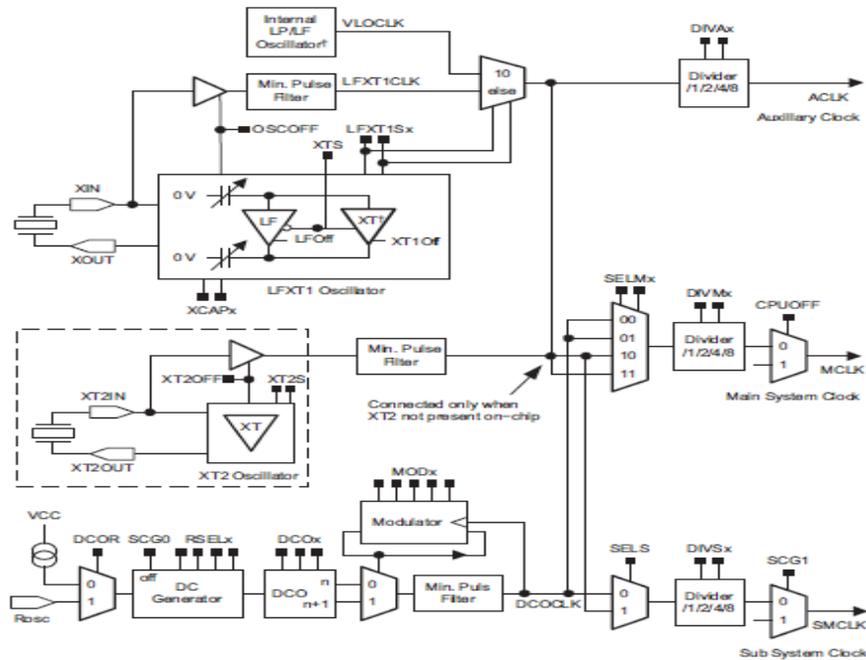
Figure 8: MSP430G2553 clock module block diagram

It is convenient because this allows the user to turn off entire sections of the clock module while they are idling, and resume operation if required. Furthermore each source passes through a divider. This block scales the incoming signal in frequency allowing user to ramp-up/ramp-down processing speed as per demands.

Another important feature is the presence of two 16-bit timers A, and B. Because they can be sourced from the SMCLK, or the ACLK, they do not run at the speed of the CPU, and thus can be configured independently. This is in important feature for applications where events are recorded in pre-defined timed intervals. For our project, timer A and B provide an accurate way to establish a time-frame in which to read the MPU-6050's register, and then compare that signal to a template for gesture recognition, see Figure 9 below:
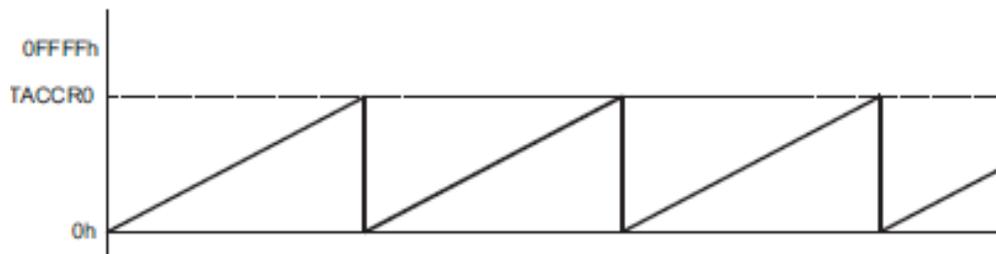

Figure 9: Timer Raises an Interrupt Fag Once the Value in TACCR0 is Reached

Lastly, it features 16KB of internal flash memory. Considering the sampling rate at 50 Hz for both the accelerometer and gyroscope, as well as a time-window for allowable measurements of two seconds, the most memory needed would be 5KB approximately,

slightly over half of the allowable range. That is for storing full 16-bit readings on each axis for both the accelerometer and gyroscope.

Microcontroller Summary: The PIC18F microcontroller seems to be a powerful microcontroller to use because of the great technical specifications. However, the price to be paid to gain access to full software package seems to be too expensive and it makes a less likely choice. The ATmega328 chip is convenient in terms of availability, price, and it is easy to use. This chip price is about $20. The MSP430 seems to be the cheapest choice with an unbeatable price – under $5-, and its software is free of any cost. The data and tolerance considerations are within the GPS project design.

3.2.3 Communication Protocol

UART or Universal Asynchronous Receiver\Transmitter protocol is a standard serial communication subsystem of a computer. UART transmit a byte of data by sending individual bits in sequential fashion. In asynchronous communications a transmission starts with a "start bit", captured by the receiving device. In our case since the TXD and RXD lines idle "high", a start bit is signified by pulling the line "low". Once the receiver captures this event, it offsets its timer by one and a half the bit time for the given clock source and baud rate. The timer will generate and interrupt during the middle of the first transmitted bit to be read. This process is repeated until the 8th bit is read. As it's evident, the receiver and transmitter must both agree on a specific baud rate, otherwise bit times will be off resulting in an unsuccessful transmission or false data. A single byte UART transmission can be seen in Figure 10.
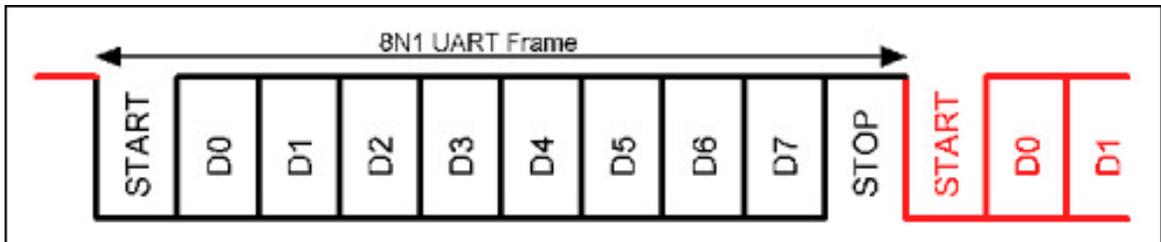

Figure 10: Single Byte Serial Transmissions in UART Protocol.

Timing requirements are more clearly depicted in Figure 11, and from then it can be seen that the clock source must have little variation over the operating condition to avoid sampling during transitional periods.
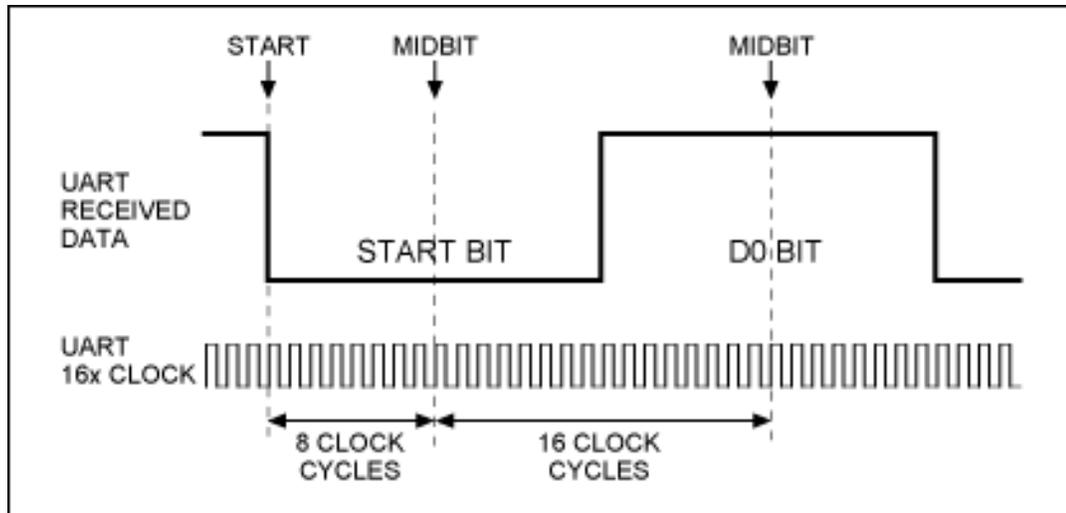
Figure 11: UART Bit Time over Microcontroller Clock Cycles

Another source of error is the selection of higher baud rates with respect to the microcontroller clock speed. As the baud rate approaches the microcontroller clock, discrete time intervals may not land during the desired sampling time. As such the MSP430G2553 allows UART speeds of at most one-third of the module's clock source. The MSP430G2553 also provides a modulation step to minimize timing error. The modulation register values are calculated using the following formulas:

$$N = \frac{f_{BRCLK}}{Baud\ Rate} \quad UCBRx = INT(N) \quad UCBRSx = round\left(\left(N - INT(N)\right) \times 8\right)$$

The MSP430G2553 dedicated UART module runs independent of the CPU and can be sourced from the ACLK or SMCLK. An advantage we plan to exploit by entering low power mode and only sourcing the clock signal used by this module. Furthermore it minimizes the transmission error by including a variable modulation stage to compensate for timing errors. Typical timing errors of various configurations of source clock and baud raters are given in Table 5. Lastly UART protocol uses a two wire interface: TXD, and RXD. Due to the limited availability of GPIO in the MSP430G2553, the RS232 TTL Transceiver module provided the best wireless solution for our project.

BRCLK frequency [Hz]	Baud Rate [Baud]	UCBRx	UCBRSx	UCBRFx	Maximum TX Error [%]	Maximum RX Error [%]
32,768	1200	27	2	0	-2.8 – 1.4	-5.9 – 2.0
32,768	2400	13	6	0	-4.8 – 6.0	-9.7 – 8.3
32,768	4800	6	7	0	-12.1 – 5.7	-13.4 – 19.0
32,768	9600	3	3	0	-21.1 – 15.2	-44.3 – 21.3
1,048,576	9600	109	2	0	-0.2 – 0.7	-1.0 – 0.8
1,048,576	19200	54	5	0	-1.1 – 1.0	-1.5 – 2.5
1,048,576	38400	27	2	0	-2.8 – 1.4	-5.9 – 2.0
1,048,576	5600	18	6	0	-3.9 – 1.1	-4.6 – 5.7
1,048,576	115200	9	1	0	-1.1 – 10.7	-11.5 – 11.3

1,048,576	128000	8	1	0	-8.9 – 7.5	-13.8 – 14.8
1,048,576	256000	4	1	0	-2.3 – 25.4	-13.4 – 38.8

Table 5: Typical Transmission Errors Given Various BRCLK Clock Speeds as well as Baud Rates

3.2.3.1 The I2C Protocol

The communication protocol used for interfacing the MSP430G2553 with any of the aforementioned digital sensors is I^2C. I^2C, also known as a two-wire interface, is a multi-master, multi-slave environment meaning that, should the design make use of the ITG-3200 and the MMA8452Q, no additional bus lines are required (No additional pins on the MSP430G2553). The I^2C bus consists of two bidirectional open-drain lines, the Serial Data Line (SDA), and the serial clock line (SCL), with both lines needing pull-up resistors for proper functionality as shown in Figure 12. Through some testing it appears that the value of the pull-up resistor is not critical; the bus operated with values in the range of 2k to 47k.
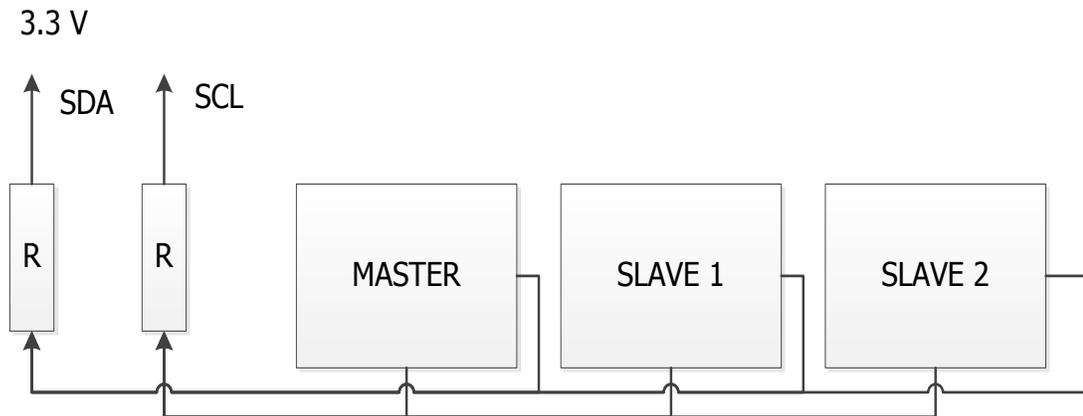

Figure 12: I2C Connection Diagram.

Under normal transmission the SCL line is driven by the master, with the SDA controlled by the master for a "write" operation and by the slave for a "read" operation. No transmission can be initiated by any of the slave devices over the I^2C bus. The I^2C protocol allows for multiple masters but, since the design is a one master environment, it is not relevant to the project and omitted in this paper. As shown in Figure 13, the master initiates transmission with a start sequence, defined as a transition from high to low on the SDA line while the SCL line is high. Following the start sequence data is transferred in 8 bit packets. All data bits must be stable while the SCL is high for a successful transfer; meaning changes in the SDA line must occur while the SCL line is low. Terminating a transfer is also up to the master. In order to cease communications and free the I^2C bus a stop sequence must be issued. The stop sequence consists of a transition from low to high on the SDA line while the SCL line is high. During a "read" operation, and in the event the slave is not ready to send data, it can hold the SCL line low. This is called "clock stretching" and allows the slave to place the data on its shift registers when ready. Furthermore, clock stretching prevents the master from continuously sending out clock pulses with no response by the slave.
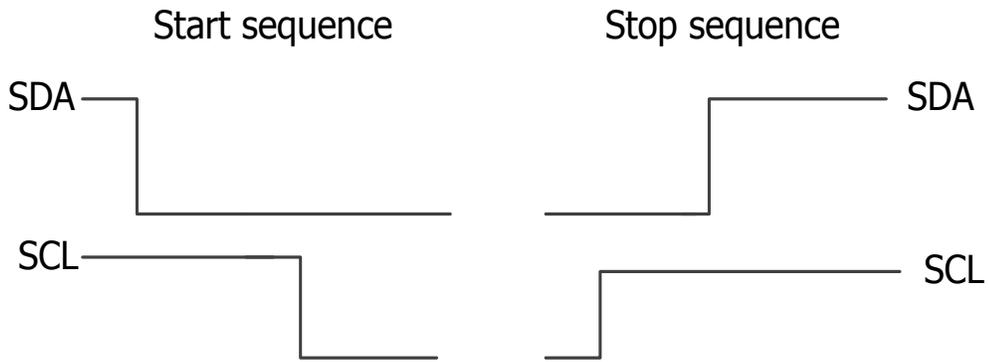
Figure 13: I2C Start and Stop Sequences

The first sequence of 8 bits is made up of 7 data bits, which refer to the slave address to be accessed, and on read/write bit to specify the type of transfer. The I^2C protocol allows for 10-bit addressing mode, but is not relevant to the project and thus omitted in this paper. Once the master sends the last data bit, and if the transmission was successful, the slave must send an ACK (acknowledge) signal by pulling the SDA line low. After the slave address is sent and acknowledged, the next 8-bit sequence specifies the slave register to be accessed. For a write operation, the register number is first sent, followed by the first byte of data (data written to the register specified), subsequent data transfers are written to the slaves registers in ascending order. A read operation is slightly more complicated. In order to read from a given register from the slave, the master must first write that register address, thus a reading sequence starts with a write operation. Once the register address has been transmitted the master sends a repeated start bit, followed by the slave address with the read/write bit set. The slave proceeds to continuously send data until a stop sequence is sent. Figure 14 and Figure 15 below depict the processes described above:
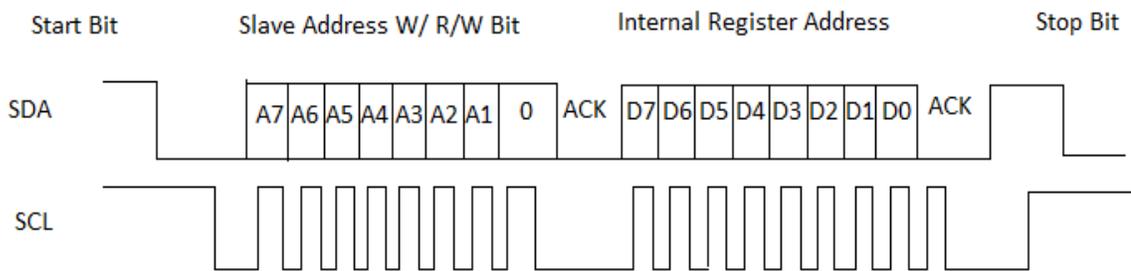

Figure 14: I2C Read Sequence Starts with a Write Operation (R/W Set to Write).
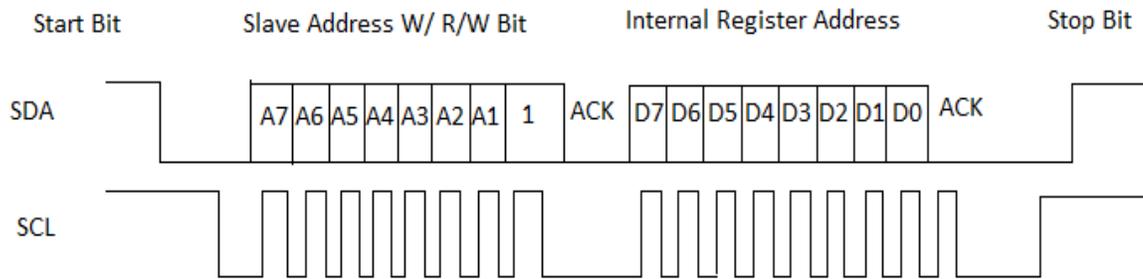
The main drawback of this serial communication protocol is the relatively slow transmission speeds. All the digital sensors that have been researched transmit in "fast-mode" which clocks at 400 KHz. Luckily, hand-based gestures are relatively slow-changing signals, therefore this max speed of 400 KHz is much faster than the aforementioned sensors sampling rate. The information from this section is gathered from.

3.2.4 Tracking Device

This device will contain a transmitter module, a rechargeable battery, an LCD character display, a microcontroller, and the GPS chip. The GPS chip will calculate its actual location and outputs the pseudo range data for each satellite. This data will be processed on the microcontroller, and the transmitter module will transfer this information to the base station. Thus, the microcontroller main purpose on this device is to change the output of the GPS chip from NMEA protocol to SIRF binary protocol. By doing so, we will be able to get the pseudo range locations in an executable format.

3.2.4.1 Character Display

The character display on the device will have many functions. Since each device will be assign to a specific person, the name, the date of birth, age and contact number of that person will be display on the device. The outside temperature will be also display on the device. This information will be transmitted to the base station and will be useful to find the person carrying the device.

As far as character displays, there are many options in the market to choose from. One limitation on deciding on the right character display is the size. As part of the design, we are trying to make the GPS tracking device as small as possible, so each part add to the device has to be no bigger than 75x53 mm.

The LCD Shield w/ 16x2 Character Display allows us to control a 16x2 character LCD, up to 3 backlight pins and 5 keypad pins using only the two I2C pins. This shield goes well with stand - alone projects because the 4 directional buttons and the select button allow basic control without having connected a computer or laptop. The assembly for this product is relatively easy and there are plenty of tutorials of how to solder this part on the PCB. The price is this LCD shield is less than $20. The negative side of this character display is the size. Its dimensions are 53.4x81.3 mm. That will exceeds our design specifications and make the GPS tracking device bigger.

The NHD-0420E2Z-FL-YBW character display could work in our project as well. It has a wide variety of backlight color combinations. This device features a higher brightness per watt, a low power back light, wide operating temperature, negative and positive image option. It has character count line 20x4, STN fluid type, with a yellow/green background color. However, this display operates a 5 Volts, and we are designing the loads of GPS device to operate at 3.3 Volts. The character display size is also a problem. The module size is 146mm x 62.5 mm x14.5 mm, which is bigger than the design specifications 75x53 mm.

The EA DOGM162B-A character display shows the characteristics we are looking for. This display runs on 3.3 Volts system without auxiliary power. This module is designed for compact hand held devices and can be used on traditional 5Volts systems. The DOGM includes 128x64-pixel and 132x132 pixel options, and satisfied the size requirement. Its size is 56x46 mm making it extremely compact and price is under $12. This character display suits our needs.

3.2.4.2 Odometer
The GPS tracking device will also has a simple implementation of an odometer to track running/walking millage. These calculations can be done on websites such as mapwywalk.com or Google, but a GPS tracking device can yield advantages over these sources. The person carrying the device can instantaneously know mileage while walking or running outside. The goal is to implement a new feature in our device since the design already has a microcontroller, a LCD character display and a GPS module.

The calculations behind the odometer are fairly simple. The GPS tracking device will just keep a running total in kilometers or miles, which will always be displayed on the LCD character display. The distance formula will be used to calculate the distance traveled between the current and most recent GPS readings, after conversion from latitude and longitude coordinates to statute miles. This distance is then added to the total. Every 2 seconds, the information is updated.

3.3 Indoor Tracking System

3.3.1 RFID
Since our goal is to build a GPS tracking device with DGPS that will be embedded on an item worn by a person, we make the provision in case that person is located inside of a house where the DGPS will not get access to it. That is why we use the radio frequency identification (RFID) that will play the same role as the DGPS when the tracking device is inside of a building for example. In brief, what is a RFID? According to Asentrix system, Radio Frequency Identification is an emerging technology gaining widespread acceptance for use in warehouse management, supply chain management, asset management, as well as personnel and patient tracking. In our case, it is going to be used as a people tracking device. Wikipedia provides a more specific definition of RFID which is the use of wireless non-contact system that uses radio frequency electromagnetic fields to transfer data from a tag attached to an object, for the purpose of automatic identification and tracking. Another definition provided by WEBOPEDIA, which is close to the one provided by Wikipedia is an explanation of radio frequency identification

instead of a definition. It states, with RFID, the electromagnetic or electrostatic coupling in the Radio Frequency portion of electromagnetic spectrum is used to transmit signals. It also establishes different parts that form the RFID system such as antenna, transceiver or reader, and transponder commonly called tag. The transceiver reads the radio frequency and transmits the information to a processing device, a microcontroller in our case. The transponder itself is an integrated circuit, another name for chip, containing the RF circuitry and information to be transmitted.

3.3.1.1 Types of RFID

RFID can be divided into three categories: Passive, Semi-Active, and Active. These tags come in many styles for different applications such as asset management, inventory systems, product tracking, access control, promotion tracking, transportation tracking, transportation payment, animal identification, and patient tracking in hospital. When we speak of RFID system, as we mention in the above paragraph, we mean the RFID Reader or transceiver, an antenna or coil, and RFID tags or transponders. RFID system can use a cellular system called Time Division Multiple Access (TDMA) to make sure the wireless communication is handled properly.

Passive RFID tags rely entirely on the reader as their power source. These tags are read up to 20 feet away, and they have lower production cost. These tags are manufactured to be disposable, along with a disposable consumer good on which they are placed. Another factor that influences the cost of RFID tags is the data storage capacity. The passive tag itself is divided into three types: Read Only, Read/Write, and Write Once Read Many. The Read only ones are less expensive and are preprogrammed during the manufacturing process. They have fastest data collection, better application performance, and high read rates (up to 1000 tags/second). The Read/Write tags are basically the same as the Read Only ones; the only difference is that the data stored in them can be changed by the system operator. Those data can be edited, added to, or completely rewritten if the tag or transponder is in the rage of the reader. As for the Write Once Read many tags, also abbreviated WORM, the user can program them once and the information is stored in a chip which is available only to be read as many times as needed. One inconvenient in the passive tags is they cannot store too much information. Only information such as names, address, phone numbers, and date of birth can be stored in them. Another inconvenient is the read range in term of distance. This limitation in range is base on the absence of its own power source because the passive tags are powered wirelessly by the interrogator. Also, they are sensible to hot temperatures or extremely cold temperatures. However, the passive tags have some advantages over the other tags. They are less expensive and data stored in them can last up to ten years. Mostly, the RFID passive tag operates in the following manner: A radio frequency is emitted through an antenna and the information stored in the tag is transmitted to the reader for further processing and manipulation. It doesn't need to be directly powered; it receives its power from the transceiver.

The semi-Active tags require battery to operate the circuitry of the microchip but it must also draw power from the magnetic field created by the reader in order to communicate with the reader via radio wave. Comparing to the passive tags, semi-active tags are faster and stronger to respond back on receiving a signal from the reader. Also, these types of

tags have a longer read range and the ability to determine the location of the person being tracked.

Like the semi-active tags, the active RFID tags contain a battery that powers the microchip and allows it to transmit a signal to the RFID reader. However, they work the same way as the passive tags. The only difference is that some active tags transmit data periodically with a certain limitation because the RF data transfer is only required processing the data for a specific task. Active tags are more reliable than passive tags because there is a power source in the circuit. As a result, they can be read hundred feet. Also, active RFID tags have about 1000 times more memory than passive tags and the data stored in them last for about the same time as the passive ones. One inconvenient of an active tag is the weight. Active tags are much heavier than the passive tags. Another aspect that we can consider as an inconvenient for the active tags compare to the passive and semi-passive ones is the price. The price for the active tags is much higher than for the others tags. As for the case of the other types of tags, the RFID active tags are sensitive to very high and very low temperature. For simplicity, since our device will be worn by certain individuals, we are using the Read only passive tags because it is lighter and less expensive. Also, they have fastest data collection, better application performance, and high read rates.

3.3.1.2 Frequency Usage

The Federal Communications Commission (FCC) restricts the use of certain frequencies; consequently, close attention needs to be paid to the frequency usage. Also, using a very low frequency may cause some inconvenient because higher is the frequency better is the read range. Frequencies can be classified into at least three categories: low frequency, high frequency, and ultra-high frequency.

- Low frequency (LF): Frequencies between 125 and 134.2 KHz. Those kinds of frequencies have a range of up to 1.5 feet and provide a shorter read range and slower data transfer rate.
- High frequencies (HF): Frequencies between 134.2 KHz and 13.56 MHz. Those kinds of frequencies have a range of up to 3 feet and provide a higher read range and a faster data transfer rate than the low frequencies.
- Ultra High Frequencies (UHF): Frequencies between 860-960 MHz. Those kinds of frequencies have a range of up to 9.5 feet and provide the highest read range and faster data transfer rate than the above frequencies.

Table 6: Frequency Types and Descriptions below is a summary of the frequency bands, types, ranges, and their applications.

Frequency Band	Description	Range	Application
125-134.2 KHz	Low Frequencies	1.5 feet	Can be used globally without a license. Often used for vehicle identification

134.2KHz-13.56 MHz	High Frequencies	3 feet	Used for library books Airlines baggage Contactless payment. Access control.
860-960 MHz	Ultra High Frequencies	9.5 feet	This band cannot be used globally. There are significant restrictions on its use. When it is used, it is often used for asset management, container tracking

<div align="center">Table 6: Frequency Types and Descriptions</div>

3.3.1.3 Interferences in RFID Networks

Caution must be taken to avoid interferences in the RFID Networks. For example, the EPC class I Generation 2 UHF is based on slotted Aloha reader-to-tag communication protocol. The collision occurs if several tags select the same time slot for communication. There are several types of interferences in the RFID networks; they include tag-to-tag, reader-to-tag, and reader- to- reader interference. The tag-to-tag interference occurs if several tags try to communicate with the same reader at the same time. Reader-to-tag interference occurs if the tag receives signal from two readers because tags are not frequency selective; so, they can be confused in that case. Reader-to-reader interference means that the signal from the neighboring readers will be stronger than the backscattered signals from the tags. In the case of the Smart GPS, there will be only one reader to communicate with the tags. The communication will be mainly between Reader and tags vice-versa. As a result, we care only about interference between reader and tags. One of the factors that can cause interference is the contact with metals. Metal causes eddy currents in the vicinity of the RFID reader antenna which absorbs RF energy; consequently, the overall effectiveness of the RFID field is reduced. These Eddy currents also create their own magnetic field that is perpendicular to the metal surface; this perpendicular magnetic field cancels the reader field. For this reason, we will do our best to avoid contact with the metal.

3.3.2 Wireless Sensor Network (WSN) Overview

Today's communication technologies promise wide possibilities including Wireless Sensor Network (WSN), which is a collection of nodes with sensors integrated to collect physical information such as temperature, pressure, or motion. In our case, it is going to be used for motion detector. These nodes act independently, transmitting the sensed data to a base station for further examination or processing. Nodes can also transmit data to other nodes, a process we are going to use in our project because of the short read range of our RFID system. It is important also to establish the difference between Radio Frequency Identification (RFID) and Wireless Sensor Network (WSN). RFID is used to

detect presence and location of objects or people (in our case) while WSN is used to sense and monitor the environment that is why integration of RFID with WSN not only provide identity and location of an object or a person but also provides information regarding the condition of the object or the person. The integration of these two RFID and WSN are very important because one is the complement of the other. For example, sensors are able to provide much more information such as temperature, humidity, pressure, vibration intensity, sound intensity, chemical concentration, and pollutants level. Also, in an RFID system, all communications are single hop and there is no communication among tags however, the integration of WSN provides RFID the ability to work in multi-hop way that potentially extends applications of RFID to operate in a wider area. In our case, a person will be carrying an RFID watch, and when she/he leaves the allocated area which is considered as our geo fence, the communication system will be activated and the appropriate action will be taken.

3.3.2.1 Application for Combining RFID and WSN

The major application of RFID networks is to detect the presence of tagged objects or people and to provide the location of those objects or persons. There are two different approaches for providing the location: detecting the position of the person with the mobile reader based on detection of tags placed at fixed known location and detecting the position of the object with tags based on the position of fixed readers.

By combining the properties of RFID and WSN, we can define four different applications for combining RFID and WSN: Integration in which RFID is used for identifying and WSN for sensing, integration in which RFID is used for identifying together with sensor, integration in which RFID is used for identifying and WSN is used for providing location, and integration in which RFID is used to assist positioning that is identified using sensors.

1) The integration, in which RFID is used for identifying and WSN for sensing itself, presents three different scenarios: case where RFID and WSN are attached to the same object, case where RFID tag is attached to the object and WSN is used for sensing the object, and the case where RFID tag is attached to the object and WSN is used for sensing the environment.
    a) Case where RFID and WSN are attached to the same object.
       In this case, RFID tags and integrated sensors are attached to the same object to perform both detecting and sensing task. The tags are used to detect the presence of the objects and the integrated sensors are used to sense the objects' temperature, vibration, etc.
    b) Case where RFID tag is attached to the object and WSN is used for sensing the object.
       In this case, the RFID tag is used to provide information about the object that is photographed in museums. Reader is integrated to the camera and tags are attached to the objects in the museum. After the object is sensed, RFID can provide additional information about the object.
    c) Case where RFID tag is attached to the object and WSN is used for sensing the environment.

In this case, typical applications include mobile robots that rely on RFID for detecting non-sensible objects and on WSN for collecting information about temperature, humidity and other environment-related information.

2) Integration in which RFID is used for identifying together with sensors.
RFID information can be read from the tag only after the fingerprint scan matches the one that is already stored in the chip. In this way sensor and RFID technology can be combined to enhance security.

3) Integration in which RFID is used for identifying and WSN is used for providing location.
There are some cases where RFID tags are used for identifying people and WSN is used to locate the leader of the group. After the location of the leader of the group is known, the lost members are guided in finding their group leader.

4) Integration in which RFID is used to assist positioning that is identified using sensors.
In this type of integration, a positioning system for first responder is described in which different sensors are used to estimate the position of first responder and RFID tags placed at known position are used to correct the estimated position.

3.3.3 Different Methods of Integrating RFID Readers and Tags

Choices are multiple in integrating RFID and WSN. Picking up a method depends on the application of that integration. We can integrate RFID tags with wireless sensor nodes and wireless device or we can integrate readers with wireless sensor nodes and wireless device. In the case of integration the RFID tags with wireless sensor nodes and wireless device, the integrated tags are able to communicate with many wireless devices which are not limited to readers. The tags in this type can communicate to each other and form a multiple hop network. Each sensor node is integrated with an RFID tag and is also provided with RFID reader capability. There are two sets of radio in each sensor node. One is an RF sensor radio for communications with sensor nodes and the other is an RFID radio called a wake-up radio. Another type of integration of RFID and sensors is the combination of RFID readers with wireless sensor nodes and wireless devices. The integration enables new functionalities and opens the door to a number of new applications. The integrated reader is able to sense environmental conditions, communicate with each other in wireless fashion, read identification numbers from tagged person and effectively transmit this information to the host. The basic idea of integration is to connect the RFID reader to a RF transceiver which has routing functions and can forward information to and from other readers. Users are able to read tags from a distance that is well beyond that of the normal range of readers through hop by hop communication of the readers. The integrated node consists of a RFID reader, a RF transceiver, and a microcontroller that coordinates different components in the node. The microcontroller is also used to control the RFID reader and other components that go into sleep mode when they are not busy. In our case we are going to integrate readers with wireless sensor nodes and wireless device. The structure of the node is shown below in Figure 16:
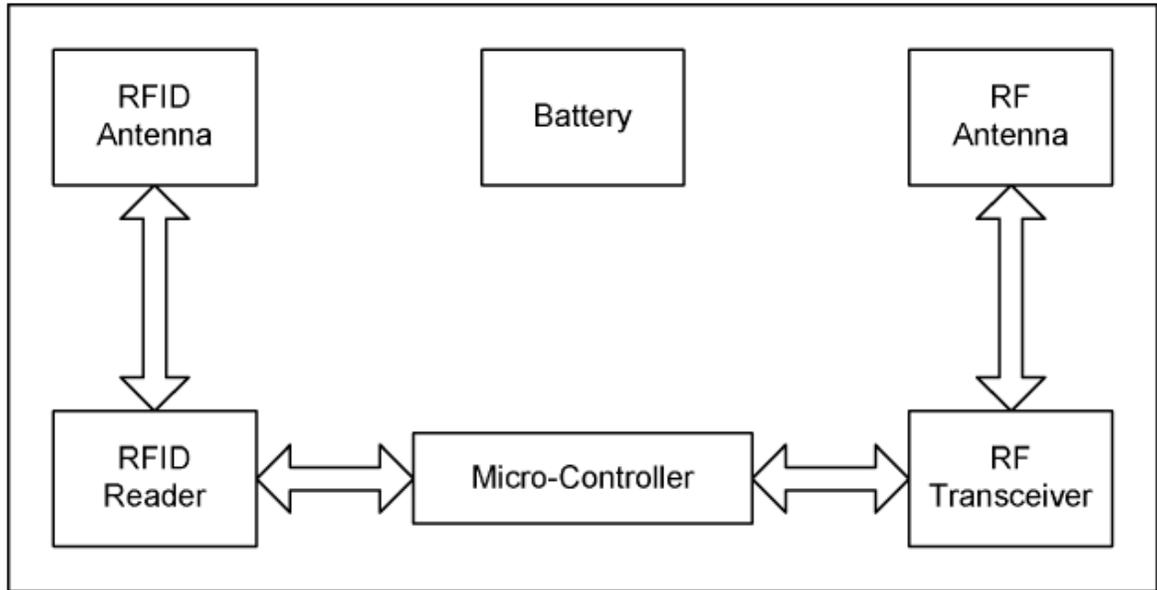
Figure 16: Structure of Integrated Reader

3.3.4 Types of Communications between Tags and Readers

The tag can communicate with the reader in many ways. These types are: communication via inductive coupling, communication via backscatter coupling, and communication via capacitive coupling

3.3.4.1 RFID Inductive coupling

In this type of communication, the transponder and the antenna are coupled by the magnetic flux through both coils, much like a transformer. All the energy used in the tag is drawn from the primary coil of the antenna. In other words, the reader emits a magnetic field. When the tag enters the field, the chip will vary its antenna response which will result in a perturbation of the magnetic field which can be detected by the reader. The strength of a magnetic field drops sharply with distance from the emitter; hence inductive systems are inherently short range.

3.3.4.2 RFID Backscatter Coupling

In this type of communication, depending on its characteristics, an antenna reflects part of an incoming electromagnetic wave back to the sender. Electromagnetic waves are reflected by most objects that are larger than half of the wavelength. The efficiency of reflection is particularly large for antennas that are in resonance with the incoming waves. The short wavelengths facilitate the construction of antennas with smaller dimensions and greater efficiency. Over short ranges, the amount of power reaching the tag from the reader is sufficient to allow operation of small low current circuits within the tag. This can be used to drive an electronic switch that can switch an antenna load resistor in and out of circuit. This will effectively modulate the returned signal and allow data to be passed back to the reader. In order to allow transmission and reception of a signal at the same time, a directional coupler is often used to allow the received signal to be separated from the transmitted one. Furthermore, the reader most be able to detect the

modulation in the presence of a host of other reflections, although this will be stable and not modulated in any way.

3.3.4.3   RFID Capacitive Coupling

A third type of communication is the RFID capacitive coupling. This type of coupling is used for short ranges where a form of RFID close coupling is needed. As the name mentions, the system uses a capacitive effect to provide the coupling between the tag and the reader. This system is often used for smart cards. This type of coupling operates best where items like smart cards are inserted into a reader. In this way, the card is in very close proximity to the reader. Instead of having coils or antennas, capacitive coupling uses electrodes. In our case we will use the inductive coupling because it is more appropriate for the Smart GPS case.

3.3.5 Data Modulation

Modulation can be defined as the process by which some characteristics of a carrier are varied in accordance with instantaneous value of some other voltage called modulating voltage. Modulation can be digital or analog. When talking about digital modulation, we talk about Amplitude Shift Keying (ASK), Frequency Shift Keying (FSK), and Phase Shift Keying (PSK) whereas when we talk about analog modulation we mean Amplitude Modulation (AM), Frequency Modulation (FM), and Phase modulation (PM). For simplicity, we will use Frequency Shift Keying (FSK) modulation for our Smart GPS.

3.3.6 Transmission and Reception

The project requires both the transmission of a certain frequency and the reception of data. For our smart GPS project, the frequency will be in the range of 134.2 KHz-13.56 MHz. So, any tag in the read range can be read. Since the read/write depends mostly on the electromagnetic coupling of the reader and the tag antenna, the reader has to be able to create the necessary electromagnetic field within the tag by using the tag's antenna to power it up for a perfect communication between them. The coupling between the reader's antenna and the tag's antenna can be increased by using a similar size antenna on the reader because it will increase the charge on both microchips.

An important remark is the reader and the tag communicates via the antennas. In addition to the frequency usage affects the read/ writes range between the reader and the tag, the RF output power level of the reader is another factor. In theory, when the carrier frequency is increased, the read range improves. However, when using frequency other than low frequency, as in our case, the antenna's beam width is narrower and position of the tag becomes a factor because of the lesser penetration ability. For instance, in the low frequency band, penetration is much better but the antenna performance and the range of the tag to the read/write zone become an issue that needs to be taken into consideration. As stated above, we will use Frequency Shift Keying (FSK) to modulate the amplitude of the backscattering signal. Since the reader uses a carrier frequency to communicate and power the tag, we need to give more details about the carrier frequency. The carrier provides energy to the tag and is also use to detect modulation data from the tag using backscattering schemes. Consider the case where we use only a read only tag where the data in the tag cannot be modified; the reader is constantly transmitting its carrier signal and also watching for any backscattering signal that the tag might transmit. Once the tag

is powered up, it begins its operating procedures and uses its own hardware to correctly modulate and send data across its own antenna coil. In the passive tag, there is a transistor that shorts correspondingly with the data in the device; this creates an amplitude differences across the antenna voltage. The reader detects the amplitude differences and decodes the data accordingly.

Another aspect that also needs to be taken into consideration is the data encoding. Data encoding deals with processing the data after it has been retrieved from the tag's memory and before it is transmitted back to the reader. There are many encoding methods; some are easier to recover, some are less expensive to implement, some need more bandwidth, and some have lower error rate. The three more popular encoding methods for RFID in use today are non-return to zero (NRZ, and the Manchester model. For the case of non-return to zero, "1" is represented by no change in physical level and "0" is represented by a change in physical level.

As for differential Manchester encoding, also called biphase mark code (BMC), is a line code in which data and clock signals are combined to form a single 2-level self-synchronizing data stream. It is a differential encoding using the presence or absence of transmission to indicate logical value.

3.3.7 Communication between GPS Device and RFID Reader

For communication between RFID reader and the GPS device we will use wireless communication mostly to ease the communication between the tag and the reader, between the reader and sensors, and between sensors and sensors.

3.3.8 Software

Decision must be taken according to the needs. Some means must be established for all the parts such as the device commonly called tag, the reader, and the base station to communicate together in order to take the right decision at the right time. To do so, we will use the C language to program a microcontroller to ease the communication between different components.

3.3.9 Hardware

For the RFID part, we will use an RFID reader, a transponder commonly called tag, a microcontroller, and a mean to send the information to the base station; we are considering XBee for that purpose. As one can see in the following figure the RFID reader, the microcontroller, and the XBEE will be powered. Since we are going to use a passive tag, it will get its power from the reader. The double arrow between the tag and the reader means only, once the tag is in the reader field, the reader will wake up the tag and the tag will backscatter the information to the reader. Once the reader receives this information, it will send them to the microcontroller and the microcontroller will send this information wirelessly to the base station via XBee. See the following figure, Figure 17 for the summarization of these processes.
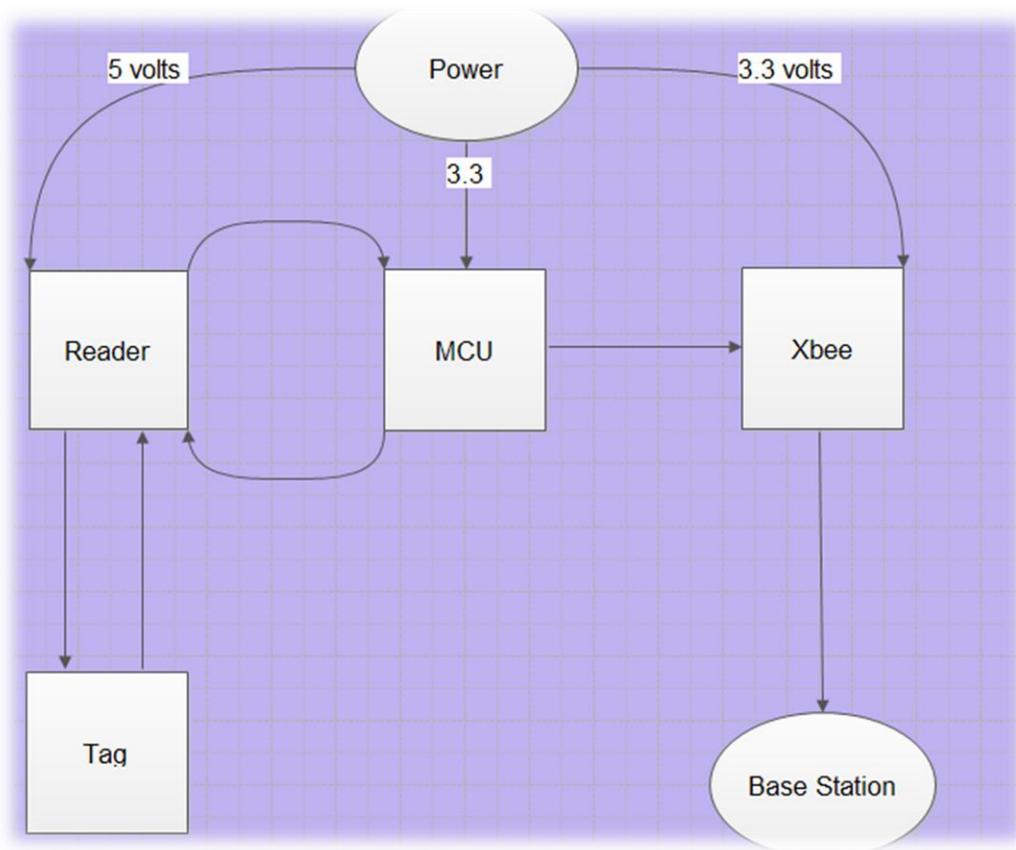
Figure 17: RFID System Diagram

3.4 Base Station

3.4.1 Microcontroller Unit

Before a project can begin, the medium upon which the endeavor will be based must be selected. This, as a result, forces a compression between both the microcontroller and microprocessor where in the best component for the application will be selected. Some of the most important criteria by which to judge said technology include memory capacity, programmability, cost, development environment, and flexibility. Other standards by which two parts can be compared include how well each amalgamates with other technologies, how easily modifiable and or easy to integrate each may be, and how durable the part is. Although the microcontroller and processor how begun to be used interchangeably in recent years, be it through ignorance or simply oversight, they are by no means the same and should not be substituted as such.

In term of cost alone the microcontroller dominates the microprocessor in that a microprocessor cannot be used on its own. RAM, ROM, and I/O ports are among the many items that must be added to even allow the processor to be affective. Not only would this IC be more costly, it could be more processing power than is needed. For a project of this caliber all that is needed realistically is a device which can, with an appropriate amount of programming, send and receive signals to other entities within the

design environment. This part would moreover act primarily as a proxy between the many other components used in the project and therefore would require too much time to develop if it were to be centered on a microprocessor.

If cost were no issue the use of a microprocessor, within a computer for instance, would greatly reduce the effort associated with obtaining wireless data from GPS, RFID, and other integrated circuits in used. The microprocessor would instantly allow communication with the Base Station, which will inevitably be either the processor or controller, to be streamlined. The focus would no long be on buying GPS receivers or RFID reader with microcontroller connectivity so information could be transferred between systems. If commutation through direct connectivity was impossible moreover the research and development required to modified or build an RFID reader for example with Bluetooth and Wi-Fi capabilities could become separate project within itself. Creating a circuit board on which each separate element would have to be soldered, circuited, and powered to enable microcontroller communication would be bypassed because of the many interfacing options a microprocessor would provide.

Aside from the ease of systems integration offered by a microprocessor based computer, the need to produce a power supply for the base station would be eliminated. Not only would the computer simple need to be plugged into any outlet to generate all the necessary power if the computer was a laptop the system would have a rechargeable battery power supply as well. Microcontrollers on the other hand require a lot of circuit analysis and design to provide the power essential to the device. A thorough understand of how capacitors, resistor, and inductors interact along which type of the aforementioned components would be most suitable most be obtained. Question regarding the portability of the system would be addressed to determine if both an AC and DC power supply should be designed or if the one would suffice. The microprocessor would seem to be the best choice if a computer which enlisted the use of a processor was applicable. Furthermore if the cost of using a computer could be justified along with the need to use a system of its ability the thought of using a microcontroller would seem inadequate.

While there is something to be said for the inconvenience of generating a power supply for a microcontroller, a microprocessor in its most basic form would require the same accommodations. Furthermore because it can be assumed that the chip will need to execute the same simple set of instructions repeatedly, a microprocessor lacking in the ROM, RAM, I/O, and CPU inherently found in a microcontroller may not be feasible. Another more important aspect of the base station design is the manner in which the chip will be programmed. Microcontrollers in general seem to have a much broader verity of chip options which also provide development environments, programs, and software enhancements which can greatly improve the development process. Finding solutions for problems that may arise while working with a microcontroller may prove to be easier as compared to a microprocessor not only because of the popularity of these devices but because of the countless forums available a developer's website.

Although the choice between a microcontroller and microprocessor may be a challenging one given the myriad of available chip types, the selection process could be simplified immensely by searching for features which complement the project. The microchip or base station will need to have wireless connectivity, the ability to receive GPS signals,

and the capacity to interpret signals for an RFID reader. One of the more challenging aspects of this multipurpose system is communication between the base station and the RFID read. This as a result required the microcontroller to be Bluetooth enabled and provide a jack for any wire connections that may be required because the manner in which information can be obtained for a reader is unclear. A chip with all of these capabilities built in would be ideal however although probably highly unlikely so a chip that provide Wi-Fi and Bluetooth connectivity with a possible Universal Asynchronous Receiver / Transmitter or UART facet would be preferred. If however a chip with these specifications is not available the effortlessness of interfacing said chip with other mediums may be jeopardized. This undoubtedly will in turn lead to an unnecessary amount of focus, allocated primarily to programming and debuting the code needed to run the base station, exhausted simply trying to generate a circuit connection which will produce an output.

It is paramount that the microcontroller or processor used has at least one pair of Rx/TX pins however if a chip were to have two or three pairs of said pins the base station would be much more robust. More robust because the receivers need to obtain information from both the GPS wrist band and RFID reader which will be communicating with the base station need both the RX and TX pins to relay information. Having a chip with many of these will also increase the rate at which information can be transmitted to the base station and its many interfaces in that they would not be required to us the same UART line. Depending on which device is selected for the station furthermore a UART master slave connection may or may not be possible. To combat this issue as a result it may be important to determine if the microcontroller or processor has an I/O expansion kit or solution.

The final factor to consider when selecting a microchip which will act as the primary channel through which information is transferred is the rate at which the information can be analyzed. Determining which bit size would best fit the given application without selecting a device which would provide too much unnecessary space is a challenge. Challenging because it is unclear as to what format information such as GPS coordinates will be in when received by the base station. If for instance the signal GPS contains the coordinates of a given location along with other useless information such as the number of GPS satellites in view, almanac, or ephemeris data a chip with a larger bit size would be ideal so all given information could be quickly assessed. An eight bit chip however could potentially be more than enough for a system that is only receiving the longitude and latitude of the device in question. Furthermore because it would be too costly to buy a number of different microchips ranging in size from 8 to 32 bits a better understanding of the information to be transmitted must be acquired as to prevent the base station from having issue with both sending and information that is needed to calculate both the position of the GPS chip that it is tracking and the information sent to and from the smartphone and RFID reader that will also be in use.

3.4.1.1 PIC32
The Peripheral Interface Controller or PIC32 Microcontroller offered by Microchip boasts a 32-bit RISC CPU with a MIPS instruction set architecture as can be seen in the figure below. In addition it provides an optional UART pin layout ranging from 1-6

which should easily accommodate the needs of the base station. Along with its outstanding UART range the PIC32 also provides a plethora of DMA channels which could potential increase the CPU's speed by allowing some hardware subsystems to access the memory without involving the CPU. With flash memory ranging from 16kbs to 512 kbs this chip should have more than enough memory to store any program or development libraries. Because wireless connectivity is an important feature within the framework of this project, the Microchip's PIC32 microcontroller also connects seamlessly to the MRF24WG0MA IEEE 802.11 b/g Wi-Fi radio transceiver module to provide the Wi-Fi communication the task requires. In case obtaining a Wi-Fi connection becomes too troublesome or is unable to be achieved, the PIC32 microcontroller also provides a 10/100 Mbps Ethernet MAC interface which can be used to connect router or cable modem. This feature in addition should enable a quick an easy internet connection without the need of a Wi-Fi connection if in the long running developing a system that does not rely exclusively on wireless internet communication proves to be more efficient and developmentally feasible. Lastly the 38 bps to 12.5 Mbps Baud rates ensure that this device will be able to connect with a number of RF receivers. Overall the PIC32 microcontroller, shown in Figure 18 below, has all the peripheral features that will allow it to interact with any and all components which many be needed to facilitate communication between all devices in correspondence with the base station.
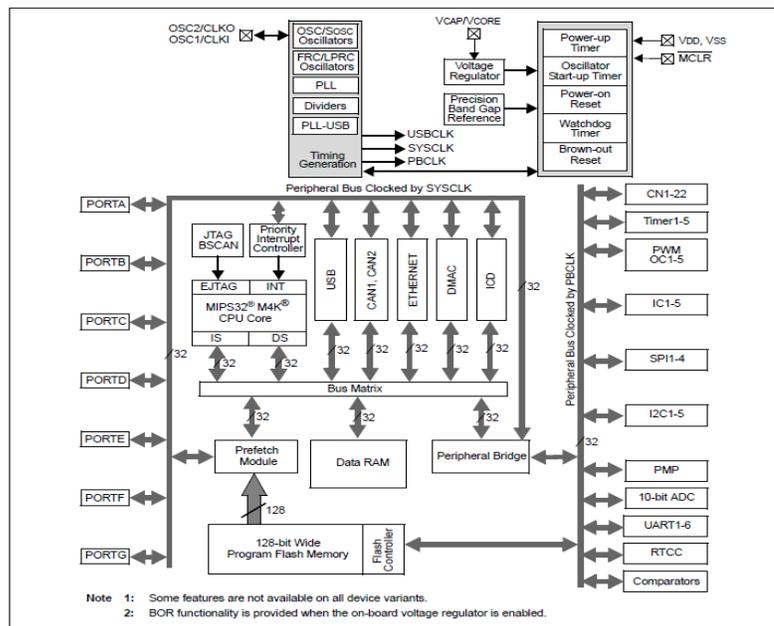

Figure 18: PIC32 Architecture
Release Pending

Although the PIC32 comes with all the necessary amenities to assist in interaction with other devices used in the base station as a whole the cost of the chip may be a little high at $8.83 per chip. This is especially obvious furthermore if for example more than one chip was desired to guard against faulty chip manufacturing or the human error which is associated with handling, programming, and mounting chip sets. A high priced

microcontroller moreover would lead one to assume that the development tools associated with said chip would as be costly as well.

3.4.1.1.1 PIC32 Development Environment

One of the most important aspects of a microcontroller is the development environment associated with it because, it will of course be, the primary medium thought which the chip will be accessed, programed, and developed. Having a chip which provides a broad programming library, technical support, and an assortment of different avenues with which to connect to the chip is paramount. If, as is the case, a microcontroller has a Ethernet it needs to provide a method though which this feature can be tests, configured, or programed. Without these crucial tools critical time, money, and effort would go into developing said tool alone before the microcontroller, selected for its many peripherals, could be used. This undoubtedly would waste precious time which should be used to program the microcontroller or design circuit which could for example be used to power, protect, or improve the system as a whole.

Fortunately the PIC32MX675F256H has a wide variety of development tools and kits which can be used to program the chip. The PIC32 Ethernet Starter Kit for example has a 10/100 Ethernet RJ-45 jack which will allow for an Ethernet cable to be connected directly to the board. Also included in the starter kit is a MPLAB IDE which can be used to run a 32 bit application on Microsoft Windows computers. Other software based features that make this system appealing is its Free MPLAB C Complier, integrated debugger, and full C source based debugging MPLAB platform. As for the hardware associated with programming the chip the PIC32 Ethernet Starter Kit boasts the 10/100 Ethernet RJ-45 jack as previously mentioned, and Ethernet cable standard A to mini B cable for the debugger, and an A to micro B cable for USB application development. Included on the board are an on-board programmer/debugger, a full-size USB host connector, and a USB micro-B connector. As is always the case, because this project not funded by a major corporation, price is a major concern. The PIC32 Ethernet Starter Kit unfortunately cost seventy two dollars per board. Seventy two dollars while not that expensive may not be the most competitive price for a board which will only be used for at most six month. As a result the PIC32 Kit may not be very competitively priced when compared to the other development boards on the market.

Aside from the cost of the development board, the language in which the system is written is also important. Will this microcontroller require its developer to learn a programming language said individual may be unfamiliar with? Can the system be programmed in a higher level language like C or C++ but then can also be written in Assembly language as well? Is the program which is to be written better suited for a RICS or CICS platform on is this something that will have little effect of the program itself but be better suited for the programmer? The PIC32 microcontroller manufactures provide the MPLAB XC Compiler to enable a developer to write in either C or C++, which is also capable or running on Window, Linux, and MAC OS X systems alike. Never forgetting cost the MPLAB XC offers a free downloadable compiler for fiscally challenged projects which provides no memory restriction as well as full support of all Standard and PRO edition of the compiler. The only disadvantage however could arise if while coding a feature only provided in the premium complier instruction set is need

leading to an unwanted surcharge and unseen surcharge. One final feature that helps this product stand out is its free TCP/IP stack specifically for the PIC32. Because of the manner in which the stack is written moreover not only are the layers embedded in the stack accessed when they are requested but also when time-outs or new packet arrivals occur. Other protocols said stack supports include ARP, IP, ICMP, UDP, TCP, DHCP, SNMP, HTTP, FTP, TFTP, socket support for TCP and UDP, NETBIOS Name Service, Domain Name System, Ethernet Device Discovery, and MPLAB compiler support. The specifications of the PIC32 are summarized in Table 7 below:

Features	Data
Processor	MIPS2 M4K 32 bit
Max Frequency	80 MHz
Flash Memory	512K
SRAM	64K
GPIO	85
UART Pins	6
10/100 Ethernet	yes
Operating Voltage	2.3V to 3.6V
Max Baud Rate	12.5 Mbps

Table 7: Microchip PIC32 MCU

3.4.1.2 Stellaris LM3S8962

The Stellaris LM3S8962 offered by Texas Instruments, like the PIC32, is a 32 bit microcontroller with one unique difference is uses an ARM Cortex central processing unit. Operating at up to 50MHz this microcontroller has 256KB flash memory and 64 KB SRAM alongside a variety of solutions to connect almost any medium. These features include a 10/100 Ethernet MAC/PHY, a CAN controller, an SSI / SPI controller, an I2C interface, and 2 UARTs. On the hardware front the Stellaris LM3S8962 simplifies the process of synchronizing multiple clocks by implementing the IEEE 1588 Precision Time Protocol or PTP. Motion control is thoroughly represented via the 6 motion-control PWM outputs with dead-band, two quadrature encoder inputs for position monitoring, and 1 fault protection inputs for low-latency shutdown. Equipped with 4 channels of 10-bit analog to digital conversion which can sample data at 500k per second and one analog comparator the other attributes of equal important include the forty two general purpose pins available, 256 bytes of non-volatile state-saving, a low drop-out voltage regulator which eliminates the need for more than one voltage supply, 4 32-bit or 8 16-bit general-purpose timers, power on reset controller, brown out reset, a real time clock or RTC, a watchdog timer, 24-bit systick timer, and 256 bytes of non-volatile state-saving memory.

No stranger to the benefits of under-pricing ones competitors, Texas Instruments prices its most basic 32 bit microcontrollers at one dollar. Because the Stellaris LM3S8962 is listed as NRND or not recommended for new designs it is clear that TI is phasing this chip out which unfortunately increase the cost of the chip. A single Stellaris chip for Digi-Key for example cost $14.12. A lot shipment from China moreover cost $45 a carton at $9 a chip which could be a deal if one of two chips could be obtained. As if to

remain competitive with hobbyist and one-off projects TI does provide a Stellaris LM3S8962 microcontroller with their Evaluation Kit for $89 however if for some reason another chip was needed obtaining one could be almost impossible. Table 8 below summarizes the specs for the MCU:

Features	Data
Processor	ARM Cortex
Max Frequency	50 MHz
Flash Memory	256K
SRAM	64K
GPIO	42
UART Pins	2
10/100 Ethernet	yes
Operating Voltage	2.25V to 2.75V
Max Baud Rate	3.125 Mbps

Table 8: TI Stellaris LM3S8962

3.4.1.2.1 Stellaris LM3S8962 Development Environment

As mentioned earlier, the Stellaris is marketed as a microcontroller evaluation board combination. Included in this package is of course an evaluation board, 10/100 embedded Ethernet controller, magnetic speaker, I/O break-out pads, Ethernet cable, CAN ribbon cable, USB and JTAG cables, standalone CAN device board, OLED graphics display with 128 x 96 pixel resolution, user LED, navigation switches, and select pushbuttons

Standard ARM® 20-pin JTAG debug connector with input and output modes, a quick start sample application which can run with Ethernet or can be connected directly to a computer, and an evaluation kit cd. This cd includes an evaluation version of the software tools, a quick start guide, source code, and the peripheral driver library with example code.

One of the most important features provided by the Stellaris is its ability to communicate with other devices through its UART connectivity because this will be the only method through which information will be sent both to and from the RFID and GPS wrist band devices. As a result the fact that this microcontroller has a programmable baud rate generator which allows for data transmission of up to 3.125 Mb per second is more than enough bit variation to communicate with whatever RF device is selected to transmit information to their respective destinations. Said pins will also be of importance because the also offer a platform through which a Wi-Fi chip can connect to the microcontroller. With only two UART pins however there may not be enough pins to allow all the necessary connections. If this is the case moreover if there is not a simply implementable solution such as an I/O expansion board or an identical chip with more I/O pins, another microcontroller may be required. Equipped with both an Ethernet and USB ports the manner in which the microcontroller will connect to these systems has already be provided and thus is not something which must be researched and developed for the base station. This more importantly greatly reduces the time needed before interaction with the chip can begin. The Stellaris like the PIC32 also has an open source TCP/IP stack

developed to minimize the memory usage associated with storing said protocol. Features include in this application include support for multiple interfaces and connections, specialized raw API for enhance performance, point to point protocol, optional Berkeley like socket API, address resolution protocol for Ethernet, dynamic host configuration protocol, autoIP automatic link-local IP configuration, Internet Protocol or IP including packet forwarding over multiple network interfaces, Transmission Control Protocol TCP with congestion control, RTT estimations, user datagram protocol (UDP) including experimental UDP-lite extensions, and Internet Control Message Protocol or ICMP.

While cost, programmability, and availability are key feature to search for in a microcontroller another more appealing aspect to consider is the environment with which a developer such as TI implements to allow for ease of use and procurement of information. Does the company have information relevant to the product they sell readily available or does one have to read through a plethora of documentation before the CPU architecture can be found for example. A company which provides quick start guides and easy to use produce comparison charts shows its understanding of what is needed by the consumer and would most likely be more than willing to help in cause of a product malfunction or technical issue. Another issue to consider when searching for a company to buy a produce from is the wealth of knowledge provide by both the company and other users of the company's product. Question which should be consider include how difficult have previous users found obtaining information about the microcontrollers, compilers, I/O boards, and power supplies needed to complement the device selected? Are there forums online which could be useful in solving the programming which will inevitable develop in the future? Is the website with which the company uses to present itself easy to navigate, understand, and find or is it misleading, useless and frustrating to use? Does the company offer free samples because not only could this be a free method of obtaining the material needed for a project it could also allow for testing of a device which may in the future be bought in bulk. Overall although a company's products may be a little more expansive than its competitors this cost could be well worth it if the said cost is being reinvested into the company to make the user's experience better.

3.4.1.3 Arduino Mega 2560
The final microcontroller researched, analyzed, and dissected to determine if it would be beneficial as the foundation upon which the base station would be based was the Arduino Mega 2560. Centered upon the 8 bit Atmel ATmega2560 microcontroller, the Arduino board has 54 digital input/output pins 14 of which can also be used for PWM outputs, 16 analog inputs, a 16Mhz crystal oscillator, a power jack, 4 UART pins, a reset button, a USB connection, and a ICSP header. Equipped with 256 KB or flash memory, 8 KB of SRAM, and 4 KB or EEPROM this chip may not provide as much memory as the other microcontrollers it's been paired against but it does offer a simple method with which to power the board. All that is required is a AC to DC adapter or a battery each of which can be connected a 2.1mm center-positive plug or Gnd and Vin pin of the power connector respectfully. The operating voltage can vary from 6 to 20 volts however if the voltage is less than 7 volts the 5 volt pin used to power the board may not generate enough energy to sustain the system. In the same vain if the input voltage is higher than 12 volts the voltage regulator could overheat causing damage to the board. The optimal operating range therefore is between 7 and 12 volts.

One of the more popular microcontroller boards the Arduino can range from outrageous to reasonable depending on where the device is purchased. This can be easily demonstrated with a quick Google search for the controller's price which would illustrate this trend. Digi-key for example sells the 2560 for 50.57 dollars while the same technology is sold by Adafruit for 65 dollars. Furthermore the mega 2560 does not come with an Ethernet jack so one must also consider the price of the Wi-Fi shield when considering the microcontroller because it will undoubtedly mirror the price of the microcontroller itself. Table 9 below shows the specs of the MCU.

Features	Data
Processor	ATmega2560
Max Frequency	16 Mhz
Flash Memory	256K
SRAM	8K
GPIO	54
UART Pins	19
10/100 Ethernet	no
Operating Voltage	7V to 12V
Max Baud Rate	96000

Table 9: Arduino Mega 2560

3.4.1.3.1 Arduino Development Environment

Because the Arduino is marketed towards both novices and experienced programmers alike it offers a preloaded bootloader which eliminates the need for external hardware programmer to upload code. The mega 2560 also provides an in-circuit serial programming header which can also be used for programming if the bootloader is not sufficient. Potentially more cumbersome and or costly to obtain, the external programmer will allow full use of the 16KB available on the controller and avoidance of any and all delays which could be caused by the loader when the board is powered or reset. Aside from the bootloader the Arduino programming environment is an open source product which can run on Mac OS X, Linux, and Windows operating systems. Furthermore Arduino offers a wide range of programming libraries which can be used to add both Wi-Fi and Ethernet connectivity to the base station. Third party hardware support including libraries, bootloaders, and programmer defined data can also be added to the Arduino platform as an extra feature. Furthermore as to be expected the Arduino software can be loaded on to any of the standard operating systems and compiled in Arduino code files, C files, C++, or header files.

Although the Arduino may seem flexible with respect to the development environment established for the microcontroller it is not cost competitive. This issue can be seen most dramatically in the mega 2560's ability to connect wirelessly or other wise to the internet. Not equipped with an Ethernet jack, an add-on would need to be bought or constructed to allow this from of connectivity. Furthermore although Arduino does offer a Wi-fi shield, to enable wireless connectivity, because the microcontroller does not have as much memory as the other chips under consideration it may not be able to support the TCP/IP

stacks need to obtain a Wi-Fi connection once the process is underway. Overall there may be a number of issues that could prevent the Arduino from being the most attractive system to center the base station around in that it may not be as robust or adjustable as this project may require. Table 10 summarizes the MCUs:

Arduino Mega 2560		TI Stellaris	Microchip PIC32
Features	Data	Data	Data
Processor	ATmega2560	ARM Cortex	MIPS2 M4K 32 bit
Max Frequency	16 Mhz	50 Mhz	80 Mhz
Flash Memory	256K	256K	512K
SRAM	8K	64K	64K
GPIO	54	42	85
UART Pins	19	2	6
10/100 Ethernet	no	yes	yes
Operating Voltage	7V to 12V	2.25V to 2.75V	2.3V to 3.6V
Max Baud Rate	96000	3.125 Mbps	12.5 Mbps

Table 10: Comparison of MCUs

3.4.2 Internet Connectivity

The primary means through which the base station will send notifications, alerts, and GPS coordinates to the smartphone application used to monitor the location of the GPS wrist band is of course the internet. Because of this obtaining at least a minimal understanding of the protocols, hardware, and programming which may be needed to support this infrastructure is imperative. Without this rudimentary understanding of the way in which said systems operates selecting the best technology to support this form of communication is, if not impossible, very challenging.

3.4.2.1 Ethernet Module

In order for a microcontroller to use a category 5 cable to connect to the internet it needs both an Ethernet "RJ-45" jack and an Ethernet controller. The RJ-45 will provide a port through which information can be relayed in accordance with any and all TCP/IP mandates. Designed with an eight pins per jack the RJ-45 pins are placed in a manner which allows them to interface with Ethernet cables wired in either the T-568A or T-568B configuration with the latter of the two being most common. Although it can go without say the speed with which the Ethernet jack will transmit data will of course be the 10/100 Mbps standard. The need for a 10/100/1000 port is unnecessary because the Ethernet switch will automatically adjust for any data transmission discrepancies. Along with the Ethernet port an Ethernet controller is needed to convert the data transmitted via the internet into data packets.

Because the focus of this project is to create a GPS tracking the intricacies of connecting a microcontroller to the internet are not the main focus. For this reason obtaining a microcontroller which already has a fully integrated Ethernet controller would greatly reduce any critically errors associated with generating the Ethernet connection. One advantage of the Stellaris LM3S8962 not previously mentioned moreover is its on board

Ethernet controller which only needs a RJ-45 jack with magnetics to enable full internet connectivity for said microcontroller. If an Ethernet controller is to be used however it is important that it features both the media access controller address and physical layers needed to effectively implement networking transmissions.

Overall, based on the information pertaining to generating an Ethernet connection for a microcontroller it cannot be over stated that obtaining a controller with as many of the features need to create a contention is imperative. General it can be assumed that the microcontroller with have a built in media address controller however the same cannot be said for the physical layer. To support the physical layer need to transmit information, an Ethernet controller must be selected which should be compatible with the pre-determined microcontroller. The final component which must be acquired to complete the process is a RJ-45 jack with magnetics. Used to regulate any electrical activity that may interfere with data transmission, it is best to buy a jack with this feature as to eliminate the need to solder the electrical components which would ultimately be required to compensate for their absence. Final although a Category 5 cable will be need to carry the Ethernet signal from its source a router is not necessary because the base station will not need to communicate with other computers. The base station, acting as a router in its own right, simply needs to have internet access so that it can route information it receives from the RFID reader and the GPS write band. If at all possible buying a microcontroller with all the components need to simplify the process of internet connectivity would greatly improve the base stations design development.

3.4.2.2 Ethernet Frame
Before an Ethernet controller can adequately be assessed a throughout understanding of the format with which said information should be transmitted is important to ensure that the hardware selected to transfer said data is capable. The Ethernet frame is transmission via the physical lay composed of six fields which is used to transmit data packets. Included in these six fields are the preambles, destination and source address, type/length, data/payload, and frame check sequence or cycle redundancy checksum "CRC". The minimum and maximum length of said frame is 46 and 1518 bytes respectfully. The preamble as its name would imply signifies the start of the data to be transmitted and is becoming obsolete as Ethernet can speed increase. The destination and source address contain the media access address for the source and destination of the information in question while the type/length field is used to indicate what higher level protocol such as TCP/IP for example is being carried within the frame. Straight forward in nomenclature the data/payload field is of course the data which is being sent and can range from 46 to 1500 bytes as previously stated. The final part of the frame, the frame check sequence is a 32 bit field used to ensure that the data delivered is indeed the correct and complete.

While there a number of Ethernet controllers on the market only a few device would be best be suited for use in the base station. Both the ENC28J60 and TLK100 developed by Microchip and Texas Instrument respectfully are under consider because they would be most compatible with the microcontrollers best studied to support the base station. The final controller produced by Silicon Labs in the CP220x Embedded Ethernet Controller which offers a universal connectively not found in either of the other devices under analysis.

3.4.2.2.1 ENC28J60 Ethernet Controller

The ENC28J60 Ethernet Controller is of course compatible with the IEEE 802.3 protocols and is fully compatible with 10/100/1000Base-T Networks. It fully supports both full and half-duplex modes and feature integrated MAC and 10Base-T PHY layers. Furthermore it can interface with any microcontroller with a serial peripheral interface bus and clock speeds of up to 20MHz or less. It operates at voltage ranging from 3.1 to 3.6 while only supporting a 5 volt input maximum. The controller has a 28 pin infrastructure and can be packed in either a rectangular or square configuration while the chip as a whole needs a 25MHz clock input to perform. The physical layer features two programmable LED outputs which can be used to indicate LINK, TX, RX, Collision and Full/Half-Duplex Status and encodes and decodes the analog data delivered via the Ethernet connection. Because this chip also has a built in media access controller there is no need for the microcontroller which would interface with the Ethernet chip to have one. Furthermore other MAC features supported by the chip include support for Unicast, Multicast and Broadcast packets and the ability to program receive packet filtering and wake up host when any of the following are logically AND or OR Unicast destination address, Multicast address, Broadcast address, and the Magic Packet.

In order to gain a descent understanding of how the Ethernet controller will interface with the any given microcontroller a clear understanding of said Ethernet controller's programming protocols is in order. First and fore most the ENC28J60 is controlled completely by the microcontroller connected to it via the serial peripheral interface instruction set. These commands moreover consisting of one or more bytes are used not only to access the control memory but also the Ethernet buffer. The instruction string consists of a 3-bit opcode followed by a 5-bit argument which can represent either a register address or a data constant. Although a list of the instruction commands can be seen in Figure 19 below, some of the more important ones to focus on include the read control register, read buffer memory, write control register, and write buffer memory.

Instruction Name and Mnemonic	Byte 0								Byte 1 and Following
	Opcode			Argument					Data
Read Control Register (RCR)	0	0	0	a	a	a	a	a	N/A
Read Buffer Memory (RBM)	0	0	1	1	1	0	1	0	N/A
Write Control Register (WCR)	0	1	0	a a a a a					d d d d d d d d
Write Buffer Memory (WBM)	0	1	1	1 1 0 1 0					d d d d d d d d
Bit Field Set (BFS)	1	0	0	a a a a a					d d d d d d d d
Bit Field Clear (BFC)	1	0	1	a a a a a					d d d d d d d d
System Reset Command (Soft Reset) (SRC)	1	1	1	1 1 1 1 1					N/A

Legend: a = Control Register Address, d = Data Payload

Figure 19: Instruction Commands

Read Control Register: This command allows a microcontroller to read any of the Eth, MAC, and MII registers in any order. The RCR command is started moreover when the CS pin low which in turn sends the RCR opcode to the Ethernet controller followed closely by the 5 bit register address A4 through A0. This 5 bit address can be linked to any of the 32 control registers available. If the address specifies either a MAC ir MII register a dummy byte will be shifted to the SO pin after which data will be sent with the most significant bit being first. Said command moreover can be stopped by raising the CS pin. Lastly if a ETH register is the 5 bit address identified by the RCR command then data in said register will be sent instantly to the SO pin.

Read Buffer Memory: The read buffer memory command or RBM starts in the same manner as the RCR command, when the CS pin is low however the similarities end there. After the pin is low the RBM command is sent to the Ethernet controller followed a 5 bit constant 1Ah which then allows for the data stored in memory to be sent most significant bit first on the SO pin. If moreover the SCK pin still receives clock input from the microcontroller directing it the data stored in memory will again be sent. As long as the AUTOINC pin is enabled information can continuously be streamed from the buffer memory without any further command from the SPI command.

Write Control Register: The WCR command enables the microcontroller to write to the ETH, MAC, and MII registers in any order because the PHY register are written to through a separate special MII register interface. Sent to the ENC28J60 the WCR command uses any of the 32 control registers available on the rising edge of the clock. Although the command ends when the CS pin goes high if said command ends before all the data is sent the write will be lost for that data byte.

Write Buffer Memory: Similar in fashion to the RBM opcode in that is uses the same 1Ah constant in its transmission of data these command can also automatically increment the pointer to the next address if the AUTOINC bit is set. Data can also be continuously written to memory if the host microcontroller continues to send clock signals via the SCK pin. These as was seen earlier is possible without the need to engage the SPI command.

PHY Registers: The PHY register is used both to configure and control the PHY module and is 16 bits wide. Furthermore although there are 32 PHY address only 9 are actually used causing information to the other 23 registers to return 0 if a read command is attempted. The PHY register differs from the ETH, MAC, and MII registers in that it is not accessed through the SPI control interface, a dedicated set of MAC control registers media independent interface management instead. It is important to note that when the PHY register is written to or read from the all 16 bits are obtained. To greatly reduce the amount of computations the microcontroller must generate when in communication with the Ethernet controller the MAC can be instructed to perform automatic consecutive read operations on the PHY register.

Control Register: The control is the main interface through which the microcontroller and Ethernet controller communicate. As would be expected writing to the control registers controls the interaction of these devices while reading the registers allows the microcontroller to monitor what is happing with respect to the Ethernet controller. The memory associated with the control register is divided into four sections each of which is

32 bytes long. Furthermore the last memory locations of the control register point to a common set of registers used to observer and or control the actions of the Ethernet controller. Lastly it is important to understand that some of the registers addresses are not available for use and any attempt to read from them will generate a zero and any attempt to write to them will be ignored.

The final parameter to consider when researching methods through which to obtain internet connectivity for a microcontroller is the manner in which an Ethernet controller will transmit and receive data packets. When transmitting data the MAC within the ENC28J60 will automatically generate the preamble and start of frame delimiter fields however the microcontroller must the four remaining fields. The Ethernet controller will also produce any padded data which may be need in the frame is programmed beforehand. Before the micro and Ethernet controllers can communicate a single per packet control byte must be transmitted any information can be sent. Furthermore before said information can be delivered the MAC registers must be initialized.

One of the major conspires associated with implementing an internet connection with an Ethernet topology is the how the inner workings of the magnetics will be circuited. As a result it is important to note that provided within the ENC28J60 data sheet is a circuit diagram which provides detailed instruction on how the connection between both the RJ-45 and Ethernet controller should be approached, this diagram is shown in Figure 20. This layout will greatly reduce any human error which may have arisen with the development of a custom circuit connecting the jack and Ethernet controller. Furthermore because the circuit is provided within the data sheet it can be assumed that the circuit is guaranteed to produce the internet connectivity needed by the base station. If internet connectivity is not achieved moreover it can be assumed that the issue is associated with the electrical components used to create the connection not the circuit itself. Lastly because the circuitry has been fully vetted by the developers at Microchip, the company can also been seen as an excellent trouble shooting tool.
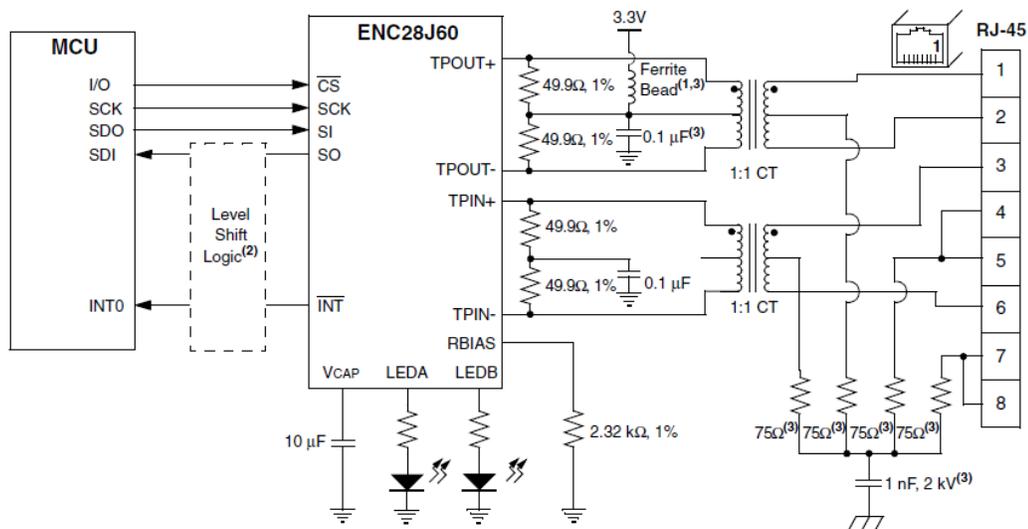

Figure 20: ENC28J60 Circuit Diagram

3.4.2.2.2 TLK100 Ethernet Controller

Unlike the ENC28J60 Ethernet Controller the TLK100 by Texas Instrument does not provide an on chip MAC interface so any microcontroller used in conjunction with this device should have its own. Officially referred to as a single port 10/100 Mbps Ethernet physical layer transceiver it is clear that this devices is not as robust as a fully integrated PHY/MAC device. Some of the more important features include in this controller include 3.3V MAC interface, 25 MHz clock rate programmable LED support link for 10/100 Mbs, activity, and collision detection modes, 10100 Mbps packet built in self-test, auto-mdix for 10/100 Mbs, low power consumption, MII Serial Management Interface, and 48 pin TQFP package. Some of the more program centered features include IEEE 802.3u MII, IEEE 802.3u auto-negotiation and parallel detection, and IEEE 802.3u ENDEC, 10BASE-T transceivers and filters.

Although the TLK100 is designed to use a power supply voltage of 3.3V it can also operate with combinations of 3.3V, 1.8V, and 1.1V power supplies in an effort to reduce power consumption. To improve communication over the Category 5 cabled used to connect to an Ethernet jack mixed signal processing is used to recovery data, correct errors, and perform equalization procedures. Because the twisted pair cable is standard in the telecommunication industry the TKL integrates all the physical layer functions needed to effectively transmit and receive data of said medium. Finally the Ethernet controller also supports media independent interface and media access controller standards to simplify the communication process. Meant only as a transverse for the physical layer of the Ethernet medium a few components must be added to actually transmit an internet signal to a microcontroller. These items include a RJ-45 jack, magnetics or resistors and capacitors which will regulate any electrical signals, a 25MHz source clock, media access controller, and status LEDs.

Despite the fact that the TLK100 does not have a built in media access controller, it does provide a diagram illustrating how such a connection should be made with a microcontroller that does have one as seen in Figure 21 below. This combined with a detailed description of how the Ethernet jack and magnetics should be connected with this controller, shown in Figure 22, completely eliminates any interfacing issues which may challenge the end user.
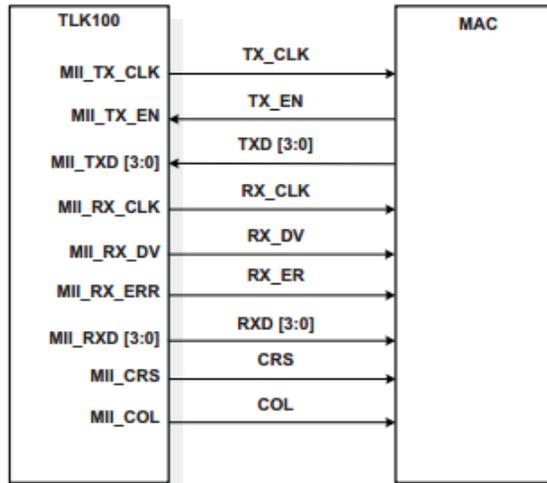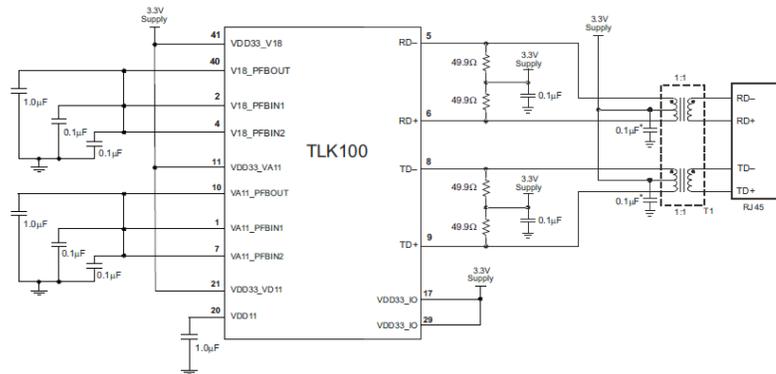
Figure 21: MAC Connection

Figure 22: TLK100 Circuit Diagram

3.4.2.2.3 CP220 Ethernet Controller

The CP2200 Ethernet Controller developed by Silicon Labs is marketed as being able to interface with any microcontroller with at least 11 I/O pins. The CP220 features integrated IEEE 802.3 MAC and 10 BASE-T PHY, fully compatible with 100/1000 BASE-T networks, full and half duplex signaling with auto-negotiation, automatic polarity detection and correction, automatic padding and CRC generation, and broadcast and multi cast MAC addressing support. Equipped with a 30 Mbps transfer rate the controller supports both the Motorola and Intel bus formats and wake on LAN and interrupt on received packet commands. As added bonus, 8 kilobytes of flash memory is included on the chip with 8192 bytes of ISP non-volatile memory, factory programmed 48 bit MAC address, and no need for an external EEPROM interface. Some of the more software oriented products provided with the controller include TCP/IP stack configuration wizard, royalty free TCP/IP stack wit device drivers, and hardware diagnostic software and example code. The supply voltage can range from 3.1 to 3.6 volts while the I/O tolerance is a slightly higher 5 volts.

The manner in which packets of data are transmitted and received by the CP220 is very important in that because it can theoretically interface with any microcontroller the way in which an Ethernet frame is created must be as seamless as possible. To that end this Ethernet controller only requires that the host microcontroller load the source and destination addresses, length/type, and data into the transmit buffer. Other requirements such as the preamble, start frame delimiter, CRC, and padding for only the full-duplex, are automatically included. The receiver interface uses 4k circular receive FIFO buffer and an 8 entry translation look aside buffer which is able to store a maximum of 8 packets at a time. Each look aside buffer can hold only a single starting address, length, and any other information to a single packet. Upon receiving a packet, information the host microcontroller can either save said information into memory or discard it. To aid in this endeavor an advanced filter and hash table are used to prevent any unwanted information from reaching the receive buffer. Although the benefits of the above mentioned features are enticing in theory they should also prove very beneficial in practice in that they will allow information to be transmitted quickly. Furthermore having the capability to discard packet data and generate full Ethernet frames with little input from the host microcontroller is impressive.

3.4.2.2.3.1 *Media Access Controller/Physical Layer*
The CP220 supports an IEEE 802.3 formatted Ethernet media access controller which can automatically pad frames which fall short of the minimum bit requirement. To improve system debugging a loopback mode is provided separate from that on the one used by the PHY layer. The media access controller is general initialized once after resetting the auto-negotiation complete interrupt and after the initialization of the physical layer. Along aside the IEEE 802.3 compliancy the physical layer also supports a transmitter, receiver, smart squelch, auto-negotiation, jabber, polarity correction, loopback, and link integrity implementation. In addition the physical layer can be both monitored through the PHYCN, PHYCF, and PHYSTA registers.

3.4.2.2.3.2 *Flash Memory*
The CP220 Ethernet controller has, unlike it competitors, an 8 kilobyte on chip non-volatile flash memory which not only stores an 48 bit media access address but also is accessible by the host microcontroller. It should be noted moreover that the last six bytes of said memory house the MAC address and can unfortunately be erased unintentionally. The flash memory is of course programmed one byte at a time via the parallel host interface and which is not only written to but read from with the FLASHADDRH:FLASHADDRL, FLASHDATA, and FLASHAUTORD registers.

3.4.2.3 Wi-Fi Connectivity
As more of the world becomes more technologically advanced the ability to connect any and all devices wirelessly to the internet has become very attractive. Because of this development in society's expectations of devices with internet capabilities it is all the more important that any product which the potential to be marketed to the masses at least explore the methods through which any device, but more specifically a microcontroller, can connect wirelessly to the internet. Furthermore because this project requires a very specific set of criteria it would also be beneficial if a Wi-Fi module for example was compatible with the microcontroller around which the base station will be centered.

Although more important ideas to consider include the ease with which the Wi-Fi module will connect with the microcontroller, how many components are needed to enable the device to work, will it consume an unnecessary amount of power, is it easier to implement than a Ethernet based internet connection would be, and what is the price range are all question which should be considered throughout the vetting process. Because it is unclear as to how in depth this project seeks to go with respect to creating the circuit layout needed for an Ethernet connection moreover it is of particular important to determine how many components will be need to connect the Wi-Fi module to the microcontroller because the Ethernet connection requires a lot of effort to provide an internet connection. It is also important to note that although the manner through which the Ethernet controller should be connected circuited to the microcontroller is provided within the controller's data sheet, it is still no guarantee that said layout will actually provide the internet connection that is needed. As a result of the many components essential to the process it is also important to be aware that this in turn will greatly increase the number of component with which an issue could arise preventing the internet connection around which the base station's commination which the smart phone is based.

As has been previously discussed above the microcontrollers around which the base station will be centered include the Arduino Mega 2560,   TI Stellaris, and Microchip PIC32. To that end Wi-Fi modules which are compatible which said controllers are of course being researched. These modules include the universal RN-171 Module, the Texas Instruments SimpleLink CC3000, the Arduino Wi-Fi Shield, and the Microchip MRF24WB0MA/ MRF24WB0MB Transceiver.

3.4.2.3.1 RN-171 Module
Because the communication between the base station and smart phone application is one of the more finicky interfaces to contend with, the first Wi-Fi module which should greatly reduce the amount of peripherals needed to ensure seamless wireless internet connectivity is the RN-171 module.

The RN-171 802.11b/g Wireless LAN Module is a chip which offers the Transmission Control Protocol / Internet Protocol or TCP/IP communication protocols needed to allow the smartphone and base station to communicate via Wi-Fi. This is important because it reduces the amount of programming time required to ensure the TCP/IP stack is installed an implemented correctly. Furthermore the only four connections required to obtain a wireless data communication include the PWR, TX, RX, and GND pins. The RN-171 Module also features a host of other networking application which include DHCP, UDP, DNS, ARP, ICMP, TCP, and HTML client. As is always the case with wireless communication Wi-Fi security is essential and in an effort to address said issue Wi-Fi authentication can be implemented with the WEP-128, WPA-PSK (TKIP), and WPA2-PSK (AES) protections provided. Lastly this microchip uses a FCC certified 2.4 GHz IEEE 802.11b/g transceiver.

Equipped with a 32 Bit CPU, 2-MB of ROM, 128 KB of RAM, and 8 Mbits of flash memory the RN-171, shown in Figure 23, seems to not even require a microcontroller. It comes preloaded with firmware to streamline the development process and its "Ultra-low power" consumption deep sleep mode allows for wonderful power saving possibilities. One disadvantage, however, is the lack of information pertaining to the programming

practices used by this device. Although it has memory it is unclear if this memory is allocated for the use of the TCP/IP stack exclusively or if it can also be used to store programming information. Described as a wireless LAN module it is a little unclear as to how the chip should be implemented. If a microcontroller must be added then the price of the RN along with the lack of a clear programming environment and the restrictions associated with obtaining a controller that is compatible with the module could be overwhelming.

Figure 23: RN-171 Module

After further analysis of the RN-171 module it has become clear that it is simply a Wi-Fi module which requires a microcontroller to be useful. Furthermore as more knowledge was gained about the RN the method through which it should be connected was also uncovered. If this Wi-Fi module is used to provide wireless internet connectivity to the base station, the circuit layout seen below would be implemented to ensure both the power requirement and resister values need by the system are the most likely to produce the desired result.

Figure 24: RN-171 Circuit Layout

3.4.2.3.2 CC3000

The TI SimpleLink CC3000 Module described as a self-contained wireless network processor is just that. Equipped with an embedded IPv4 TCP/IP stack this chip uses the IEEE 802.11 b/g protocols. Furthermore because it does not need to be connected to an Ethernet jack there is no need for a physical layer, RJ-45 jack, or the magnetics required to enable data transmission. Compatible will all Texas Instruments microcontrollers not only does this module work with a MIPS it also has integrated crystal and power management. The TX and RX baud rates have a maximum capacity of 11Mbps. The CC3000 uses five serial peripheral interface wires which include the SPI_CLD, SPI_CS, SPI_DIN, SPI_IRQ, and SPI_DOUT to interface with any microcontroller or processor with a clock speed of up to 16MHz. If a TI microcontroller is used in conjunction with this module moreover a low footprint driver is provided to simplify the communication process between the CC3000 and the MCU.

Other more software oriented features offer by this module includes Wi-Fi security support for WEP, WPA, and WPA2 security protocols. As CC3000 will be connect to a microcontroller the Smart Config WLAN provisioning subsystem allows the connection of a headless device to a said WLAN network with a smart phone, PC, or tablet. Other inherent protocols on the chip include ARP, ICMP, DHCP client, and DNS along with the ability to support UDP and TCP sockets. The EEPROM found on the chip can store 5 kilobytes of user data which can also be accessed by the microcontroller giving the controller the ability to enhance its non-volatile memory. The EEPROM can also store firmware patch, network configuration, and MAC address and is programmable through both the APIs and I2C interfaces on the chip. The power features described in the CC3000 data sheet include the separate I/O voltage rails to allow two devices with different voltage requirement to interface smoothly. A ultra-low shut down mode capable of using current less than 5 micro amps. Furthermore the chip does not require an AC power supply in that it can connect directly to a battery if the pre-regulated power supply features are not needed.

The CC3000, as is the case with any device whose primary method of communication is wireless, requires an antenna. One of the more beneficial features associated with this system is the auto-calibrated radio with single-ended 50-Ω interface which allow for a much easier connection to the required antenna. Furthermore it reduces the needed for an inordinate amount of research with respect to the manner in which antennas operate and how they should best be arranged to enable optimal signal retention. Lastly there is no needed to research the myriad of antennas available for the Wi-Fi module, TI suggest the 8.0×1.0 mm AT8010-E2R9HAA 2.4-GHz chip antenna manufactured by ACX.

If these module is used to provide internet connectivity to the microcontroller it is most likely that the circuit diagram provide within the CC3000, shown below in Figure 25, data sheet will be used as the reference design in an effort to reduce an unnecessary research required to create not only the best circuit design for the system be the most efficient and reliable layout.
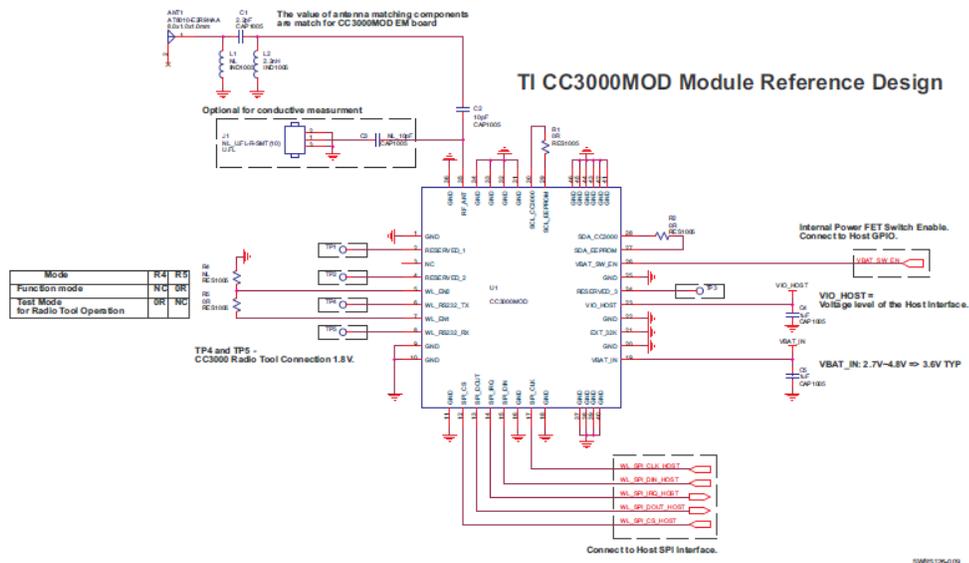
Figure 25: CC3000 Circuit Diagram

3.4.2.3.3 MRF24WB0MA/MRF24WB0MB

The MRF24WB0MA/ MRF24WB0MB is low powered IEEE standard 802.11 2.4 GHz transceiver developed by Microchip to interface will any and all of its PIC18, PIC24, dsPIC33, and PIC32 microcontrollers. Much like its Texas Instruments equivalent this Wi-Fi module is also surface mounted and is compatible with the IEEE 802.11b/g/n standards. Other statistics to mention include the 1300 ft. signal range, 21mm x 31mm 36-pin dimensions, 1 and 2 Mbps data rate, and integrated media access control. Although the MRF24WB0MA and MRF24WB0MB are described as the same module there is of course a small different in the two chips as the difference in part number would imply. The MRF24WB0MA has an integrated printed circuit board antenna while the MRF24WB0MB which offers all of the same operational, radio frequency, and MAC, and software features provided an external antenna with a miniature coaxial U.FL connector. To that end the details to will are present on both the MRF24WB0MA and MRF24WB0MB and will be noted as such.

Despite the lack of a detailed image depicting the manner in which the printed circuit board antenna should be mounted the data sheet does provide some useful information on the topic. First it is suggested that the antenna be mounted on the edge of the PCB with no copper traces or planes underneath said device. The antenna should also be mounted on the top cooper layer and covered in solder mask.

The software, without which hardware is useless with respect to internet connectivity, supported by the MRF24WB0MA/MRF24WB0MB include the Microchip TCP/IP stack which said Microchip Wi-Fi module has be designed to implement. The software stack moreover bouts a preinstalled driver which runs the API used not only for command and control but for data packet traffic and management. This software is, as indicated by the data sheet, in the free Microchip Application Libraries which also provides example applications and source code for download as well. If the MRF24WB0MA or MRF24WB0MB module is selected as the best module to provide internet connectivity to

the base station, it must first be determined if both the base station microcontroller and Wi-Fi module must run the TCP/IP stack as it is unclear in the data sheet. Although the exact phrasing on the data sheet is "the combination of the module and a PIC running the

TCP/IP stack results in support for IEEE Standard 802.11 and IP services" ones initial thought would suggest the need for only one device to implement the TCP/IP stack. Not to be out done by its competitors Microchips Wi-Fi solution also has built in hardware support for both AES, and TKIP which includes WEP, WPA, and WPA2 security.

The Microchip Wi-Fi module can operate with the 2.7 to 3.6 volt range but is typically set at 3.3 volts. Furthermore it has a wide temperature range spanning from 0 to 70 degrees Celsius with RX and TX current requirements of 85 and 154 milliamps respectfully. Although the variation in the ISM Band for the module is miniscule as is described in the data sheet as 2.400-2.483.5 GHz, the MRF24WB0MA/MRF24WB0MB has a 14 channel infrastructure along with a data rate of 1000kbps.

In order to interface the microcontroller used by the base station the MRF24WB0MA and MRF24WB0MB uses the slave Serial Peripheral Interface Bus or SPI. The four main wires which allow this process to take place include the SDI, SCK, INT, AND SDO pins and can be seen in Figure 26 below. The chip also supports JTAG and serial debug for testing purposes and has a debug port which operates at 3.3 volts and can use a level shifter to interface with RS-232 devices.
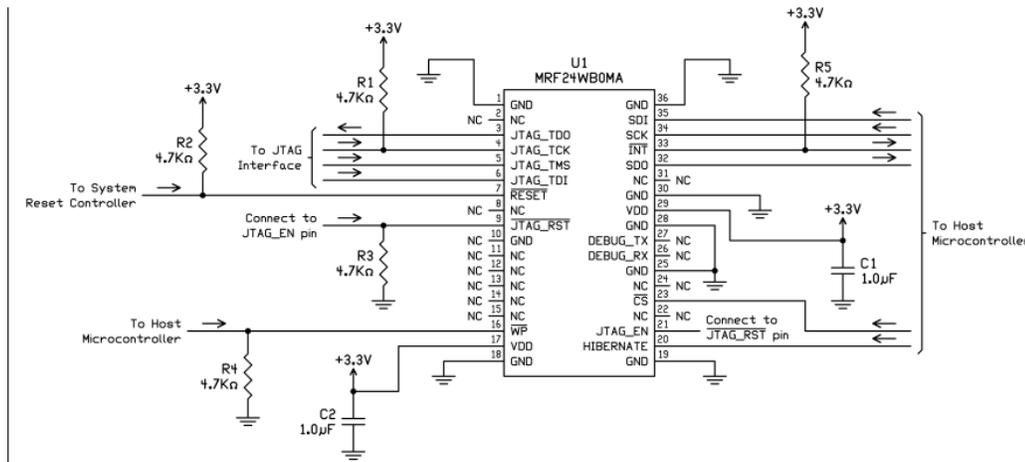
Figure 26: MRF24WB0MA Circuit Diagram

3.4.2.3.4 Arduino Wi-Fi Shield

The Arduino Wi-Fi Shield as the name implies is a produce of the open source platform known as Arduino. The Wi-Fi shield is also only compatible with the Arduino Uno and Mega microcontrollers and cannot be modified to connect with the either the PIC32 or Stellaris LM3S8962 microcontrollers which are as stated previously also under consideration as chips around which the base station will be centered. It should also be noted that the Arduino shield is not a chip but a prefabricated board upon which the chip is mounted which eliminates the need to have a printed circuit board fabricated for the

Wi-Fi chip. Include on the board are the I/O ports need to interface with the Arduino Mega microcontroller along with an SD slot, Micro-USB, a reset button, and ICSP headers.

Now that it has been made clear exactly what an Arduino Wi-Fi Shield and what unique differences it has compared to the CC3000 and MRF24WB0MA/MRF24WB0MB modules a more detailed description of its hardware can be provided. The Arduino Wi-Fi Shield enables the Arduino to use IEEE 802.11 standers to obtain an internet connection with 802.11b/g networks. Based on the HGG104 for the aforementioned Wireless LAN 802.11b/g the Atmega 32 UC3 generates an IP stack with both TCP and UDP capabilities. Also embedded in the board are both the WEP and WPA2 Personal securities to allow for a lot of flexibility with respect to system circuit. Include in the Arduino environment is the Wi-Fi library which can be used to create programs to which will connect to the internet. The library moreover is free and allows for the download of programs or source code which may be needed to permit the system to function correctly.

Interfacing the Wi-Fi shield to the Arduino microcontroller is done via wire-wrap headers which allow the shield to sit on top of the controller. The shield communicates with the controller the SPI bus which more specifically uses the ICSP headers on the board. This is carried out through pins 50, 51, and 52 on the Mega which undoubtedly would be used with said shield. Furthermore pin 53 on the Mega microcontroller must be kept open as an output or the SPI interface will not work while pin 7 is used to facilitate negotiation between the shield and the controller. Although the base station will not require the use of both the SD card slot and the SPI bus at the same time one limitation the controller shield combination has is the inability to use both the SD and SPI buses simultaneously. This issue if encountered however should be eliminated by the SD and SPI software found in the Arduino Wi-Fi libraries.

3.4.3 Power Supply

There are many methods through which the base station can be powered. The two main choices best suited for the system include AC and DC power supplies. Furthermore although it would be provide much more flexibility for the base station with respect to its mobility an AC/DC power supply which would generate power for the base station as the DC battery charged would distract from the main focus of the project as a whole. That said it is not the main focus of the project to create such an in-depth power supply and based on the time allotted it can be assumed there will not be enough time to ensure the power supply is implemented sufficiently. Some important parameters to consider when determining the best power source the amount of time the source should be able to power the base station, should the system be rechargeable, and how much power is needed to support all the components circuited to the base station.

3.4.3.1 DC Power Supply

With respect to determine the best DC power supply to use it must first be determined which battery would best be suited for the situation. A few of the more popular battery types include alkaline, lithium, nickel-cadmium, nickel-metal hydride, and zinc. Furthermore the battery must provide enough voltage to support the demands of the wireless transmitter, Ethernet module, microcontroller, and any other components which

may be needed to support the base station. Because this DC power supply will be used to power a stationary base station, the longer the battery life and the easier the batteries are to replace and or charge will of course be of particular importance in that it will reduce the amount of maintain required by the base station. In order to determine if a give battery will proved an adequate amount of battery life lastly the battery capacity in milliamps per hour is divided by the total of the load currents.

The first battery under consideration for the base is the lithium battery. Most often used in laptops and cell phones. This battery type loses about 5 percent of its charge as compared to the 20 percent seen in nickel metal hydride batteries. Because the battery will be placed inside the temperature sensitivity associated with this battery will not pose an issue however the life expectance of the lithium battery is only about or three years, which when compared with other DC power sources could greatly reduce the cost of product replacement. The storage capacity of the source moreover is about 150 watt-hours of electricity per 1 kilogram of battery. The two main types of lithium batteries include the lithium-ion battery pack and lithium-photo batteries, the former of which is rechargeable while the latter is not. Lastly it in important to note that this battery does not need to be completely discharged before recharging can take place, which will most likely be the case for a system which will be used daily.

The nickel-metal hydride or NiMH battery like the lithium battery is rechargeable but does not provide the same storage capacity. Only capable of storing 100 watt-hours per kilogram can however be thrown away. Furthermore although the NIMH battery may be heavier and larger compared to the lithium battery it is much more cost effective which many prove more beneficial in a privately funded project. Temperature is aside from cost is also another area where in the nickel metal hydride battery shines, in that this battery is much less temperature sensitive.

3.4.3.2 AC Power Supply

A more feasible power supply to support the base stations load requirements could be alternating current. Capable of providing more than enough power one of the only limitations associated with this option is the restriction it places on the mobility of the base station. Furthermore because this source will be supply power to devices which require direct current to operate properly a number of components including voltage regulators, full bridge rectifiers, resistors, and capacitors will be required. An ac power supply will also provide the flexibility required to add new components without concern for battery life reduction or the need to continuously adjust a battery's storage capacity. Some of the more important aspects of ac power usage to consider when researched said system as a potential power supply include how to convert ac to the needed dc source, which wall adapter if any are required, and which circuit components are integral to the design.

3.4.3.2.1 Adapter

Although a bridge rectifier could be used to convert the alternating current delivered from a power out let into the direct current need by the base station and its subsystems it is a process that could be handled by a wall adapter. Not only would said wall adapter reduce the amount of circuit space allocated on the printed circuit board it will also reduce the

amount of soldering required in production. When selecting a wall adapter the most important options to take under consideration include if the adapter should be unregulated or regulated, linear or switching, and if the maximum amount of current produce by the wall adapter will support the load it supplies.

A regulated adapter unlike an unregulated one always produces the rated voltage. This is important to consider when selecting an adapter because if an unregulated device is specified for a system sensitive to unexpected changes in voltage, the circuit could be destroyed. As said adapter will be used to power a custom built circuit composted of microcontrollers, radio frequency transmitters, and Ethernet controllers it can be assumed that the need for an unregulated wall adapter in minimal. A linear regulates voltage by taking the difference between the input and output voltages and rectifies the difference as heat. Although this type of regulator is cheap it is very inefficient with respect to generating the desired voltage output. A switching regulator in comparison reduces the amount of heat that is exhausted by transferring small bits of energy at a time to be output through the use of an electrical switch and a controller. In order to best determine if a switching or linear regulator is needed all that must be determined is if the linear regulator is wasting less than .5 watts of power, which can be done with the following equation. Power wasted = (input voltage – output voltage) * load current. Lastly yhe amount of current provide by the wall adapter should also be considered in that it will ensure that all component are adequately powered. The desired current level can be determined moreover by adding all the current loads specified by the data sheets of each device using power from the adapter. Because a wall adapter will be used to provide power to the base station as a whole a dc barrel power jack connector will also be needed to distribute the current to the board.

3.4.4 Wireless Transmitter

In order to send and receive information to both the GPS wrist band and RFID reader a wireless transmitter is required. While there are a plethora of methods with which to accomplish this transmission of data there a few constraints which decrease the selection pool. Among some of said restrictions include the need for a communication system which can transmit data up to a mile away. The transmitting device must also be fairly small in that not only will it need to be mounted on the base station but it will also need to be mountable and the GPS tracking device. As always the price of such a system must also be reasonable in order to accommodate the minimum of three devices needed to enable communication between the various data transmitting components. To achieve the desired results, radio frequency, Bluetooth, and Wi-Fi were all consider in an effort to generate the best results.

3.4.4.1 Radio Frequency

Touted for its ability to send information of long distance the type of RF transmitter used for this project needed to not only transmit information by receive it as well. Because information will need to be transmitted over at list a miles distance it is important to understand the differences, advantages, and short comings of both AM and FM signals. Although both are used in analog and digital communication AM signals tend to have poor sound quality in comparison to its FM counterpart. Moreover despite the fact that FM is more resistance to interference it is more heavily impacted by physical barriers

which could prove to be an issue for a system which seeks to track a device in an urban setting.

3.4.4.2 Bluetooth

Because the base station will needed to communicate with the RFID reader which will undoubtedly be in the same build or are as the afore mentioned reader, Bluetooth could simplify the transmission process. Capable of transmitting data with in the 100 to 300 feet range said distance will be more than enough to support communication within a building. Also able to interpret both voice and data, this feature could allow the base station to provide voice activated features which could vastly improve the security abilities of both the RFID reader and base station. Because Bluetooth can allow a variety of systems to communicate seamlessly this technology could not only be used to enable communication between the base station and RFID reader but also between the smartphone and base station as well. This furthermore could eliminate the need for internet connectivity on the base station if the infrastructure offered by Bluetooth's technologies is robust enough to support the demand placed on the system by required transmissions.

3.4.4.3 Hardware Components

Despite the fact that Bluetooth would provide added features to capable of enhancing the novelty of the communication infrastructure supporting the base stations communication system as a whole is would not provide the range needed to justify the use of the technology. To that end an RF bases system will be used in that it will not only provide the distance needed for the transmission of data it will also allow the transmitter to easily integrate will the countless variety of microcontrollers used with the project. As a consequence of using a RF transvers an antenna will also needed to be integrated into the design of the system. The devices under consideration as potential data transmitters include the XBee and the Modem Long Range 433MHz module.

3.4.4.3.1 HAC-UM96

The Modem Long Range 433MHz HAC-UM96 Module distributed by Sparkfun is a 26 by 47 mm device which can transmit data at 12000bps over 1000 meter. This modem has 8 channels with which to select, operates at a voltage range from 3.3 to 5 volts, and uses 3mA to receive and 4omA to send data. With respect to interfacing with microcontrollers and or other devices this long range module provides TTL and RS232 serial connectivity. As an added feature this chip comes equipped with a quarter wave 500hm antenna and communication cable to eliminate the needed developing, researching, or purchasing a compatible antenna. In order to achieve the longest transmission range listed for the 433MHz model it is best to mount the device at the heights point available and ensure the chip is place in the light of sight of the transmitter it is in communication with. Furthermore as suggested by the data sheet this component supports transparent data transmission which allows any standard or nonstandard protocol which may needed to be implemented.

To facility communication with a microcontroller the Modem Long Range 433MHz module offers a dual serial port which has 3 interface modes. The COM1 pin is used to interface with the TxD or TTL pin present on the host controller while COM2 can be

used to support the RS-232/RS-485 standards. A complete pin diagram can be seen in Figure 27 below.
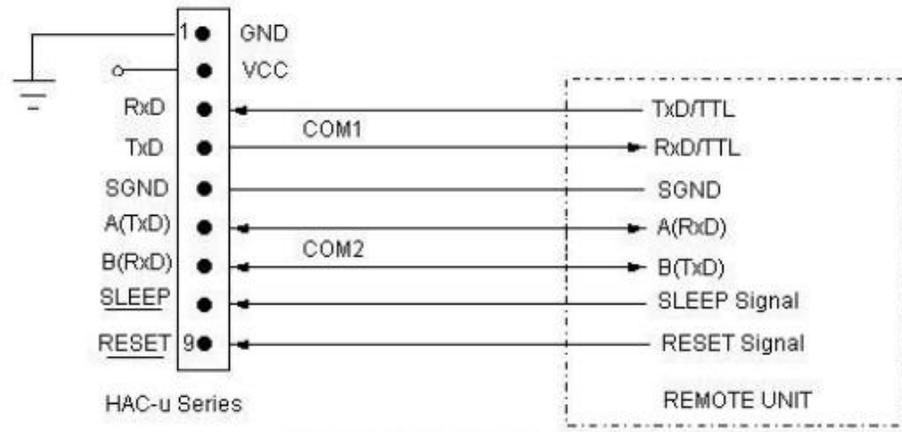

Figure 27: HAC-UM96

Although the HAC-UM96 is capable of interface with any microcontroller it is limited in the range with which it can transmit information. This short coming while the only issue associated with this device is the feature around which this project is base. If information cannot be transmitted over at least a mile modification to the projects overall purpose will needed to be considered.

3.4.4.3.2 XBee

Distributed by a number of manufactures the XBee 900 RF module best suited for point to multipoint networking. This RF transvers can also provide point-to-point, peer-to-peer and point-to-multipoint networking alongside a plethora of long range distances. Operating within the 900 MHz frequency band operates at a 3.3V using 210mA of current, requires an external antenna, transmits data up to 6 miles within the sight of the transmitter, and uses a 156 kilobytes per second RF data rate. Although the initial description of the XBee 900 states the data transmission range of the chip is 6 miles this distance can only be reached when a high gain antenna is attached to the device. Furthermore because this device will need to be able to transmit data in urban areas the difference in outdoor and indoor line of sight distance is concerning. Boasting only a 450ft indoor range, it is unclear if the chip, which will be mounted on an indoor base station, will be able to communicate with a chip which will not only be mobile but outside as well.

The XBee, similar to the other devices researched throughout this process, uses UART to communicate with the host microcontroller it interfaces with. To further simplify the process only four pins which include the DIN, CTS, DOUT, and RTS pins are needed to create a connection sufficient enough to transmit data as can be seen in Figure 28 below.
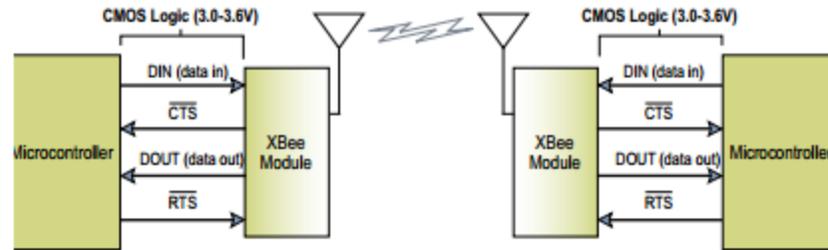
Figure 28: Xbee Diagram

3.5 PCB

According with the specifications of the project, at least one PCB will be ordered for the GPS tracking system. The GPS tracking device is the device that we will order a PCB for. In this section the pricing of the PCBs will be considered in which choosing the right PCB vendor is critical for the project's success. There are many vendors to choose from when it comes to ordering this section; therefore will be extensive and detailed. The group decided to set criteria for choosing the PCB vendor for the project. Because this project requires particular specifications, a set of criteria were developed which required the vendor to comply with this specifications to master the end result the microcontroller and FPGA. Later in this paper the details for the budget of the group will be considered but is important to mention it in this section. It was determined that price and completion time will be considered as part of the criteria for this project.

Because the project is set to a limited budget, it was needed to ensure that the vendor offers PCBs within the designated price range. The maximum amount of money allotted for the PCB is $200. However, the group set a goal to find a PCB that is well under the maximum allotted price range. By setting a specific maximum price range, the group was able to quickly eliminate vendors that do not meet the proposed requirements for the PCB design.

Another criterion to consider is the time it takes for the PCB to be delivered which would eventually be an important parameter to consider. The project is restricted in schedule, therefore is vital that a vendor is found to have a quick turnaround time. Finding a vendor that has a fast turnaround will allow the team to build this part of the project as early as possible. The PCB is the foundation for the project; therefore, it is important that the team begins working with it so that issues that could arise can be found earlier. Without the PCB, the project would not succeed. This is why finding the right vendor is so important.

Also, the team has a standard size for its PCB, which is 12 square inches and 4 layers. By setting a PCB size for this project, it diminishes any chance of miscommunication regarding the ordering of the PCB. The size is important to be considered due to the project requirements in which the wireless-wearable mouse should weigh less than 3 lbs. Setting this standard size for the PCB allows the team to make sure that it fits the other design elements of the project. When searching for the prices of the PCB, using the size requirements is easy to draw a prize by selecting the size of the PCB. Therefore, the exact price is known for the PCB from the specific vendor.

Out of the four group members no one is familiar with the PCB vendors. In order to best vendor for the needs, the team decided that it would be beneficial to research five different vendors. Using developed criteria, the team was able to narrow down the pros and cons of each vendor, as well as any additional companies needed to contact, such as for assembly.

3.5.1 Express PCB

The first vendor to consider is ExpressPCB, which offers several convenient services. This vendor includes several packages, which includes standard, miniboard, production, protopro, 4 layer productions, and 4 layer protopro. The option considered is the 4 layer production. This package allows the group to capture the 4 layers needed for the project's PCB. The 4 layer production allows a more compact design, as well as eases the amount of work involved for layout. Express PCB also assembles the PCB, making it less work on the design end as far as contacting a company that assembles PCB's. They also offer the PCB size that the group is looking for. The total lead-time for Express PCB was 10 days.

The pricing was determined using a set formula. The particular vendor has a 10 day option, which adds option, $273 + (.68 * Number of boards * Board area in square inches) + (.5 * Number of boards) − Quantity Discount + Shipping. Express PCF requires an order of at least 2 PCBs in which the team will make an order of two PCBs. The total cost for the PCB without shipping is $290. The team has a set budget of $200 for the PCB, which wouldn't meet the group budget needs, the group decided to explore other options.

3.5.2 PCB4Less

The website PCB4less.com is a much known PCB manufacturer and offers a short lead-time of 5 days. They offer the option to test the PCBs before sending them out to the customer. By testing their products before delivery they can validate that all specifications are met and the device is fully functional. This feature will assure the group that the PCB was built correctly and will reduce testing time. This website offers all of the services that Express PCB does however the way they price their products is very different. PCB4less has a very complex quote system.

3.5.3 Ultimate PCB

After much research on PCB vendors the group stumbled upon the website Ultimatepcb.com. This website was found to be very simple to navigate and offers a much more user-friendly quoting system. An interesting feature about this vendor is that they offer many customization options to the costumers. One of the things that called the group's attention is that they allow the customers to order single PCBs rather than bulk orders. This is a great advantage to the group since only two boards are needed for this project. Ultimate PCB also offers a variety of sizes which one of those is ideal for this project. The total turnaround time was 5 days.

Although this vendor has many great features to offer for this project they are out of the budget. The price of the PCB from this vendor averaged $230 without shipping. Therefore, it goes over the price range and all of the group's criteria.

3.5.4 PCB Express

Another vendor which the group explored is PCBExpress is another excellent website to order PCBs from. This particular vendor is not associated with the vendor mention earlier ExpressPCB even though the names can be very similar. This vendor requires that at least two PCBs at a time be ordered. This vendor also assembles the PCB like the other vendors researched. They offer the correct PCB size for the project, and have a simple ordering system. The total lead-time was 3 days.

For the group's specifications, the total cost will come to $500 without shipping. Because of PCB Express' high cost, the group decided that this was not a valid option for this project. The price exceeds the allotted amount by almost $200, an amount that is too high for the group to even consider expanding the PCB budget.

3.5.5 Imagineering Inc.

Imagineering Inc. is another PCB vendor that was researched for this project. The website for this vendor is also very user friendly and offers many customization options. Although they meet all the PCB requirements for this group they are outside of the price range for the group. The minimum number of boards the group can order is 5, which also exceeds the number of boards needed. This vendor also charges a tooling fee and he total price after the $200 tool charge was approximately $635. The lead-time is 7 days. It was after the group discovered the high price of their products that this vendor was eliminated from the options.

3.5.6 4PCB.com

Finally the group decided to research 4PCB.com. This website is very famous as they offer special deals on generic size PCBs. One of the advantages of using this website is that they offer a free PCB-layout software called PCB Artist. In this software you can lay out the board and upload it so they can print it. Not only that, but the group will be able to order multiple boards at a low price. The boards come with white legends, 2-Layers and are 60 sq. in. The boards are also lead-free, routed to overall dimensions and have all the wholes plated. The lead time for this vendor is 5 days. For the price and many other reasons the group will choose 4PCB.com as the PCB vendor of choice.

3.6 User Interface

In order for a smartphone to receive alerts and warnings from the base station, a phone application that provides a graphical user interface will be used that can receive incoming messages from the base station and also respond to them. It will also receive GPS coordinates that will allow the smartphone user to track the person wearing the tracking device. There are several options available to create a user interface, The operating systems considered for creating an application to hold the GUI are the Android OS and the iPhone OS.

3.6.1 Android OS

The Android Operating System is a multi-layered, multi-user Linux system in which each application is treated as a different user and runs in its own Linux process. The reason for this is because Linux assigns each application a unique user ID which gives the

application access only to the components it needs in order to execute, making it more efficient by keeping the memory usage low. Two applications are allowed to access each other's files which give the application a lot of flexibility to use other application's features when needed. The Android OS architecture features an underlying system of event managers to oversee and allow the interaction of different applications, such as Views, Content Providers, Resource Managers, Notification Manager, and Activity Manager. The Views manager includes tools for useful components that include graphical layouts, lists, grids, buttons, and labels. The Content Provider allows an application to share its resources with other applications by putting its data into a shareable secure resource component. The Resource Manager is a component that provides the means for an application to access resources outside its own resources, such as graphics, specific layouts, and configuration settings. The Notification Manager allows the application to send alerts to the user's status bar and notification panel and the Activity Manager manages and interacts with the overall activities running in the system and retrieves information such as available memory, processes that are in an error condition, and more. These tools provide the necessary features to perform the project's objectives. Any application written for Android will interact with the Operating System directly or indirectly and this will be done through coding by making use of the above mentioned features. In this project, the Smart GPS System application will need to access features of other applications in order to do its job, especially the map application. If the base station sends GPS coordinates to the smartphone application, the Smart GPS System application will have to access the map application in order to show the location sent constantly by the base station without terminating the process.

The figure below, Figure 29, shows the different layers of the Android operating system as previously described in this section. The diagram gives an overview of the OS architecture including libraries, framework services in the Application Framework layer, libraries, and drivers available at the Linux Kernel layer.
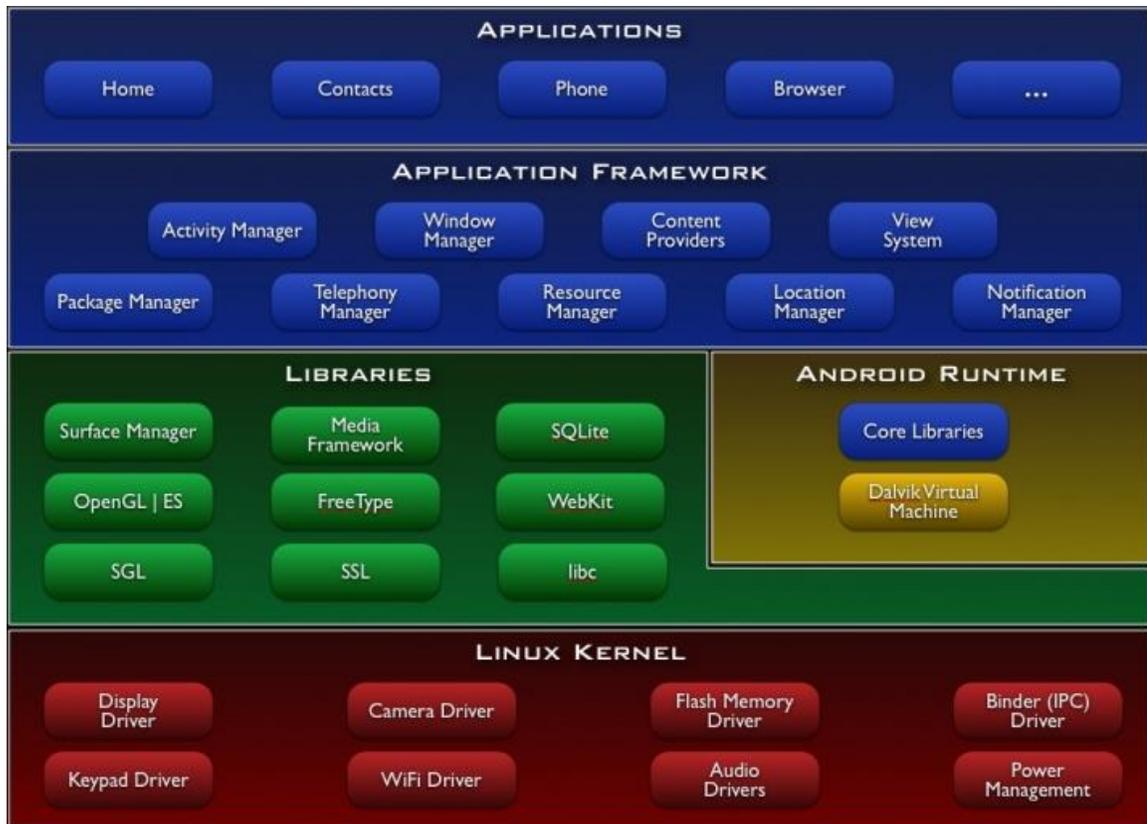
Figure 29: Android Operating System

Courtesy of Google

 Moreover, Android development framework is very powerful and it makes it easy to use for application development. It already has built-in tools that allow you to create a single binary that is automatically optimized for multiple screens, including those of phones and tablets. One of the advantages of programming an Android application is that it uses Java, a class-based, object oriented language and a language that the group is already familiar with which shortens the learning curve. Another plus that comes with the developer tools are the graphical UI builders which allow you to customize the look and feel of the application graphically instead of doing it through XML code. It also includes many standard C/C++ libraries, such as SGL (2D graphics), OpenGL (3D graphics), and SQLite.

Furthermore, the Android SDK and developing tools are free to download and use and the only cost required is a onetime fee of $25 to get a publisher account in the Android market in order to publish Android apps. The developer tools can be downloaded on any computer that meets the system requirements for Operating Systems, including Windows, Mac, and Linux. There is also an Eclipse IDE plugin for Android development, an IDE that most members in the group are familiar with.

3.6.2 IPhone OS

One of the choices that are being considered for the user interface is using Apple's iOS to create an iPhone application. Developing an iPhone application uses the Objective-C language, a superset of the C language that provides object-oriented capabilities. Building an iPhone app is mainly based on working with objects, some of which are provided by the frameworks in the layers of the operating system. The iPhone operating system is multi-layered and consists of four abstraction layers: the Core OS layer, the Core Services layer, the Media layer, and the Cocoa Touch layer.

The Cocoa Touch layer, the highest level of layers, is a UI framework based on the Mac OS X Cocoa API toolset. This is where most of the application UI interaction happens from multitasking to push notifications. Cocoa contains the key frameworks for developing applications such as the Foundation Kit, UIKit, Game Kit, iAd, and Map Kit frameworks. The Foundation Kit framework provides basic Objective-C classes such as wrapper classes and data structure classes, including memory management, as well as defines functionality not covered by the Objective-C Language. The UIKit framework provides classes needed for graphical user interface construction and management, including event handling, drawing model, controls specifically designed for a touch screen interface, and Storyboards. Storyboards let you design your entire user interface in one place by allowing you to see all your views and view controllers and how they work together. This technology makes it easy to integrate the different functionalities of the project's application and allow the group to see how they work together even before testing begins. The Game Kit framework provides functionalities such as the game center, peer-to-peer connectivity and in-game voice chat. The iAd framework, which works like Google's AdMob mobile advertising service, allows third-party developers to embed advertisements into their apps; and the Map Kit framework provides an interface for embedding maps directly into the app's windows and views and other functionalities to support interaction with the map, including performing reverse-geocoding lookups to determine location for a given map coordinate. Several of these functionalities, such as the ability to interact with the map functionalities and event handling at the user interface level, are key functionalities that are needed for the Smart GPS System application to interact with the user. The Cocoa Touch layer also has a multitasking manager that allows an application to be put in the background but remain in memory, or to be put in a suspended state, which allows it to still run in the background, for example if there is music playing. Regardless of the state, the application can resume execution faster since it was in memory and does not have to execute from the beginning. Another feature is the gesture recognizers, which can detect a number of different screen interactions such as tapping, pinching, dragging, swiping, and rotating. These features can be easily integrated in the application with the use of the cocoa touch layer, which takes care of the complex code.

The Media Layer is responsible for audio mixing and recording as well as core animation. The Core Services layer provides fundamental system services that all applications use, although not directly. These services include data protection, file-sharing support and the use of Grand Central Dispatch (GCD). GCD allows the developer to manage the execution of tasks in the application as an alternative to threading. This comes in handy for those critical times when the application needs to receive data from

the microcontroller and at the same time handle other events such as showing coordinates on the map. The Core OS layer contains the low-level features that all the other layers are built upon. Most of the interactions with this layer are done implicitly through the layers. This layer contains the accelerate framework, for performing DSP, and image-processing calculations, the core Bluetooth framework, to interact with Bluetooth Low-Energy accessories, the Security framework, to secure data managed by the application, and the System level, which encompasses the kernel environment, drivers, and low-level UNIX interfaces of the OS. The interfaces at this level provide support for features such as threading, networking, memory allocation and DNS services, among others.

Figure 30 below depicts the operating system layers of the iPhone OS. The application can directly call any of the layers of the stack to perform tasks on the device whereas the Core OS is the only layer that directly communicates with the iPhone hardware. This direct relationship with each layer allows the application to make calls to perform operations, including calls to manage the execution of tasks within the application, which is a key factor to the project's application when communicating with the base station.
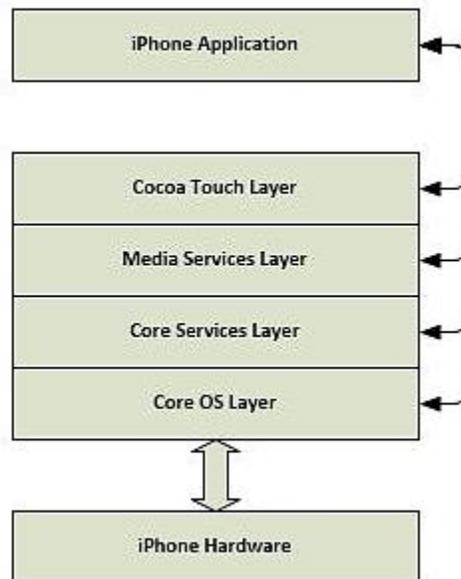
Figure 30: iOS Architecture

Developing an iPhone application creates some issues for the group. The Xcode IDE, the only available IDE to build apps for iOS, can be downloaded for free but it requires the Mac OS to run and no one in the group has a Mac. Also, even though there is no cost involved to start developing an iPhone app, in order to test it on an actual device, a developer's license needs to be purchased. A $99 fee must be paid to join the iPhone Developer Program in order to obtain a developers license. Moreover, the fee must be paid annually in order to maintain the license. There is an iPhone simulator that is available for testing but it has limited functionalities and does not fully emulate an Apple device which can limit the testing that can be done.

3.6.3 Google App Engine

Another option that can be considered for the implementation of the user interface is to use a web-based application via Google App Engine. Using a web-based application has several advantages such as the availability of a database and support for the Android platform, which allows for portability, a necessity for this project. Google App Engine, in particular, enables the creation of a web application on the same scalable system that power Google applications. App engine applications are easy to build and there are no servers to sustain. Google hosts and scales the applications so there is no need to worry about server administration. Another advantage to using Google App Engine is the accessibility of a database; each application has access to its own database.

Figure 31 represents the communication between the server side (Google App Engine) and the client side (the user). As it will be discussed in this section, Google App Engine provides a lot of flexibility with languages and database options.
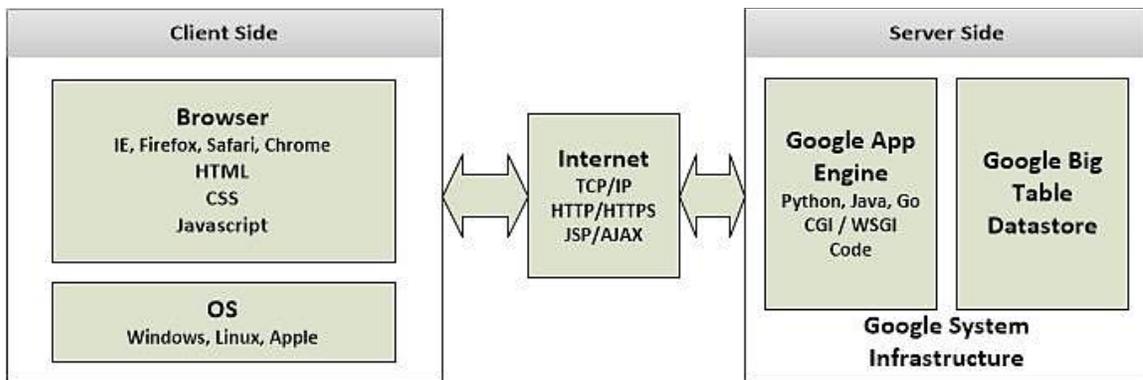
Figure 31: Overview of Google App Engine

Google App Engine supports different programming languages making it more flexible to choose and work with the languages that the group is familiar with. Web-based applications can be built using Java, Python or Go languages and Google provides runtime environments to build apps in each language. Java runtime environment lets you build apps using standard Java technologies, including JVM, Java servlets, and any language using a JVM-based interpreter or compiler, such as JavaScript or Ruby. There are two dedicated Python runtime environments that include a fast Python interpreter and the Python standard library. The same holds true for the Go runtime environment, it runs natively compiled Go code. A great advantage to the group because this project is not only to test our existing knowledge but to give us the opportunity to explore and discover technologies that can be beneficial in the near future. It provides an Eclipse Plugin that is a real advantage since most of the group members are already familiar with it.

Using Google App Engine has no cost to get started. All that is needed is a Google account that allows the account holder to create 10 free applications with up to 1GB storage and enough CPU and bandwidth to support around 5 million page views a month. This is a great advantage for prototyping and testing purposes and is more than enough for the project objectives to be completed. If there is the need to scale up, Google allows

for the purchase of more resources and only charges for what is used. There are no set-up costs or recurring fees.

Google offers a wide array of features, such as APIs for authenticating users and sending email using Google Accounts, traffic control, scheduled tasks for triggering events at specified times and regular intervals, access to Google infrastructure and services, including calendar, maps and email; automatic scalability, and persistent storage with queries, sorting and transactions. The App Engine environment features a range of options for storing data including the BigTable Datastore, a NoSQL schemaless object datastore; a relational SQL database service, and the Google Cloud Storage for storing files and objects up to terabytes in size.

According to Google Developers, the NoSQL datastore provides two data storage options: High Replication Datastore and Master/Slave Datastore. The main differences between the two are latency and availability. The Master/Slave Datastore is designed with a single data center holding the master copy of all the data. Data written to the master data center is then replicated asynchronously to the slave data centers. This design offers low read and write latency but it does not protect the application from planned downtime due to maintenance or global failures which can lead to data loss and inconsistencies. The High Replication Datastore implements the Paxos consensus algorithm to replicate data synchronously across multiple data centers. This results in higher availability of data reading. The only downside is the higher write latency but this is balanced out by the increased data consistency especially in the rare event of a global failure, which would not result in data loss. Also there are no enforced read-only periods.

The higher write latency means that there is a delay from the time a write is committed to the time it becomes visible in all data centers, which can sometimes lead to inconsistent query results. In order to obtain stronger consistent query results, Google uses an ancestor query which limits the results to a single entity group. According to Google Developers, datastore entities are schemaless, the structure of data entities is provided by the application code. The Java JDO/JPA interfaces provide features for applying and enforcing structure within the app. It gives the app the flexibility to apply as much or as little structure as it needs. The main difference between noSQL and MySQL is that noSQL does not feature primary/foreign keys, joins, or relational calculus. NoSQL allows the datastore to automatically scale to maintain high performance as they receive more traffic. Other than that, it allows for entity relationships which form the data hierarchy upon which the application relies for queries. NoSQL does not require entities of the same kind to have consistent property set but it is possible to do so in the application code. These differences make writing the code easier and give you more control over the structure of the database.

There are many websites that offer pre-made templates to work on Google App Engine. Depending if we find one that integrates well with the project, we might create our website from the ground up using HTML and JSP. With the App Engine, the group does not have to worry about maintaining the back-end of the application and that eliminates all the complex coding and risks associated with handling our own database, such as data loss or server downtimes.

3.7 Communication Systems

3.7.1 Wireless Communication

Wireless communication is essential in transmitting and receiving data from the base station to the smartphone. Data such as notifications, real-time GPS location, and control signals will all be sent wirelessly and this is why it is important that the technology used for the communication system is high quality and dependable. Since the base station consists of a battery-powered microcontroller, it is important to look into power consumption, range, and bandwidth. There are different methods by which the communication system between the microcontroller and the smartphone can be implemented such as through the use of Wi-Fi, XBee Wireless or Zigbee

3.7.2 Internet Communication Protocol

Communication between the microcontroller and the mobile application will be done through the internet. TCP/IP is the communication protocol for transferring data through the internet, it encompasses several protocols for handling data communication, including how electronic devices should be connected to the Internet and how data should be transmitted between them. TCP/IP stands for Transmission Control Protocol / Internet Protocol, where IP is used for communication between computers, and is responsible for routing data to the correct destination. It is designed around a four-layer model known as the Internet Reference Model, where each layer implements a service. Table 11 shows the layers in the Internet Reference Model:

Application Layer	Consists of applications and processes that use the network (e.g. HTTP, telnet, e-mail)
Transport Layer	Provides communication between applications (e.g. TCP, UDP)
Network Layer	Handles routing/delivering of data (e.g. IP, ICMP, ARP)
Data Link Layer	Comprises routines for accessing physical networks (e.g. IEEE 802.3, PPP)

Table 11: Internet Reference Model Layers

The application layer is where the applications reside. Every time the application layer needs to send data to another application, it must rely on the lower layers to transfer the data across the underlying network. In order to do this, each layer adds its own header to the segment which is then removed, step by step, by the TCP/IP stack on the receiving end. Figure 32 describes this interaction.
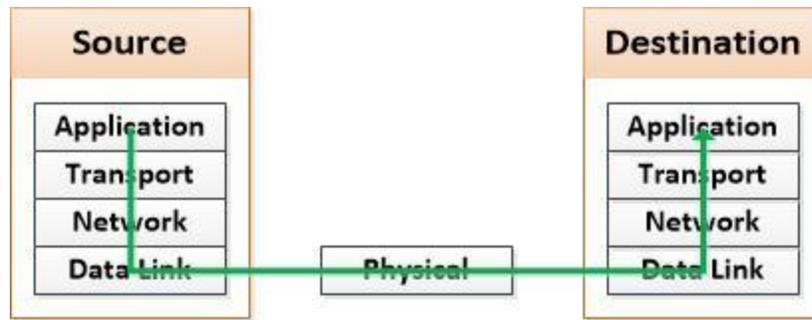
Figure 32: Transfer of Data across Network Diagram

The application relies on the transport layer to carry the data, which is encapsulated in an IP frame; likewise, the transport layer relies on the network layer to handle the routing of the data based on the IP-frame header information. The network layer relies on the data link layer to know how it can transport the data across the underlying network. Lastly, the physical layer is the means of transportation, the actual physical medium of transportation (e.g. wires, fiber optic links).

As mentioned above, the protocols included in the TCP/IP family, that deal with communication between applications, are TCP and UDP protocols. They both handle the type of communication that is needed to communicate between the project's user application and the base station. The information that is going to be sent between the base station and the mobile application can be of a sensitive matter, so we are looking for a reliable channel of communication that will guarantee our data does not get lost in transit. We are also looking at time, the data needs to be relayed in a timely manner with the least amount of unnecessary delay. With these things in mind, we focused on the above mentioned protocols that can be used to communicate through the internet. TCP and UDP protocols offer their own way of transporting data that can be an advantage or a disadvantage when used in this project.

3.7.2.1 TCP

TCP is a highly reliable, connection-oriented protocol that is used for transmission of data from an application to the network. TCP splits the data bytes into segments that are send out as IP-frames. When an application wants to communicate with another via TCP, it sends a communication request to the exact address. It requires a handshake to take place, that is, it waits for an acknowledgement (ACK) from the receiving end. This "handshake" is what establishes the connection between the two applications and allows for a full duplex communication between them, meaning that each TCP connection supports bi-directional data flow in the same connection, until one of the applications closes the connection. The need for an acknowledgment (ACK) every time a data packet is sent makes it a highly reliable channel of communication, it is absolutely guaranteed that the data being transferred will remain intact and arrive in the same order in which it was sent. The way this is done is that if the sending TCP sends a data segment and does not receive an ACK before the timeout period expires, it re-sends the data before sending any new segments.

It also implements an error checking mechanism to make sure that the data segments sent are received without error and in the correct order. These features benefit the project's application when it is crucial to send and receive correct data, especially when sending updates concerning the GPS device. Another great feature of TCP is traffic control; there is no need to worry about overloading the network and possibly losing data, the protocol implements congestion control by letting the sender TCP know how many bytes it is allowed to send to prevent a network overload. And another very important feature is that TCP allows for multiplexing, which means that it allows many processes within a single host use TCP communication simultaneously through the use of sockets. This means that we can have several users communicating with the base station independently from each other by creating sockets to communicate. TCP is mainly used for connections that require reliability and no loss of data such as HTTP, HTTPS, FTP, SMTP, and Telnet.

3.7.2.2 UDP

UDP stands for User Datagram Protocol and is also a protocol used for communication between applications. UDP offers simpler means of communication that does not rely on an established communication to send data. Its main advantage is that it transmits data faster since it does not have to rely on an acknowledgement or handshaking to send data. The lack of retransmission delays makes it more suitable for applications that require real-time transmission of data, such as online games and VoIP applications. It is stateless which makes it suitable for streaming media applications where it is not critical if some data corruption happens. UDP is definitely a protocol that suits the need for fast transmission of data, which is a plus for our project's objectives. The only downside is that there is no guarantee that the data sent would reach its destination at all or on the specified order.

Table 12 summarizes the differences, the pros and cons of TCP and UDP when related to our project.

	TCP	**UDP**
Acronym	Transmission Control Protocol	User Datagram Protocol
Function	Communication between applications across network	Communication between applications across network
Header Size	20 bytes	8 bytes
Error Checking	Yes	No
Reliability	Connection-oriented. Guaranteed the data will be delivered without corruption	Connectionless protocol. Data could get lost or arrived corrupted
Speed	Slower. Subject to delays due to waiting for connection and re-transmissions	Faster. No waiting involved when sending data packets.
Weight	Heavyweight. Requires three packets to set up socket connections. Connection/ordering overhead	Lightweight. Very few overhead. No connection/ordering management

Table 12: TCP vs UDP

4 Project Hardware and Software Design Details

4.1 Initial Design Architectures and Related Diagrams

The following diagram in Figure 33 represents the initial architecture design that the group agreed upon to implement the Smart GPS System project. As can be seen in the diagram, the base station unit is the command center for the project. It is the only module that can interface with all the other modules in the system. The base station will be in charge of receiving and sending commands to all other modules. These commands will be in the form of flags that will let the subsystem know what actions to execute based on the meaning of the flag. The base station, web app and mobile app will have access to the online database residing in Google App Engine. Their communication will be mainly triggered by the user, with the special case of when the GPS device sets off the RFID reader, at which time the base station will be handling the communication. The system is driven by events that are triggered by flags and/or the user.
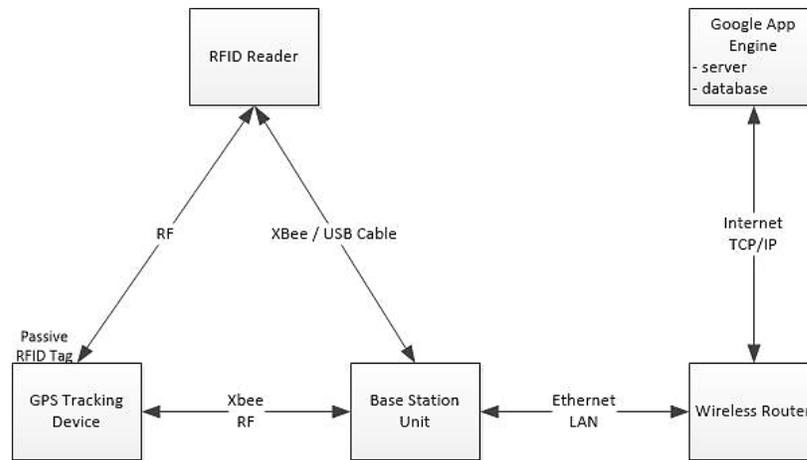
Figure 33: High Level Architecture Diagram

4.2 Outdoor Tracking System

4.2.1 GPS Module Specifications

The GPS module that was implemented in our project is the LS20031 because this module meets the size and price requirements we are looking for. It is about 30 mm square and its price is about 64 dollar. This module operates at frequency of 1575.42 MHz, with 1.023 MHz chip rate, 20 channels all in view tracking, -159 dBm sensitivity, and baud rate of 4,800 bps. The acquisition time for this GPS module is as follow:

- Reacquisition 0.1 sec., average
- Hot start 1 sec., average
- Warm Start 38 sec., average
- Cold Start 42 sec., average

There are six different pins for the EM LS20031. The Vin is the main DC supply input power. The TX is the main transmits channel for measuring data to user's navigation software or user written software and outputting navigation. RX is the receive channel, and GND is the ground for the engine board. Finally, 1PPS provides one pule-per-second output from the engine board that is synchronized to GPS time.

Because our project was looking for more than the latitude and longitude, the Recommended Minimum Specific GNSS Data (RMC), example shown in Figure 34, output will be used for getting the information from the GPS Module. One of the advantages of using this output is that velocity can be obtained and the speed user can be calculated.

```
$GPRMC,123519,A,4807.038,N,01131.000,E,022.4,084.4,230394,003.1,W*6A

Where:
     RMC              Recommended Minimum sentence C
     123519           Fix taken at 12:35:19 UTC
     A                Status A=active or V=Void.
     4807.038,N       Latitude 48 deg 07.038' N
     01131.000,E      Longitude 11 deg 31.000' E
     022.4            Speed over the ground in knots
     084.4            Track angle in degrees True
     230394           Date - 23rd of March 1994
     003.1,W          Magnetic Variation
     *6A              The checksum data, always begins with *
```

Figure 34 GPS Output RMC

As it said before, the LS20031 uses an external antenna. A GPS External Digital Antenna with MMCX Connector and 3-Meter Cable (1.5 GHz) suits our need. This antenna is under 5-dollar price and according with some reviews, it has excellent performance and durability. Its dimensions are Dimensions: 44.96 mm x 38.1 mm x 12.95 mm. Weight: 2.93 oz. Antenna GPS 3V Magnetic Mount SMA: Some of the features of this antenna are high gain and low noise, ultra-low power consumption, compact constriction, temperature stability and a magnetic mount base. Its dimensions are 46 mm x 46 mm x 13.7 mm. Weight: 80g.

4.2.2 Power Supply Design

In the research part of this paper, we said that a charge controller is an important part on energy based electrical systems. Controllers will be important in limiting the flow in electric current from the batteries, and preventing overvoltage. Thus, the GPS tracking device will be safer because charge controllers prevent heavy current flow that cause fire or explosion of the battery. The BQ24193 is a good choice because it provides 92% charge efficiency, accelerate charge time by battery path impedance compensation, uses a single input USB-compliant/Adapter charger, and its input operating range is between 3.9V and 17V. In addition, this controller provides over-voltage/over-current protection, and programmable thresholds for the minimum current in the CV phase. Figure 35 shows the typical connection for the BQ24193
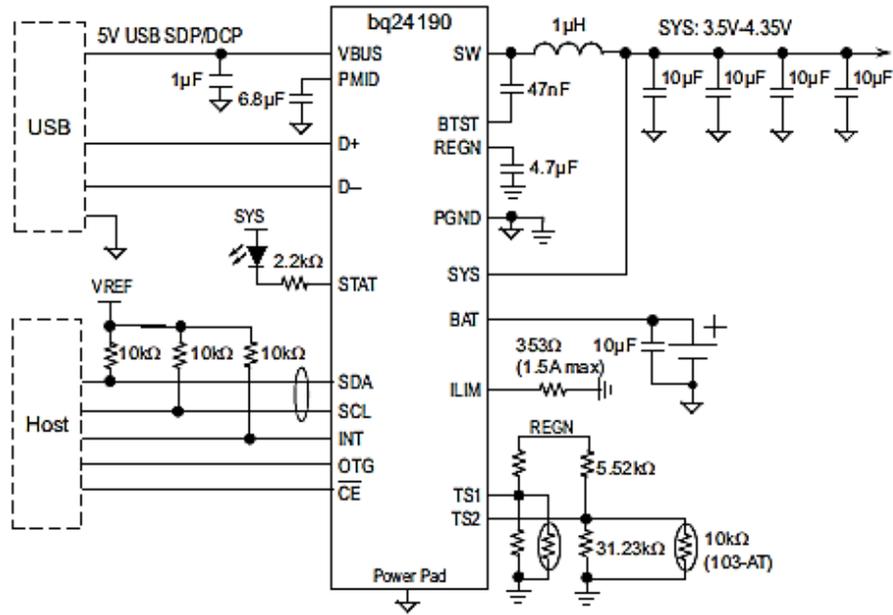
Figure 35 BQ24193 Typical Connection Circuit

Because the GPS tracking device user should be located in less than one hour within a mile away from the base station, the 3.7V at 1500mAh 14500 Li-ions rechargeable battery pack with PCB plus plug is the battery that suits our needs. It is 15x15x52 mm, which is a good size for the device. Table 13 refers to its specifications:

Model:	SuPower 2P 3.7V Li-ion Battery Pack
Capacity:	1500mAh
Battery Cell:	Bran-new 14500 Cell
Colors:	Black PVC
Chemistry:	Li-ion Rechargeable
Charging Voltage:	4.2V
Working Current:	1 – 3A, Continuing Discharging Current Less than 2A
Max. Dischargeing Voltage:	4.2V
Capacity	1500mAh (Full Capacity)
Size:	15 x 30 x 52 mm
Weight:	65g
Assemble:	2P, Red + / Black - Plug type HX2.54
Built-in Protection Circuit:	- Over-charge - Over-discharge - Over current - Over temperature - Short circuit protection
Charge & Discharge Plug	OEM / Can be Customer Design

Table 13 Battery Specifications

In addition, a buck regulator will be implemented in our design. The LTC3549 is the one we are going to implement because of its high efficiency. The output voltage of this regulator is adjusted via an external resistor divider, and the fixed switching frequency is at 2.25MHz, which allows the use of small surface mount inductors and capacitors. The LTC3549 has an input voltage range of 1.6V to 5.5V and it is compatible with battery we

are going to use. This switching offers 100% duty cycle, which provides low dropout operation, and extended battery life in portable systems. There are some of the main features:

- Internal Soft-Start
- Low ripple burst mode operation
- Up to 93% of high efficiency
- Low dropout operation
- Stable with ceramic capacitors
- Over temperature protection

4.2.3 Microcontroller MSP430G2553

Because the GPS tracking device will be off inside the building, low power characteristics are critical in order to meet the design specifications. One of the advantages of using the MSP430G2553 is that it offers programmable modulation for each source, multiple clock sources and low-power modes. The Figure 36 shows a direct relationship between frequency of operation and power consumption. In our project, in order to maximize power efficiency, we will take advantage of the MSP430's digitally controlled oscillator (DCO) in order to scale the speed in accordance to the current task.
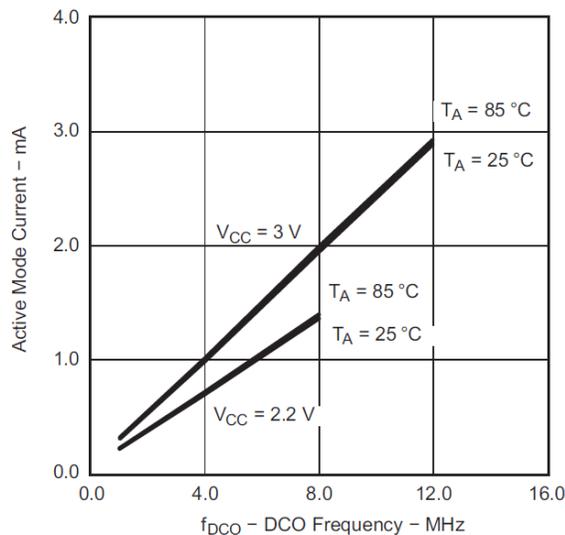
Figure 36 MSP430G2553 current vs DCO frequency

Moreover, the MSP430G2553 offers many low-power modes allowing the user entering and exiting in one clock cycle time. This feature lets us to go into a low power mode during periods of inactivity. There is no impact on performance because of the fast wake up time. In Table 14, there is detail information on low power modes.

Parameter	Test Conditions	T_A	V_{cc}	MIN TYP MAX	UNIT
Low-power mode 0 (LMP0) current.	MCLK = 0 MHz, SMCLK = DCO = 1 MHz, ACLK = 32,768 Hz. BCSCTL1 = CALBC1_1MHZ, DCOCTL = CALDCO_1MHZ, CPUOFF = 1, SCGO = 0, OSCOFF = 0	25°C	2.2 V	56	µA
Low-power mode 2 (LPM2) current.	MCLK = 0 MHz, SMCLK = 0, DCO = 1 MHz, ACLK = 32,768 Hz. BCSCTL1 = CALBC1_1MHZ, DCOCTL = CALDCO_1MHZ, CPUOFF = 1, SCGO = 0, SCG1 = 1 OSCOFF = 0	25°C	2.2 V	22	µA
Low-power mode 3 (LPM3) current. (LFXT1)	MCLK = 0 MHz, SMCLK = 0 MHz, DCO = 0 MHz, ACLK = 32768 Hz. BCSCTL1 = CALBC1_1MHZ, DCOCTL = CALDCO_1MHZ, CPUOFF = 1, SCGO = 0, OSCOFF = 0	25°C	2.2	0.7 1.5	µA
Low-power mode 3 (LPM3) current.(VLO)	MCLK = 0 MHz, SMCLK = 0 MHz, DCO = 0 MHz, ACLK from internal LF oscillator (VLO). CPUOFF = 1, SCG0 = 1, SCG1 = 1, OSCOFF = 0.	25°C	2.2 V	0.5 0.7	µA
Low-power mode 4 (LPM4) current.	MCLK = 0 MHz, SMCLK = 0 MHz, DCO = 0 MHz, ACLK = 0 Hz. CPUOFF = 1, SCG0 = 1, SCG1 = 1, OSCOFF = 1	25°C	2.2 V	0.1 0.5	µA
" "	" "	85°C	2.2 V	0.8 1.7	

Table 14 MSP430G2553 low power mode functions

Another reason for this microcontroller choice is that its cost is pretty low. The chip cost less than a dollar for a single unit. Also, development cost is small, thanks to the TI's Launchpad. The Texas Instrument Launchpad is a starter development kit that includes: MSP430G2553, the development board, extra headers for prototyping, and a 32 kHz external crystal, all for $4.30, and with free shipping. TI also offers a code-limited version of their IDE Code Composer Studio free of charge.

4.2.4 LCD Character Display

For the purpose of this project it was found that the best option that could be used for the display was a character LCD screen. One of the key advantages of a character display is

its low power consumption when compared to other display technologies. In fact, a character display consume less than 100mA of current. Also, since LCD character displays are specifically designed for basic text, they are less complex, less expensive and easier to use. Graphic displays on the other hand, are best for projecting images and therefore more complicated, costly and difficult to install because of all the pins. Graphic displays require more programming complexity, which for the purpose of this project is not justified, to use because of the low requirements needed for the information that will be displayed. Moreover, the power consumption of graphical LCD screens is much higher than the power consumption of a typical character LCD. Another benefit of using a LCD character display is that it is lightweight, and inexpensive.

Eventually it was determined that based on the requirements of this project, the best option was to use the serial enabled LCD-09395. This LCD is manufactured by spark fun electronics. The LCD-09395 is a 16x2 character LCD that will be implemented into the charge controller. In this system, the on-board PIC microcontroller takes a TTL serial input and prints the characters it receives onto the LCD. The PCB measures 103x36mm while the actual LCD screen is 71.4x26.4mm. This display is monochrome (White on Black) and has a processing speed of 10 MHz The backlight brightness is adjustable giving the option to dim the backlight in situations where power consumption is a concern. This display also has a potentiometer on the back, which is advantageous to adjust the contrast of the display. The cost of the LCD-09395 is 25$.

The serial enabled 16x2 LCD screen (LCD-09395) shown in Figure 37 will communicate with the microcontroller which will be the MSP430 manufactured by Texas Instruments. The main advantage of a serial LCD is that it is easier to wire up, since the microcontroller communicates to the LCD over a single pair of wires.

Figure 37 Serial Enabled White on Black LCD (LCD-09395)

5V DC will power the LCD-09395 since a voltage higher than 5.5V will cause damage to the PIC, LCD, and backlight. This specific display uses 3mA of current with the backlight turned off and about 60mA when the backlight is activated. Therefore, the maximum power consumption of this character LCD is estimated to be 15 watts.

4.2.5 Software
Code composer Studio allows the user to write all code in C or in assembly. Because of our experience with C we choose it as the preferred language for the microcontroller. In order to properly communicate with the MSP430G2553 we looked at the header file

MSP430G2553.h in order to see register definitions and interrupt vector definitions, as well as example code found on TI's website.

Code Composer studio also facilitates debugging through its own debugging environment. This feature gives the user full control of the chip at any given time, even allowing access to current variable values. All of the MSP430G2553 control registers are also available for viewing at any one instance in the code. This includes: interrupt enable register, interrupt flags status, GIOP pin configuration for port1 and port2, also status and configuration registers for each of the modules (e.g. timers, ten bit analog to digital converter, USCI). For added control the user can choose to "dive into the instruction" in which case it will (for the case of a function call) dive into the function and perform the code within. The other case is "jump over", in which case it will perform all lines of code within the function, but only the register statuses at the end of the call will be available for viewing.

4.2.6 Base Station Interaction

In the flow chart in Figure 3, we describe how the GPS device is communicating with the base station, and the information that is being sent to it. When the person carrying the GPS device is out of the safety range, an alarm state will be activated. At that moment, coordinates involving latitude and longitude will be transmitted to the base station. As safety method, the battery percentage is also being sent to the base station, so the caretaker will know for how long the device will be on.
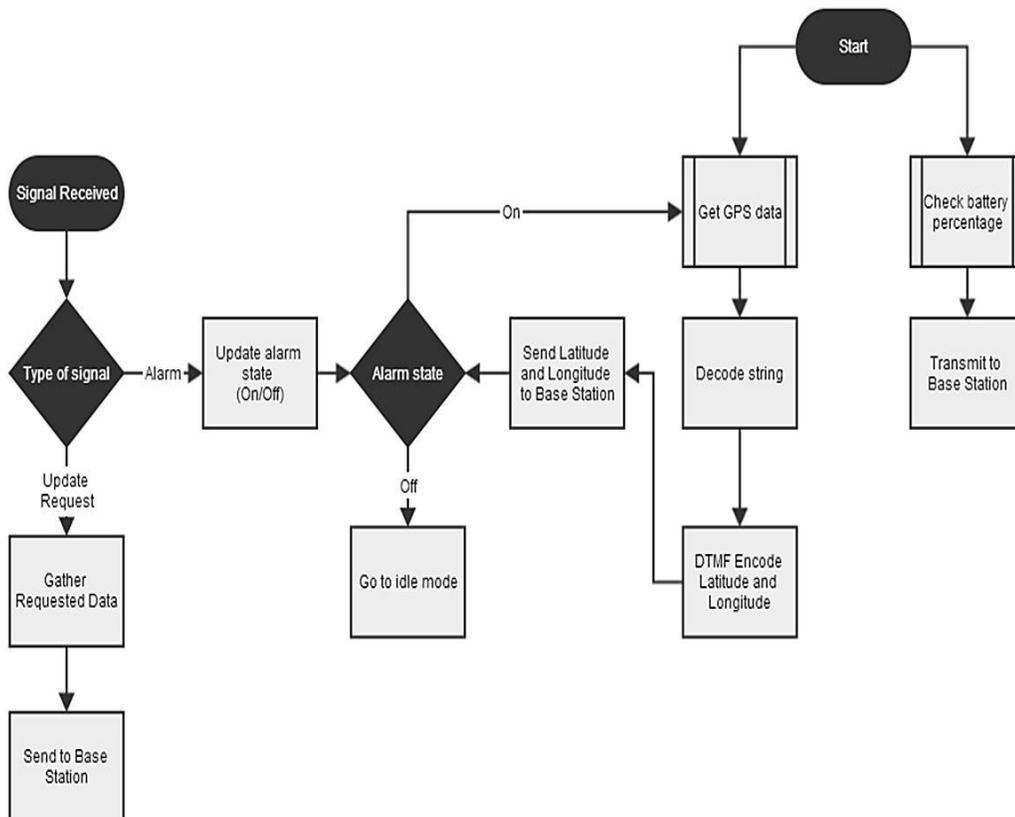
Figure 38: Flowchart of GPS Subsystem

4.2.7 Schematic Design

We used Eagle to create the final schematic diagram that includes the entire component used for the GPS tracking device, shown in Figure 39, and the PCB layout, shown in Figure 40.

Figure 39 GPS Tracking Device Schematic Design
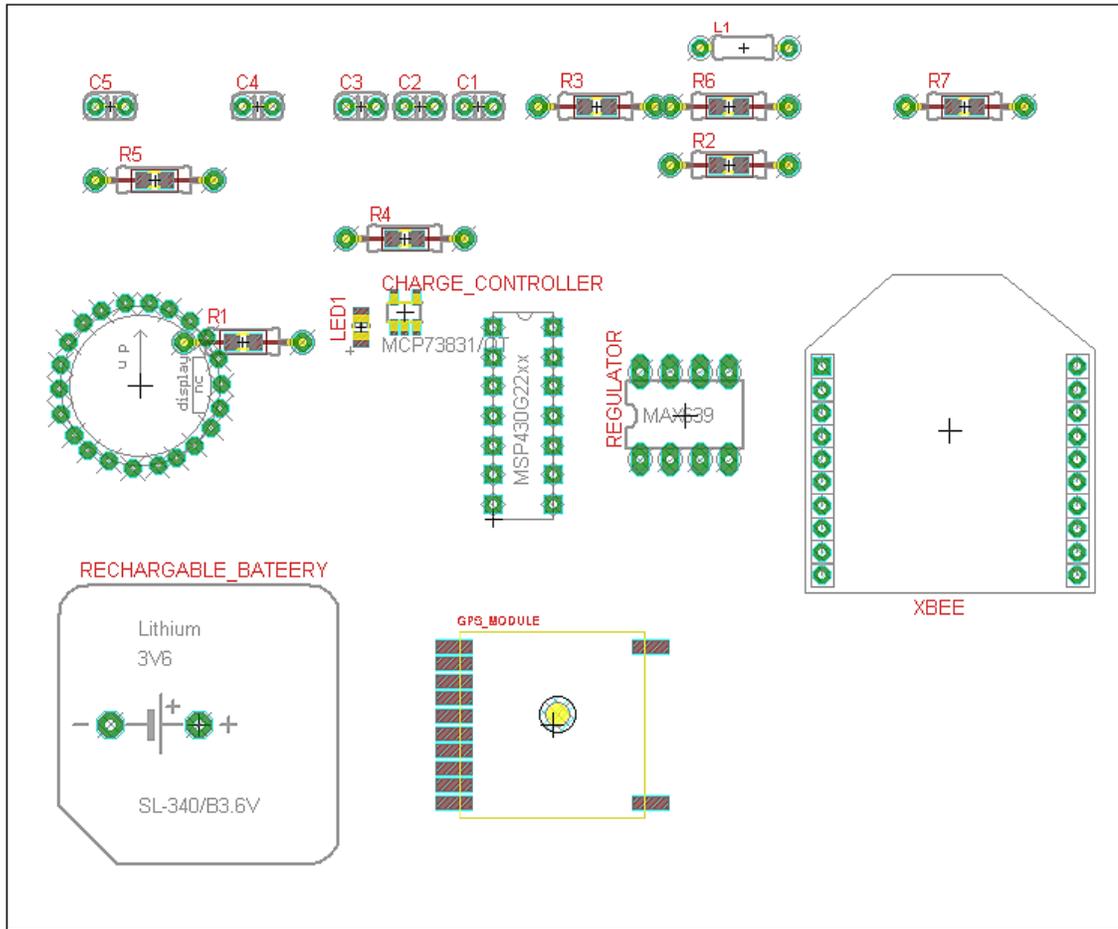
4.3 Indoor Tracking System

4.3.1 RFID Software and Hardware Design

As mentioned earlier, the RFID reader is the key component that lets the MCU at the base station know when the GPS tracking device has left the perimeter. It will use the RF wave to communicate with the tag attached to the GPS device, collect information and send it to the microcontroller for further manipulation. Because of the restriction in frequency usage, we want to use a reader that can provide the read range needed by using the allowance frequency for the passive tag which is 125-134.2 kHz. We have done a lot of research in order to make a good choice. The advantage is we already know the frequency range we need to make the research about; however, there are a lot of parameters that we need to take in consideration such as which part that can work with another part before we can make a final decision. We compare many 134.2 KHz readers. For instance, we compare RI-STU-MRDI, RI-RFM-007B, and RI-STU-251B. All these three readers are manufactured by Texas Instrument. Let us underline some important specifications in each of these three readers. First, let us consider RI-STU-MRDI; this reader has a frequency range of 134.2 KHz as required by the low frequency regulation

which our Smart GPS will use. This reader uses a power supply of 5 VDC, a current of 100 mA, and a read range of less than 1 foot. It requires a transponder with the same frequency range which is 134.2 KHz. Second, let us consider RI-RFM-007B; this reader is capable of driving a variety of antennas with inductance ranges from 26.0 μH to 27.9 μH. It functions also on a frequency range of 134.2 KHz and operates on a range of voltage between 7 to 24 VDC. Also, RI-RFM-007B has a reading range of up to 200 centimeters or six feet and half. Third, let us consider RI-STU-251B. Like RI-RFM-007B, it also has a frequency range of 123.2 KHz, a reading range of 200 centimeters, and an inductance ranges from 26.0 μH to 27.9 μH. It has an operating voltage from 10 to 24 VDC. See the following table, Table 7, for a summarization of these comparisons.

READERS' NUMBER:	RI-STU-251B	RI-STU-MRDI	RI-RFM-007B
OPERATING FREQUENCY	134.2 KHZ	134.2 KHZ	134.2 KHZ
OPERATING VOLTAGE	10-24VDC	5VDC	7 to 24 VDC
READ RANGE	200cm	30cm	200cm
NUMBER OF PINS	10 pins	30 pins	40 pins
ANTENNA INDUCTANCE RANGE	26.0 μH to 27.9 μH	47 μH	26.0 μH to 27.9 μH

Table 15: Comparison of RFID Readers

For a better understanding of what the readers look like, we included snapshots seen in titled Figures 22, 23, and 24 for RF-STU-251B, RI-STU-MRDI, and RI-RFM-007B respectively.

4.3.2 Antenna

Up to this point we have not decided what reader to use yet. Before making a choice, we decided to search for the antenna. The choice of a good antenna is also important for any RFID project, especially when it is a question of using the passive tag, because the reader will wake up the tag via the antenna. It also takes time to search for a right size of antenna for our project. Now, another consideration is to choose either a stick or gate antenna. We make some researches to know what difference between the stick and the gate antennas. According to TI, a stick and gate antennas manufacturer, the gate antennas creates a large zone including greater read distance; whereas, stick antennas provide a more focused read zone and have the ability to discriminate between tags. In order to find the appropriate antenna, we compare four antennas, one stick and three gates, manufactured by Texas Instrument. The RI-ANT-S01C is a stick antenna and uses a frequency of 134.2 KHz. It has an inductance of 27 μH. After the RI-ANT-S01C, we analyze the RI-ANT-P02A which also a134.2 KHz gate antenna. This one has an inductance of 116 μH. in addition to these two antennas we analyze RI-ANT-G01E which is also a 134.2 KHz gate antenna. Like the RI-ANT-S01C, this one has an

inductance of 27 µH. A last one we analyze is the RI-ANT-G02E which is also a 134.2 KHz gate antenna. For a quick view of resemblance and difference between these antennas; I will place them on a table. Refer to the following table, Table 8, for more details regarding these antennas.

ANTENNAS' NUMBER	RI-ANT-S01C	RI-ANT-P02A	RI-ANT-G01E	RI-ANT-G02E
OPERATING FREQUENCY	134.2 KHz	134.2 KHz	134.2 KHz	134.2 KHz
INDUCTANCE RANGE	27 µH	116 µH	27 µH	27 µH
TYPE OF ANTENNAS	STICK	GATE	GATE	GATE
PROTECTION CLASS	IP66	IP65	IP65	IP65

Table 16: Comparison of Antennas

With the permission of Texas Instrument, the images of the antennas mentioned above are shown below.

Figure 41 gives a first view about how the antenna, the reader and the transponder will work together.
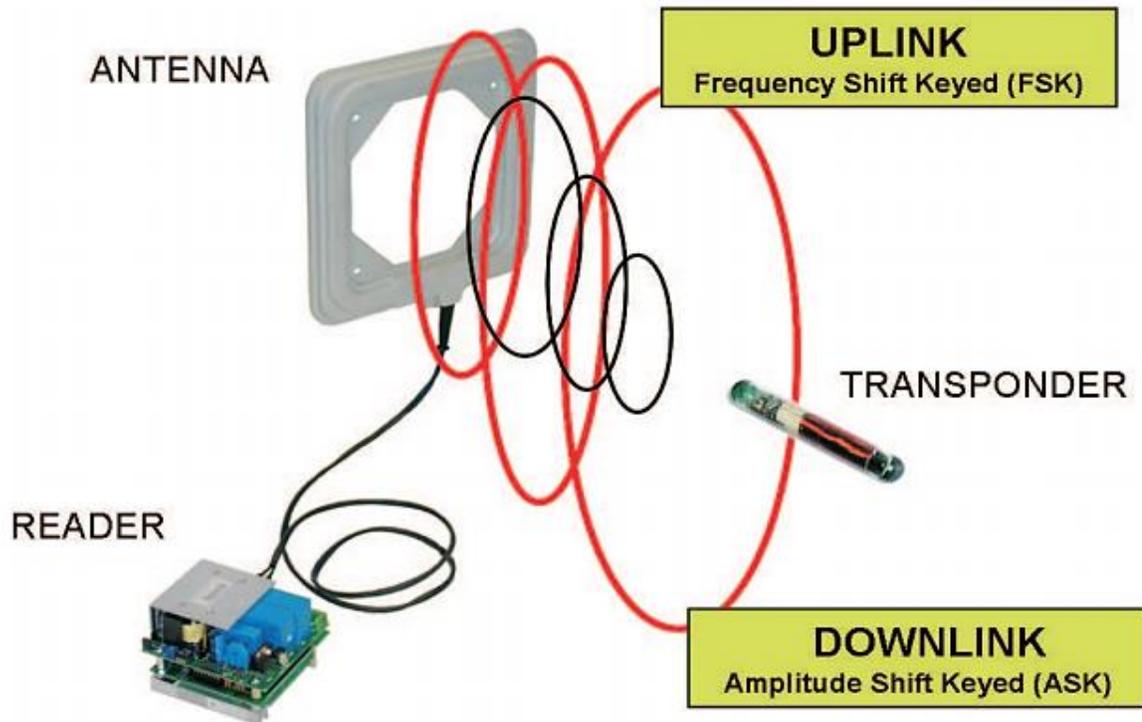
Figure 41: Interaction between RFID parts
Courtesy of TI

4.3.3 RFID Part Selection

After all the research and comparisons, we have to make a choice. The choice that we have to make must respond to our Smart GPS needs. This project requires the use of a passive tag in turn which requires the use of low frequency. The good news is all of these parts, such as the reader and the antennas, operate with low frequency. However, not all of them have the same performance. Based on our project needs, the RI-STU-MRDI reader cannot be used because its read range is too short. We have now to choose between RI-STU-251B and RI-RFM-007B. When we compare these two readers, they have a lot of resemblance but they operate on different voltage levels and have different number of pins. The RI-RFM-007B has a wider range of voltage than the RI-STU-251B. Also, it has much more pins than RI-STU-251B but when take into consideration of the entire RFID project requirement we will use the RI-RFM-007B. As for the antenna, we can use either RI-ANT-G01E or RI-ANT-G02E orRI-ANT-P02A because they provide them all about the same performance.

4.3.4 Microcontroller Selection

As stated before, a microcontroller will be used to manipulate the information that the reader will collect from the tag. It will also play the role of a bridge between the reader and the base station. Microcontrollers are designed for embedded applications in contrast to the microprocessors used in personal computers or other general purpose applications. Microcontrollers are used in automatically controlled products and devices. Another advantage of microcontrollers is they can be considered as a self-contained system with a processor, memory, and peripherals and can be used as an embedded system. Microcontrollers must provide real time response to events in the embedded system they are controlling. Since we choose all the other parts from TI, we see it is easier for us to use a Ti microcontroller also. The TI microcontroller, especially MSP430, has a 16-bit RISC (**R**educed **I**nstruction **S**et **C**omputing) architecture that is highly transparent to the application. The CPU is integrated with 16 registers that provide reduced instruction execution time. The family is MSP430 but not all have the same function or performance. We compared three of them in order to choose the one that fits better the RFID part: MSP430F437, MSP430G2153, and CC430F5123. The MSP430F437 is a 16-bit and at least 80 pins microcontroller; it uses a supply voltage between 1.8 volts and 3.6 volts. Also, it consumes a current of 280 µA. The instruction cycle is 125 nanoseconds. It can be interfaced with the other components via UART (Universal Asynchronous Receiver/Transmitter) or USART (Universal Synchronous/Asynchronous Receiver/Transmitter) whereas the MSP430G2153 is a 16-bit microcontroller that has only 20 pins. It uses the same supply voltage ranged between 1.8 volts to 3.6 volts as the MSp430F437. It consumes a current of 230 µA which is less than that consumed by the other one. Also, it takes less instruction time (62.5 nanoseconds. It also can be interfaced with the other components using UART. Another type of microcontroller that can be used is the CC430F5123. According to TI, the manufacturer of these microcontrollers, the CC430 family of ultra-low power microcontroller system-on-chip (SOC) with integrated RF transceiver cores provides a tight integration between the microcontroller core, its peripherals, software, and the RF transceiver, making true system-on-chip solution easy to use as well as improving performance. The CC430 is a combination of microcontroller and receiver. Using a CC430, we will not need to use a reader. The CC430F5123 is a 16-

bit RF microcontroller which CPU speed is 20MHz and operates on a voltage between 1.8 Volts and 3.6 volts; it has two Universal Serial Communication Interfaces (USCI) which are USCI_A0 supports UART and USCI_B0 supports I^2C^{TM}; also, the CC430F5123 has a wake up from standby mode less than 6 µs based on The RFID system requirements, the one we are going to use is CC430F5123 because it is more appropriate to the type of project we are doing. This microcontroller will be able to comply with the requirement of our project and it requires less instruction time. It is a 16 bit low frequency device and it has 80 pins. This microcontroller has a bootstrap loader which enables users to program the flash memory or RAM using UART serial interface. See the following table, Table 17, for a brief summary of these microcontrollers.

USCI: *Universal Serial Communication Interface*.

PARAMETERS	MSP430F437	MSP430G2153	CC430F5123
SUPPLY VOLTAGE	1.8v-3.6v	1.8v-3.6v	1.8v-3.6v
CURRENT USE	280 µA	230 µA	160 µA
NUMBER OF BITS	16	16	16
INSTRUCTION CYCLE TIME	125nS	62.5ns	
USCI	USART, UART	UART	UART, I^2C^{TM}
Number of pins	100	20	48
PRICES	4.30 1ku ***	0.701 ku***	2.5 1ku ***

Table 17: Comparison of MCUs

*** NOTES 1ku price for 1000 units

4.3.5 Interface

One of the important steps is how to connect the components together after being selected. There are many ways of interfacing components today; each type has its advantage and its disadvantage. As mentioned earlier, some components will be interfaced wirelessly while some other components will use other means to be connected together. We research many types of connections and compare them in order to find which one which is more appropriate or can best fit our project. There is no doubt the reader and the transponder will communicate wirelessly. We have done a lot of research about the types of connection we must use to connect the parts that will not communicate wirelessly. We did some research about the RS-232, RS-422, RS-485, the firewire, and the Universal Serial Bus (USB).

According to the National Instrument, "the RS-232 is the most common serial interface and ships as a standard component on most windows compatible desktop computers". RS-232 allows for only one transmitter and one receiver on each line. It uses a full-Duplex transmission method. The RS-232 has a baud rate of up to 115.2 kbps. As for compatibility, using the RS-232 should not be a problem because modern computers still use this type of connection for printers, monitors, and even some modems.

The RS-422 is the serial connection used in Apple computers. It is a technical standard that specifies electrical characteristics of a digital signaling circuit. The standard only defines signal level. Several keys advantages offered by RS-422 include the differential receiver, a differential driver and data rate as high as 10 mega bauds at 40 feet. The specification itself doesn't set an upper limit on data rate, but rather shows how signal rate degrades with cable length. RS-422 specifies only the electrical signaling characteristics of a single balanced signal. RS-422 uses a nominal voltage0 to 5 volts signal. It transmits data with a rate up to 10 Mbps. It sends each signal using two wires in order to increase the maximum baud rate and cable length. That type of serial connection is used where only one transmitter is connected and transmits on a bus of up to ten receivers.

The RS-485 is a superset of RS-422. It is a standard defining the electrical characteristics of drivers and receivers for use in balanced digital multipoint system. RS-485 standard can be used effectively over long distance and in electrically noisy environments. Multiple receivers may be connected to such a network in a linear, multi-drop configuration. It was made to address the multi-drop limitation of RS-422. It allows up to 32 devices to communicate through the same data line. In one word, the RS-422 is a subset of the RS-485; as a result, all RS-422 devices may be controlled by RS-485. See the following table, Table 18, for the comparisons of these three types of serials.

Specification	RS-232	RS-422	RS-485
Mode of operation	Single- ended	Differential	Differential
# of drivers and receivers on 1 line	1 Driver 1 Receiver	1 Driver 10 Receivers	32 Drivers 32 Receivers
Maximum cable length	50 feet	4000 feet	4000 feet
Maximum data rate	20 Kbps	10 Mbps	10 Mbps
Prices	$23.99	$35	$58

Table 18: Comparison of Serial Cable

4.3.5.1 Universal Serial Bus - USB 1.0, USB 1.1, USB 2.0, and USB 3.0

USB is a high-performance serial bus communication technology. Most new computers and associated peripheral devices contain built-in support for this technology. Multiple versions of USB have been developed by the computer industries. The use of the Universal Serial Bus (USB) is the most popular connection today. Today, almost devices such as computers, laptop, and cell phone have at least one connection port where an USB can be connected. Like the RS serial, there are many types of USB. There are many types of; however, I am going to compare only USB 1.0, USB 1.1, USB 2.0, and USB 3.0

USB 1.0 was the original USB connection. It can operate at 1.5 Mbps. The invention of the newer USB causes the USB 1.0 become obsolete for most of today's devices which use USB. The USB 1.1 is sometimes called the full speed USB. It has a maximum transfer rate of 12 Mbps which is better than 1.5 Mbps that a 1.0 can transfer. However, we can have a better rate by using a higher type which is USB 2.0. This type of USB, USB 2.0, has a raw data rate of 480 Mbps; that means, it is 40 times faster than USB 1.1. Another type of USB we want to compare also is the USB 3.0. The USB 3.0 is the second major version of the Universal serial Bus (USB) standard for computer connectivity. It adds a new transfer mode called "SuperSpeed". It is capable of transferring data at a rate of 4.8 Gbps which is more than ten times faster than the 480 Mbps of the USB 2.0. The USB 3.0 specification is similar to the USB 2.0 but with many improvements and an alternative implementation. The specification defines a physically separate channel to carry USB 3.0 traffic. The changes in this specification make improvement in the transfer speed, increase the bandwidth (instead of one-way communication, USB 3.0 uses two unidirectional data paths: one to receive data and the other to transmit data), Improvements are also made in power management and bus utilization. One of the great advantages of the USB is the ability to plug in and unplug whenever you want even if the device is on. Whereas, RS-232 interface requires you to restart the device or the computer before it can read the peripherals. The following table, Table 19, is summary of the above description include the price of each type of USB.

USB TYPE	SPEED	PRICE
USB 1.0	1.5 Mbps	$29.58
USB 1.1	12 Mbps	$29.58
USB 2.0	480 Mbps	$5
USB 3.0	4.8 Gbps	$2.57

Table 19: Comparison of USB Types

4.3.5.2 Firewire (IEEE 1394)

Firewire is a serial bus interface standard for high-speed communication and isochronous real-time data transfer. It is comparable to USB; often, these two technologies are considered together. Apple first included firewire in some of its 1999 models and most apple computers since the year 2000 have included firewire ports. Firewire allows peer-

to-peer device communication. Such communication between scanner and a printer, for example, can take place without using system memory or the CPU. Firewire supports multiple hosts per bus. It is designed to support plug. The copper cable it uses in its most common implementation can be up to 15 feet long; it can supply up to 45 watts of power per port at up to 30 volts. This type of connection is not popular like the RS or the USB ones even if It is a serial bus interface standard for high-speed communication and there are some applications where it is used in conjunction with USB. Firewires come in many modes such as S100, S2000, S400, S1600, S3200, and S8001. In our case, we don't need write a report about each mode. For simplicity, we distinguish between three modes in order to make a selection. We compare the S100, S200, and S400. As the number indicates, the S100 can transfer data at a rate of 100 Mbps; the S200 and S400 can transfer bate at a rate of 200 and 400 Mbps respectively. In term of speed, firewire is faster than even the USB 2.0. However, the main drawback with the firewire is the space and compatibility. As we said before, USB is found everywhere. In the following table, Table 20, we compare the price and the speed of three of them.

FIREWIRE	SPEED	PRICE
S100	100 Mbps	$7.56
S200	200 Mbps	$5.99
S400	400 Mbps	$5.99

Table 20: Firewires Comparison

Now, it is time to make a choice. At first sight, it looks there is no difference between USB, RS, and firewire cables. However, when a close study is made on each type, there is a big difference between them. When deciding on the type of interface to use in the RFID system, we must take into consideration ease of use, compatibility, and price. By comparing the RS (RS-232, RS-422, and RS-485), RS-232 best fit the RFID part. When we compare the USB (USB 1.0, USB 1.1, and USB 2.0) the USB 2.0 interface offers the most compatibility, availability, and price. Now, let's compare firewire and USB. Both firewire and USB technologies provide similar end results; however, there are fundamental differences between these two technologies. USB requires the presence of bus master, typically a pc, which connects point-to-point with the USB slave. This allows for simpler peripherals at the cost of lowered functionality of the bus. Intelligent hubs are required to connect multiple USB devices to a single USB bus master. In contrast, firewire is essentially a peer-to-peer network allowing multiple devices to be connected on one bus. The firewire host interface supports DMA and memory-mapped devices, allowing data transfer to happen without loading the host CPU with interrupts and buffer-copy operations. Additionally, firewire features two data buses for each segment of the bus network; whereas, until USB 3.0, USB features only one. In another word, firewire can have communication in both directions at the same time whereas USB communication can occur in one direction at any one time. However, the firewire interface is not as available as the other two interfaces; as a result, it is not necessary to choose it as a means of connection. Up to this point, even if it requires the users to

constantly plug and unplug the hardware, RS-232 best fits the RFID system. The main advantage that RS-232 offers over the other types of connections is that it requires less software because it is not as complex as the USB. RS-232 has the ability to directly connect analog inputs whereas USB will need more backing software and a decoder. Base on all these advantages that RS-232 has over the other types of interface, RS-232 will fit our needs well.

4.3.5.3 Part Selection – Wireless Communication

The reader and the transponder will communicate wirelessly via the antenna's coils. The microcontroller and the base station will communicate wirelessly via an XBee transponder and UART. UART is commonly used in conjunction with RS-232, RS-422, and RS-485. In our case, it is going to be used in conjunction with RS-232. An UART is usually an individual or part of an integrated circuit used for serial communication over a computer or peripheral device serial port. UART is now commonly included in microcontrollers. A dual UART or DUART combines two UARTs into a single chip. UART takes bytes of data and transmits the individual bit in a sequential fashion; at the destination, a second UART reassembles the bits into complete bytes. Each UART contains a shift register, which is the fundamental method of conversion between serial and parallel forms. Serial transmission of bits through a single wire or other mediums is less costly than parallel transmission through multiple wires. The UART usually doesn't directly generate or receive the external signals used between different items of equipment. Separate interface devices are used to convert the logic level signal of the UART to and from the external signaling levels. All operations of UART hardware are controlled by a clock signal which runs at a multiple of a data rate, typically eight times the bit rate. The receiver tests the state of the incoming signal on each clock pulse, looking for the beginning of the start bit.

Since the microcontroller will communicate with the base station via XBee, we need to select the right type of XBee that will match the frequency used by the transponder on the base station. Table 21 compares 3 different types of XBee devices that we are considering:

PRODUCTS	XBEE-PRO 868	XBEE ZB	XBEE PRO ZB
RF DATA RATE	24 Kbps	250 Kbps	250Kbps
INDOOR RANGE	1800 ft	133 ft	300ft
TRANSMIT POWER	1mW to 315mW	1.25 to 2mW	63mW
SERIAL DATA INTERFACE	3.3 V	3.3V	3.3V
FREQUENCY BAND	868 MHz	2.4GHz	2.4GHz
SERIAL DATA RATE	1.2 to 230.4 Kbps	1200bps to 1Mbps	1200bps to 1Mbps
VOLTAGE	3.0 to 3.6 VDC	2.1 to 3.6VDC	2.7 -3.6VDC
TRANSMIT CURRENT	500mA	35mA	205mA
RECEIVE CURRENT	65mA	38 to 40mA	47 to 62mA
PRICE	$45	$22.95	$37.95

Table 21: XBee Devices Comparison

A small difference between these three choices can make a big difference in performance. Taking into consideration the data rate of the serial interface RS-232, which is going to interface the microcontroller and the XBee, we believe that the XBee ZB will best fit our RFID system.

4.3.6 Base Station Interaction

The logic of events for the RFID component is to use the reader to monitor a specific area which depends on the range of the reader and alert the base station whenever a passive tag passes through that range. Since the reader is able to pull the tag number from the passive tag, this will be sent to the base station to identify which GPS-device has left the perimeter.
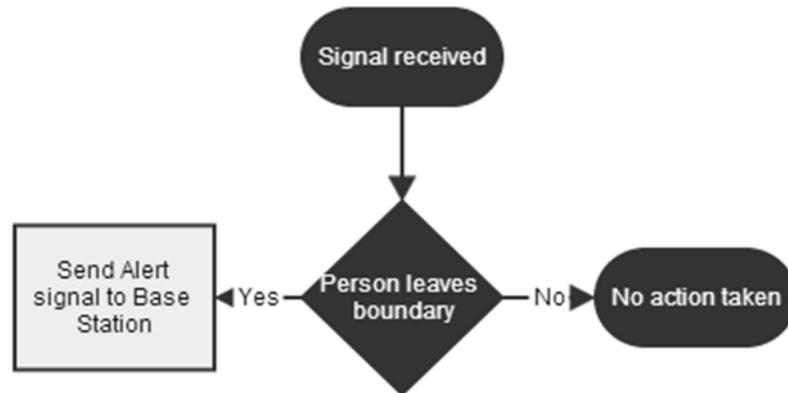
Figure 42: Flowchart of RFID Subsystem

4.3.7 Power

A vital part of the program is the power supply. All the parts I have selected require DC voltage. We understand that we are going to deal with Direct Current as opposed to Alternating Current. Now, we must consider the functionality of the parts we are going to interface. The RFID system will compose of the transponder, the reader, the microcontroller, and the XBEE. All of these parts that will need power will use DC power as we said above. Since we know that we are going to be working mostly with DC throughout the RFID system, we must consider different ways of application. The simplest way would be using some type of battery to supply different components with DC power; however, that might not be the best way for devices that will be on all the time. Another way DC power can be supplied is by using an AC/DC adapter which will be connected to a typical 120 VAC receptacle. Up to now, it appears to be the best way to power the system. Also, a rectifying adaptor can be used as opposed to having AC/DC converting circuitry inside the device. Since we decide to use an AC/DC adapter, we must determine which type we must use. At this point, we must be very careful in choosing the type of adapter because not all the parts require the same voltage. However, the adapter will be chose base on the part that requires the maximum voltage. If we take a look back to all the components specifications or datasheets, we can conclude the reader will require more power. As a result, the adapter will be chosen base on the reader voltage. The following figure, Figure 43, for the schematic of the power supply.
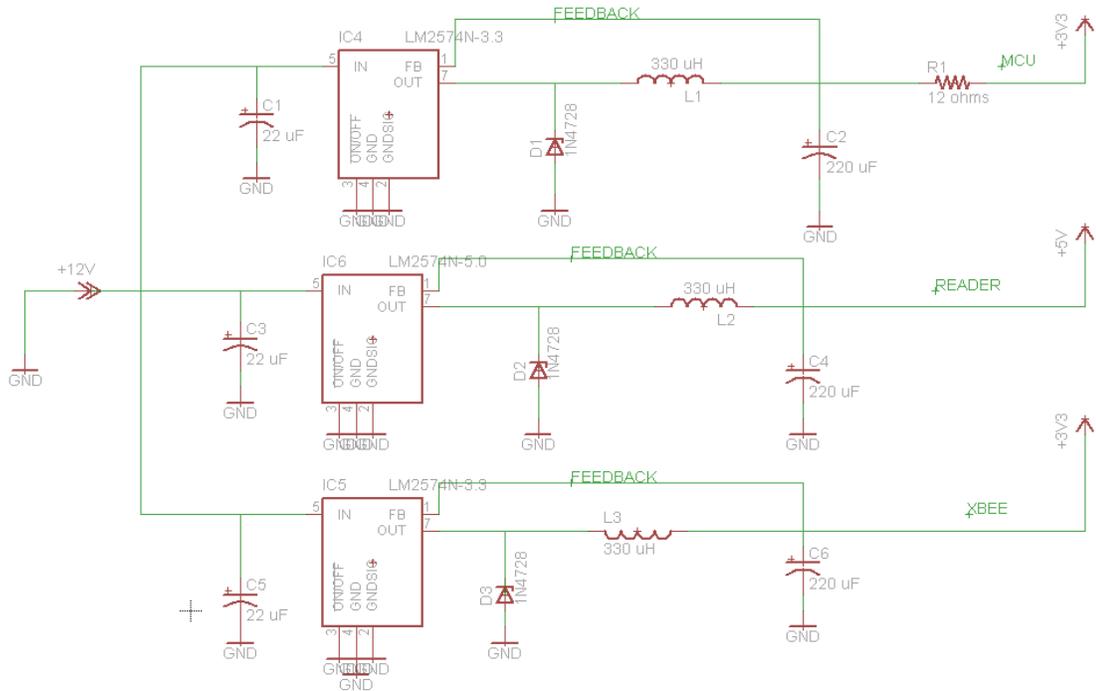
Figure 43: Power Supply Schematic

4.4 Base Station

Developed as a means through which information can be routed, the primary purpose of the base station is to use wireless technology to transmit data between the GPS device, RFID reader, and smartphone. With respect to the information exchanged between the base station and RFID reader only unidirectional communication is taking place. The base station simply waits for a flag sent from the RFID reader which will indicated that the GPS device has left the designated area. Once this signal is received the base station will then send a command to the GPS device signaling the continuous transmission of GPS coordinates. Once the device has been located moreover the Base Station will send another command terminating the transmission of information. Other information which can be transmitted to the base station upon request is the temperature and battery life.

Once the base station begins to receive GPS coordinates from the GPS device it can then begin communication with the smartphone by first alerting the smartphone application to the breach of perimeter indicated by the RFID reader. This will then allow the application's end user to request an information update allowing the end user to determine any further action should be taken which would include continuing to track or note track the GPS signal. Within the charts that follow both the flags and descriptions can be seen.

RFID to Base Station Communication Flags	
Flags	Representation
00FF08	Perimeter Breach

Table 22: RFID to Base Station Flags

Base Station to GPS Communication Flags	
Flags	Representation
00FF03	Data update Request
00FF04	Stop Tracking Request
00FF06	Temperature Request
00FF07	Battery Life

Table 23: Base Station to GPS Device Commands

Base Station to Phone Communication Flags	
Flags	Representation
00FF08	Emergency Alert
00FF09	Request for Info Confirmation

Table 24: Base Station to Phone Flags

Phone To Base Station Communication Flags	
Flags	Representation
00FF00	Data Update Request
00FF01	Track Device
00FF02	Don't Track Device

Table 25: Phone to Base Station Flags
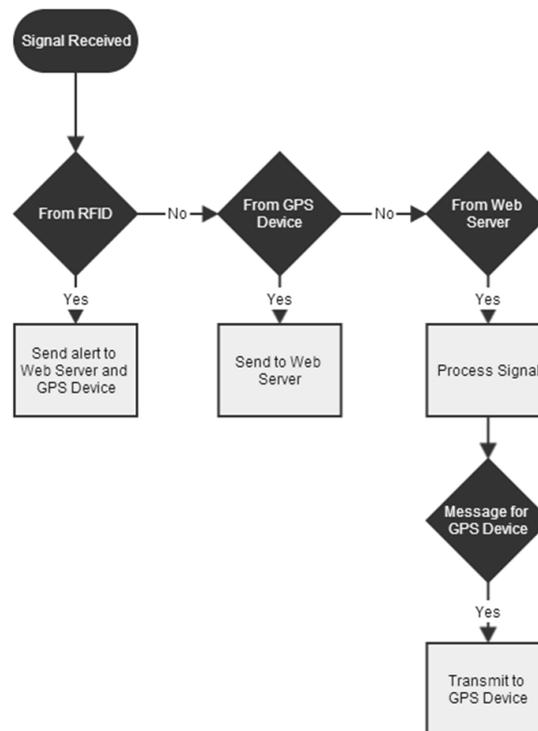
Figure 44: Flowchart of Base Station Logic

4.4.1 Microcontroller

The microcontroller which best supports the base station is the Stellaris LM3S8962 by Texas Instruments (see the specifications in Table 26). This controller was selected because it provides the MAC layer needed to support Ethernet connectivity. Furthermore the chip has more than enough memory, I/O pins and UART pins to allow for the transverse to connect seamlessly.

Features	Data
Processor	ARM Cortex
Max Frequency	50 Mhz
Flash Memory	256K
SRAM	64K
GPIO	42
UART Pins	2
10/100 Ethernet	yes
Operating Voltage	2.25V to 2.75V
Max Baud Rate	3.125 Mbps

Table 26: TI LM3S8962 Specs

4.4.2 UART

The UART infrastructure on the Stellaris performs parallel-to-serial and serial to paraller conversions. Information is transmitted and received via the TXE and RXE bits of the UART Control Register. The TX and RX pins reduce CPU interrupts by implementing FIFO for each 16x8 register. The baud rate can be programmed to reach speeds of up to 3.125 MBPS. In order to program the UART the peripheral clock must first be enabled by setting the UART0 or UART1 bits in the RCGC1 register. Once this is complete the following steps should be taken.

1) Clear the UARTEN bit in the UARTCTL register to disable the UART
2) Write the integer part of the BRD to the UARTIBRD register.
3) Write the fractional part of the BRD to the UARTFBRD register.
4) Write the serial parameters to the UARTLCRH register
5) Set the UARTEN bit in the UARTCTL register to enable the UART

4.4.2.1 Data Transmission

The data transmitted and received by the UART is stored in two 16 byte FIFO while the information that is received has an addition four bit per character for status information. If data is sent to the microcontroller the UART, when enabled, will generate a data frame which triggering the transmission of data which indicated by the busy bit in the UART flag register. Data read from the transmit FIFO has parallel to serial conversions performed on it as previously stated. The information is output by the control logic in 5 to 8 bit packets beginning with a start bit, followed by the LSB, the parity bit, and finally the stop bit. Information included in the serial to parallel conversion undergone by the data received only after a valid start pulse is detected. Other data transmitted alongside

that receiver data includes overrun, parity, frame error checking, and line-break detection information, see Figure.
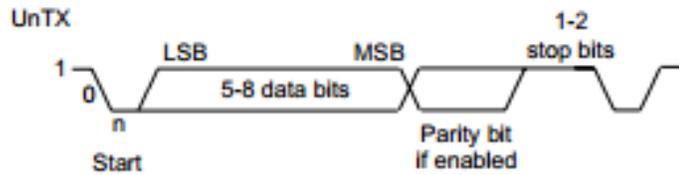
Figure 46: Data Transmission Diagram

4.4.2.2 Serial IR (SIR)

The IrDa serial-IR encoder/decoder block which converts asynchronous UART data into half-duplex serial SIR which takes a digitally encoded output and transforms it into data the UART can understand. The IrDA SIR physical layer also generates a 10ms e3lay between transmitted and received data which must be done by the software used to program the microcontroller as it is not a feature the UART can support.

4.4.2.3 FIFO Operation

The UART has two 16 bit FIFO registers which are addressed through the UART DATA register. 12 bits are generated during a read operation 8 of which are data leaving the 4 reaming as error flags. The write operation on the other had places 8 bits in the FIFO transmit register. Both TX and RX registers can be configured to create interrupts at different levels which include ⅛, ¼, ½, ¾, and ⅞. If, for instance, the ¼ level is selected the with respect to the receive FIFO the UART will interrupt the receive register after 4 data bytes are received.

4.4.3 Software

Texas Instrument provides the LM Flash Programmer as a free programming method through which both the Stellaris microcontroller and evaluation board can be programmed with. A whole host of software libraries are provide by Texas Instruments which include but are not limited to standalone driver libraries, USB libraries, and schematic part libraries.

4.4.4 Hardware Components

4.4.4.1 Pulse J3011G21DNL RJ-45

The Pulse J3011G21DNL RJ-45 Ethernet jack was selected because it eliminates the need to provide the 1:1 transformer needed by the chip. Furthermore this part should work seamlessly with the TLK as it is the jack used by the evaluation board developed by TI for the Stellaris microcontroller. The pin descriptions and circuit components needed by the jack can be seen in Figure below.
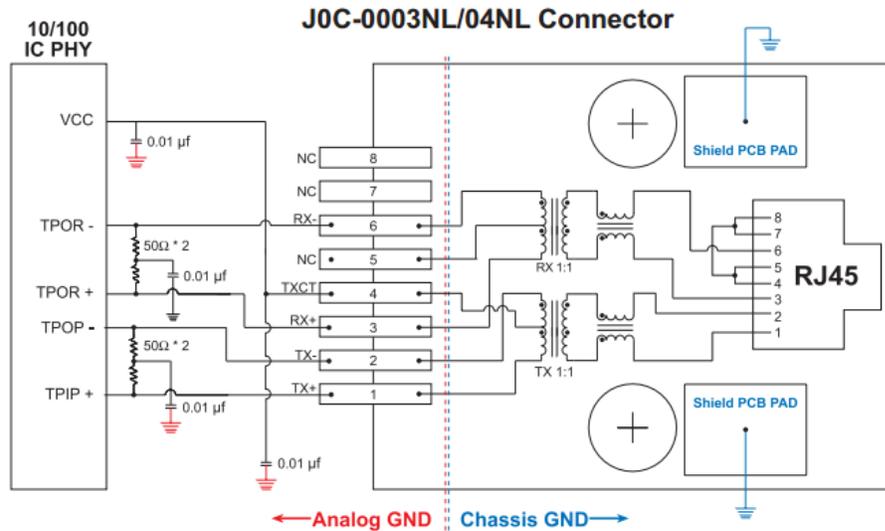
4.4.5 Wireless Communication

Because wireless communication is the best method through which to transmit data of long distances the wireless module selected as the back bone of the communication system is of particular important. The Xbee Pro 900 was selected as the manner thought which said communications would take place because it provides the best long range data transmission in addition to simplifying the process through which the transmitter/receiver is interfaced which the myriad of microcontrollers used with the project. Another important feature associated with the Xbee is the variety of antenna mounting optional available. Because the Xbee will not only need to connect to a fairly small GPS device, RFID reader, and base station the range of antenna requirement is immense. With this device a high gain antenna can be used for the antenna associated with the Xbee connected to the base station while a wire antenna can be used to support the GPS device.

4.4.5.1 XBee Pro 900 U.FL Connection

The criteria with which the Xbee Pro was selected include transmission range, baud rate, and power output can be seen in Table 27 below.

XBee Pro 900	
Features	Data
Transmission Range	6 miles
Voltage	3.3vV
Baud Rate	230Kbps
Power Output	50mW
RF Data Rate	156 Kbps
Max Current	210mA

Table 27: XBee Pro 900

Although the Xbee Pro 900 is advertised as having a transmission range of 6 miles, the information provided in the data sheet is a little more telling. Upon further inspection a 6

mile range can only be obtained with a high gain antenna. If the device is intended for indoor use the range drops considerable from around 6 miles to 450ft. Furthermore it is important to note the data sheet refers to all ranges assuming the transmitters are in line of sight of each other. This is of particular importance because the most important Xbee communication will take place as the GPS device is at most a mile away from a second Xbee which will be station within a build.

The Xbee Pro 900 interfaces with the host microcontroller through four pins which include the DIN, CTS, DOUT, and RTS pins. The DIN pin as the name implies is the means through which asynchronous serial signals are sent to the UART. If no data is being transmitted the signal is high. The format of the data byte consists of a start bit, 8 data bits least significant bit first, and a stop bit. The pattern with which data passes through the module can be seen below in Figure . In order to enable information to be transmitted between two UART moreover the baud rate, parity, start bits, stop bits, data bits of each system must be equal.
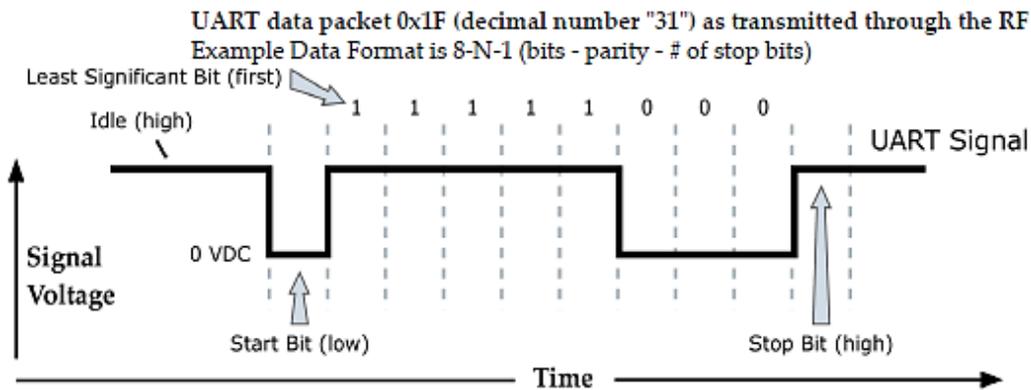
Figure 50: UART

4.4.5.1.1 Serial Buffers
The Xbee Pro 900 contains buffers to collect and retain serial and RF data until needed for processing. If large amounts of data are sent to the serial receive buffer the CTS flow control can be used to avoid the loss of data. With respect to the transmit buffer it is important to note that if said buffer is overwhelmed an entire RF data packet will be dropped.

- CTS Flow Control: used to stop sending data when receive buffer is full
- RTS Flow Control: used to stop data transmission to transmit buffer
- Serial Transmit Buffer: used to store data until it can be sent to the serial port
- Serial Receive Buffer: used to store data until it can be processed

4.4.5.1.2 API Operation
The Application Programming Interface is used to package data into frames which define the method through which they should be processed before leaving the module. This operation can be used to send data to many destinations without the need for command mode, receive data transmit statuses, and determine the address from which a packet came. The receive data frame contains a command response, sent notification, and the

data frame itself. The transmit data frames include the RF transmit data frame, and command frame. The API frame moreover can be seen below.
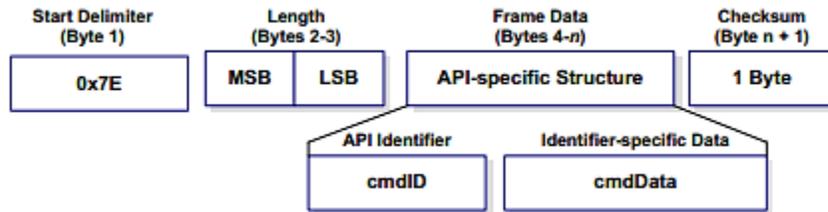
Figure 51: API Data Frame

4.4.5.1.3 Antenna

In order to obtain the 6 mile transmission range advertised by the data sheet a high gain A09-HASM-675 antenna was selected. This antenna was selected for a list of compatible Xbee antennas and uses a U.FL connector to allow for add flexibility with respect to housing and mounting the antenna to the base station. The antennas used on the RFID Xbee and GPS device are wire as they should note need a high gain antenna.

4.4.6 Schematic Design

The following two figures, Figure and Figure, show the schematic layout for the base station unit as well as the PCB layout.
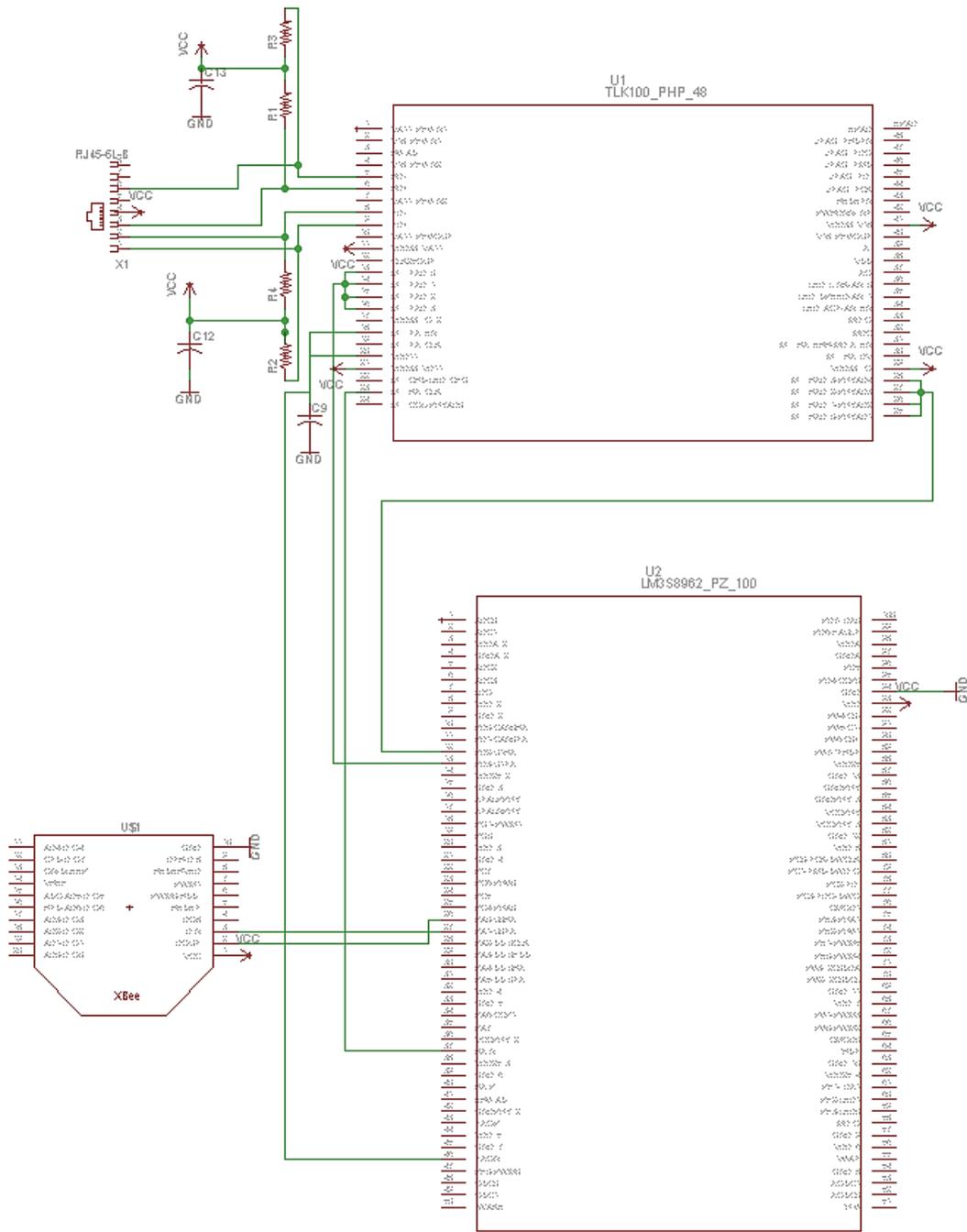
Figure 52: Base Station Schematic
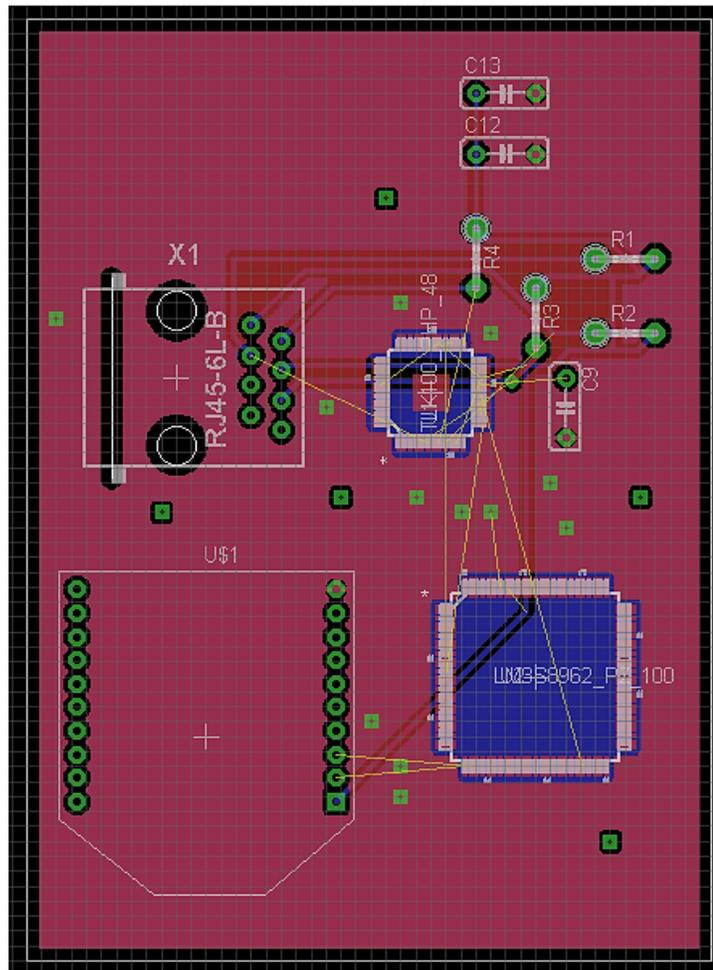
Figure53: Base Station PCB

4.5 Internet Communication Protocol

We decided to use TCP instead of UDP to oversee the communication over the internet. The reason for this is because even though it is slower than its counterpart, it makes up for it by its reliability and consistency. TCP guarantees that the data being transferred will arrive intact and in the same order that it was sent whereas UDP does not, even though it is faster. TCP is a heavyweight protocol to implement on a microcontroller; fortunately, there are two variations of TCP that are more suitable for embedded systems because they are lighter in size, these are uIP and lwIP. They both make it possible to communicate over the internet using the TCP/IP protocol family without the added complexity. They use a light-weight stack instead of the complex, full-size one. At first we looked into using uIP because it requires extremely little RAM and can work with only a few kilobytes of RAM, unfortunately, this also means low performance. Micro IP (uIP) is designed mainly for small data transfer and it only has one buffer to receive/deliver IP packets which can cause delays. The next stack we looked into was Lightweight IP (lwIP) which is more powerful than uIP and still small in size to be used for embedded systems. lwIP offers congestion control and allows for socket interface,

which are features that uIP does not offer, and it can also handle larger amounts of data transfer over the internet. We decided to use lwIP.

Figure below demonstrates how the connection is established and how the transfer of data will take place between the MCU at the base station and the user application. Whenever the MCU or the application has data to send, the sending TCP will establish a connection with the receiving TCP, it will do this by sending a request to start a connection. The receiver TCP will then send its response and an acknowledgement that it received the request. The sending TCP will then send an acknowledgement letting the receiving TCP know that it received its response; this will establish the connection for the transfer of data. The data will be split into segments and sent as IP frames through the internet, one after the other until all frames are sent. The receiver TCP will keep the IP frames on a buffer until all frames have been received, the connection will then be closed and the receiving TCP will extract the data packets from the IP frames and put back together the message to be processed.
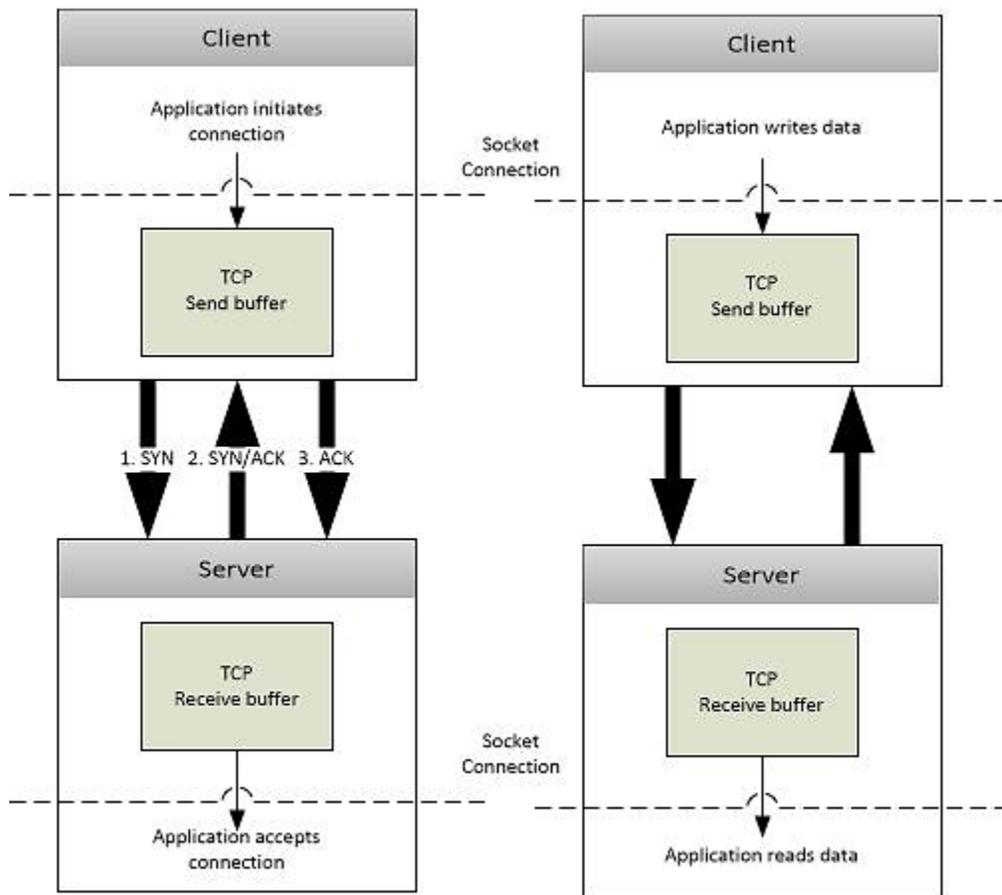
Figure 54: TCP Diagram

4.6 Client Side Application

The user is able to interface with the Smart GPS system through a web-based application built using Google App Engine. We did not implement the Android application as was planned due to time constraints. The application provides a user interface to interact with

the user. The goal of the user interface for the application is to allow the user to control and monitor the data pertaining to the GPS tracking device and the person wearing it. In order to guarantee that the user's information will not be corrupted by third parties or that its security will be compromised, we implemented a login system using Google's authentication system.

Google allows developers the use their Google APIs and authentication system. This allows the user to sign in using their Google account by being re-directed to Google's login page and then being sent back to our application. This saves us from having to save this sensitive data on our database.

4.6.1 Google App Engine

In the Google App Engine web application, the user will be able to view and manage the information acquired from the GPS tracking device. An interface will allow the user to view last known location of the GPS device, request current location, view battery life percentage, and view/modify the information of the GPS device carrier, such as name, date of birth, age, and emergency contact number.

4.6.1.1 Data Storage

Choosing the right data storage among the several options given to us from Google App Engine was based on the needs of the project. Some of the choices were very powerful data storage services, such as the SQL database service, that can implement and manage a wide array of queries. But based on the objective of the project and the size of the data that we will be storing, it was decided that a simpler datastore service would suffice. We decided to use the BigTable feature of the Google App Engine. It is a NoSQL schemaless object datastore that includes persistent storage with queries, sorting, and transactions. Our database system does not require join operations or complex schema objects to reach the objectives of the project.

Google App Engine featured two data repository options, the High Replication Datastore and the Master/Slave Datastore. When choosing the storage option for the project, we based our decision on reliability and data security. High Replication Datastore was chosen over the Master/Slave Datastore due to the low error rates and high reliability. Even though High Replication Datastore is said to have a higher latency than Master/Slave Datastore, the difference is not much, with High Replication Datastore taking up to 2x longer than Master/Slave when writing data. This difference becomes minimal when taking into consideration the strong consistency of data reading and security of the data, since it will be protected even in the rare case of a global failure. Low latency of data reading is important for this project because there are three different modules that will be handling the same data with two of those modules having direct access to the datastore, the base station and the user interface (from phone app and web app).

4.6.1.2 Database Layout

The advantage about this project is that we are not dealing with complex relationship between objects; this is a one-to-one relationship which simplifies the implementation. There are primarily two objects that need information saved in the database, the GPS

tracking device and the person associated to it. Based on this scenario, a device can only be associated with one use. We could create two objects in the database to represent the GPS device and the person wearing the device but this increases the complexity of the code and increases the chance of errors in stating the relationship. For the future, if the tracking device changes user, this can still be modified in the code and requires less maintenance.

Figure below depicts the table that will be used to store information on the GPS tracking device and its user as one object.

Figure 55: Database Table

The *device_serial* represents the unique identification number associated with the GPS-device. This will be the tag number. The *battery_life* variable will display the percentage of charge left on the device's battery and will be updated consistently. The variables *lat* and *lng* hold the GPS coordinates. The variable *time_last_reading* holds the date the information was last updated on. The next two, *fname* and *lname*, hold the first name and last name of the person wearing the device and *dob* holds the date of both of the person. The last four variables fold the information for the emergency person to be contacted when the alert goes off.

4.6.1.3 Front End: User Interface
The Google App Engine supports three different languages for web application development: Java, Python and Go. The group decided to use Python as the programming language on our project. Python is easier to learn and there are a lot of resources available to create a website. There are several frameworks available such as Django and web2py. We decided to use web2py which is an open source full-stack python web framework that follows the Model-View-Controller (MVC) model. It was developed to easily integrate with Google App Engine out of the box. One of the best feature web2py offers is its Database Abstraction Layer (DAL), an API that dynamically generates the objects and queries needed for a specified database backend from Python objects. This eliminates the

need of writing the database tables, queries, and records of learning different database dialects and makes the application portable among different types of databases.

Web2py automatically addresses and prevents security issues such as SQL injections and cross-site scripting vulnerabilities. It uses a Web Server Gateway Interface (WSGI) setup to handle requests. This means that when a page is requested, it is routed to the appropriate controller function to be processed. The response file is then formulated and then sent back to the browser. Web2py templating engine allows for python holders to be placed in the HTML file to indicate where the generated content should be placed.

The interaction between the user and the Google App Engine web-based application can take place from any computer or smartphone that has access to the internet. The first page that will be seen on the website by the user will be the Google login page where the user will be asked to log in using their Google account as seen on the figure below.
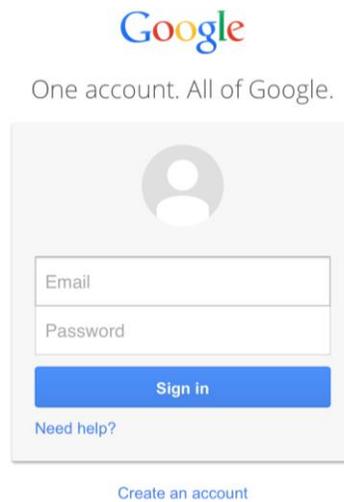
Figure 45: Google Login Screen

It is the same authentication process used throughout the Google infrastructure. After signing in, the user will be taken to the main page where the information regarding the GPS tracking device will reside. The options that will be available to user are the following:

- View/modify the data regarding the person wearing the device
- Locate person on the map using last known location
- View last known or request up-to-date information regarding the device
  - Battery life (percentage)
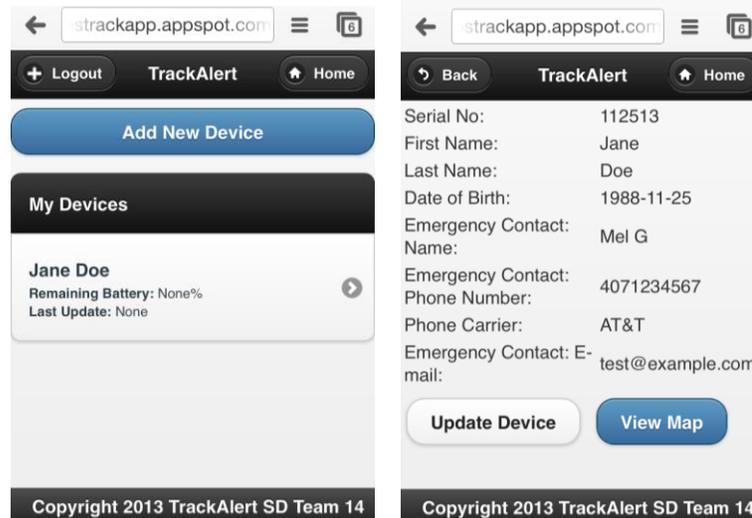 - Current location

Figure 46: Web-App User Interface

The first time they log in to the system, they will be prompted to fill out the information regarding the person wearing the GPS tracking device.

4.6.2 Android Application

The Android mobile application was not developed due to time constraints. Instead, the web application was designed in a way that, when accessed from a smartphone, it has the look and feel of a native application.

5   Design Summary of Hardware and Software

5.1 Outdoor Tracking System

The LS20031 was the GPS Module implemented on the GPS tracking device because it met the requirements for our project. Out all outputs we available, the RMC was the one used to get the data from the GPS module. One of the advantages of using this output was that the velocity was obtained and the speed of the user was calculated.

The GPS tracking device was safer because of the use of a charge controller. The BQ24193 was a good choice because it provided 92% charge efficiency, accelerate charge time by battery path impedance compensation, uses a single input USB-compliant/Adapter charger, and its input operating range is between 3.9V and 17V. Because the GPS tracking device user was located in less than one hour within a mile away from the base station, the 3.7V at 1500mAh 14500 Li-ions rechargeable battery pack with PCB was implemented.

In addition, the LTC3549 buck regulator was regulating power delivered to all loads. The output voltage of this regulator was adjusted via an external resistor divider, and had an input voltage range of 1.6V to 5.5V. It was compatible with battery we used. This switching offered 100% duty cycle, which provided low dropout operation, and extended battery life in portable systems. The Atmega328 is the microprocessor that took place on

the device because it offered programmable modulation for each source, multiple clock sources and low-power modes.

For the purpose of this project it was found that the best option that could be used for the display was a character LCD screen. One of the key advantages of a character display was its low power consumption when compared to other display technologies.

5.2 Indoor Tracking System

The indoor tracking system comprises an RFID reader, RFID tag attached to the GPS tracking device, a microcontroller, a power supply, and an XBee Tx/Rx to communicate with the base station. For the microcontroller, we are going to use the CC430F5123. The Universal Serial Communication Interface (USCI) module on the CC430 supports multiple serial communication modes. The CC430 has one module that has two independent communication channels supporting UART and I^2C^{TM}. The JTAG interface will be used for programming. Pins 35-39 will be used to program the CC430. Not only the JTAG interface provides a way to program the CC430, it is also allowed for debugging and emulation capabilities. The CC430 has an Embedded Emulation Module that allows for non-intrusive code execution with real-time breakpoint control, debugging line-by-line functionality, full support for all low power modes, and up to 10 complex triggers and breakpoints. This facilitates the ability to access the internal registers and memory. There is a need for an antenna to be used for a good transmission and reception. The RI-ANT-S01C, also built by TI, will be used in conjunction with the CC430. The antenna will be connected to pins 29 RF_P and 30 RF_N. The CC430 needs to be powered and grounded. Pins 7, 8, 22, 27, 28, 31, 32, 41, and 45 can be used for power. Pin 42 will be used for ground. Pins 5 and pin 6 will be used to interface the CC430 and the XBee because these two pins use the UART as Universal serial communication interface. See the figure below, Figure58a, for a better view of where and how these pins are placed.
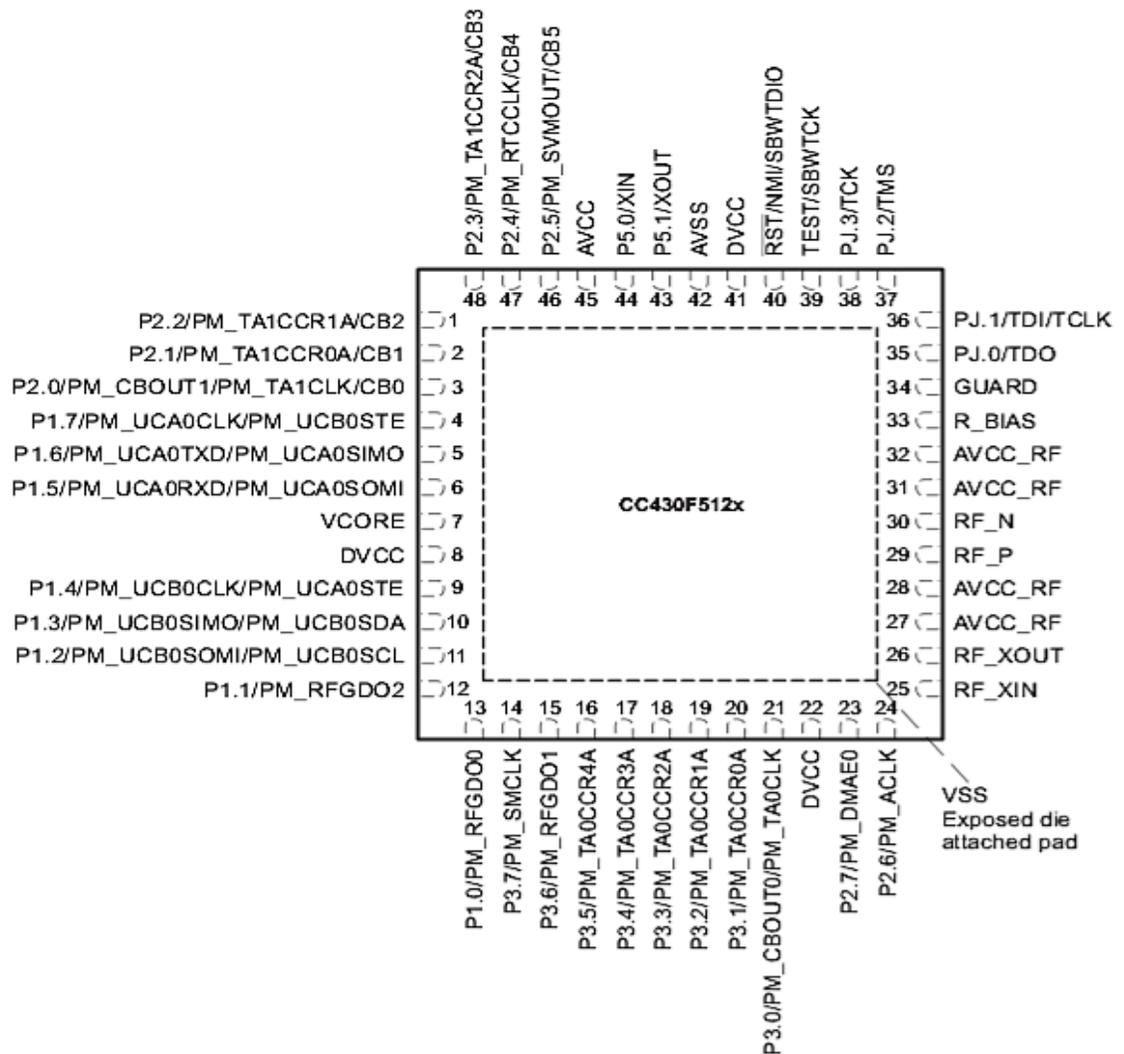
Figure 58a: CC430F512x
Courtesy of TI

Even if the microcontroller is the heart of the project, it is not the only important component. When the person wearing the tag is leaving the perimeter, the reader will automatically read the tag when it is within the range of the reader. After collecting information on the tag, the reader will forward it to the microcontroller. The microcontroller will analyze the information and send a message to the base station via the XBee. The following figure, Figure58b, demonstrates how these components will communicate to each other if we use the CC430F5123 which eliminates the use of a separate reader.
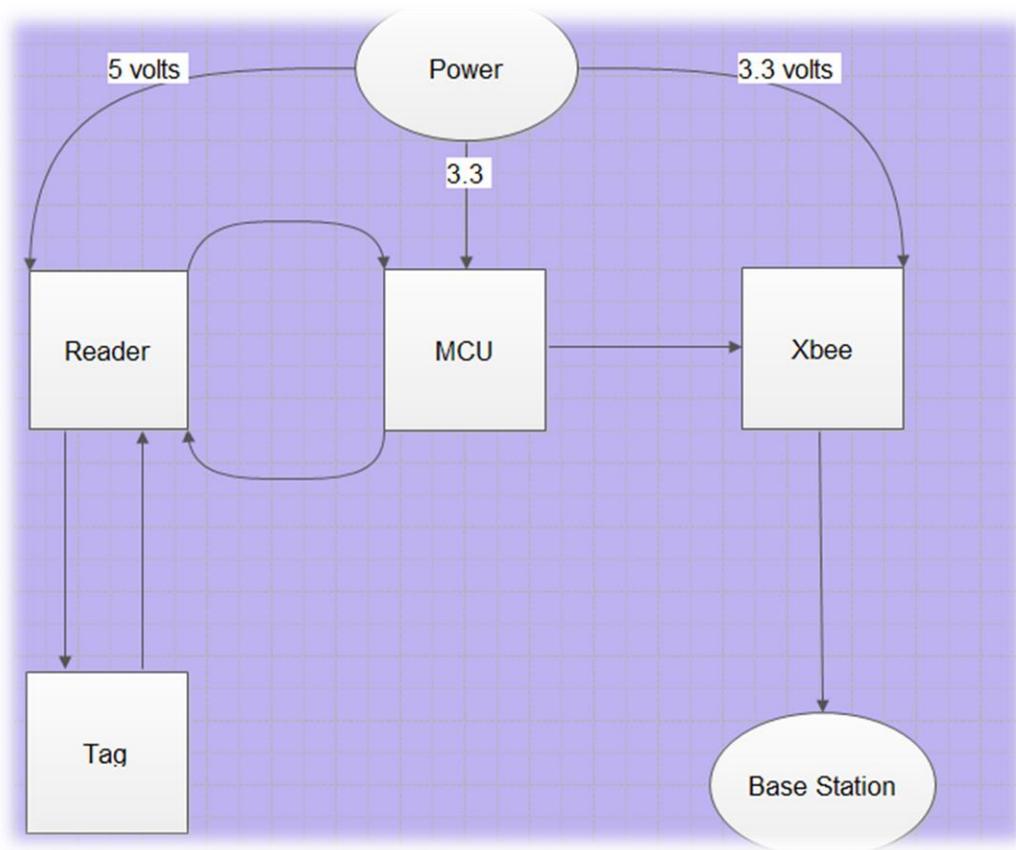
Figure 58b: RFID System

5.3 Base Station

The base station as a whole acts the routing system through which any and all information is direct. Once the GPS tracking device leaves the designated area the base station is notified by the RFID reader which allow the said station to instruct the GPS to being transmitting GPS coordinates. After this is successfully completed the base station alerts the smart phone application to the movement of the GPS device via an emergency notification. This in turn allows the smartphone application to determine if the device should continue to be tracked or not.

5.3.1 Stellaris LM3S8962 Microcontroller

The microcontroller through which information will be routed and translated is the Stellaris LM3S8962. This chip was selected because it provides both the MAC and UART components to enable communication with both the transceiver and Ethernet controller. The Stellaris is in direct communication with the GPS device, RFID Reader, and smartphone via RF transmissions and internet connectivity.

In order to obtain internet connectivity the TLK100 Ethernet controller will be used. This along with the magnetics specified in the data sheet should provide the circuitry needed to deliver the desired signals. The Pulse J3011G21DNL RJ-45 jack moreover will be

used to enable the Ethernet cable to interface with the TLK100 physical layer as it already has the required transformer rations embedded into the device.

5.3.2 XBee Pro 900

The XBee Pro 900 is the RF module selected to facilitate communication between the base station, RFID reader, and GPS device. It was selected for its ability to transmit information at distances of mile or more. It requires the use of a high gain antenna to ensure the specified distance is achieved and is easily connected to any microcontrollers with RX and TX pins.

5.4 Google App Engine

Google App Engine was used to create a Python web-based application using Google's Python SDK, Web2Py Framework and Jetbrains's PyCharm IDE. Google App Engine was also be used to create the central database to store data for the Smart GPS system.

5.4.1 Web Application – User Interaction

The web-based application allows the user to interact with the Smart GPS system. The first page the user comes into contact with is the Google login page. The user will need their Google account username and password in order to sign up and login. Once signed in, the user will have the ability to:

- View and modify the personal information regarding the person wearing the GPS tracking device, including their name, date of birth, age, emergency contact person and number.
- View the information regarding the GPS tracking device, including the battery life, and last known location.
- Request updated information on the GPS tracking device.
- View the last known location on a map.

The web application is available through any internet-enabled device. It was developed to have a native-app look and feel when viewing it through a handheld smartphone.

5.4.2 Database

The database was created using the High Replication Datastore (HRD) repository option of the BigTable Datastore, a NoSQL schemaless object datastore. The data stored was the information pertaining to the GPS tracking device and the information of the person wearing it. The person and the GPS tracking device were represented by one table in the database.

6 Project Prototype Testing

The system as a whole was tested once the individual modules had been tested and verified. To test the whole system, we selected different environments, with line-of-sight and without line-of-sight, to make sure that the GPS device could communicate with the base station under different circumstances. The whole system was tested by having the GPS-device create a geo-fence in order to know if it had left the perimeter. The tracking

device was moved to various locations to ensure that the device was not only receiving the GPS coordinates but was sending them to the base station. To make sure that the prototype passed the test, everything was monitored from the base station because this is the central hub of communications and has the means of communicating with every single module in the Smart GPS system. So, if something does not work, we will know at the base station due to the lack of notifications. As part of the system testing, we had the web-based application available on one of our phones and on a computer to gauge the response of both after requests from the MCU based on the activity of the GPS. We also tested the communication that is initiated from the user to make sure that the base station received it and passed the request to the GPS tracking device. In this case, the prototype passed the test if the base station returned the requested data back to the user and that it was also available on the database and web application

In this section we will also discuss the testing that was conducted at each module of the system.

6.1 Outdoor Tracking System Testing

Testing was an important part of any design or implementation. We needed to ensure a project works and also met its design requirements. There were many parts that needed to be tested individually to make sure they were working properly and there were not factory error issues. The signals transmitted from the GPS needed to be also be tested, and a high level of accuracy is expected.

A number of different approaches were used to test the digital circuits. All the digital components were tested using the oscilloscopes, which helped us debugging problems by checking power dissipation, inputs and outputs voltages, and currents going through all the parts and throughout the circuit.

Because the GPS chip data has to be submitted to a long period of testing time to verify outputs and inputs of the GPS chip, a logic analyzer proved advantageous was used. To specifically test the GPS chip, a test circuit on a protoboard with just the GPS chip and a dual driver/receiver that includes a voltage generator that supplies voltage of 5 Volts were used as well. This implementation was simple and involved the driver/receiver direct connected to the GPS's transmit and receive pins. The dual driver/receiver used for this testing was the MAX232 from Texas Instruments. This driver/receiver operates from a single 5-V power supply with 1.0 uF charge-Pump capacitors, operates up to 120 Kbit/s, and has two drivers and two receivers.

Having this type of setup was also useful to program the GPS chip from the computer using, SirfDemo, labView, and HyperTerminal. One of the advantages of using the LS20031 chip was that the SirfDemo comes with it, and it was easy for writing to and reading from the GPS chip.

As it stated before, a 5-V switching regulator for the GPS tracking device was used. This regulator has to be tested separately using a voltmeter and a DC power supply. The input regulator was consumed about 2.5 mA and was output a stable 5.013 V. The GPS droped approximately 10 mA with a voltage of 3.3 Volts. By setting the transmitter to high, the

current draw approximately to 2mA with a voltage of 3.3 Volts. To avoid problems later on, we decided to set all loads on the GPS tracking device to be a 3.3 Volts.

We transmitted the data via transmitter and receiver after analyzing the GPS output. This output data was analyzed using both the logic analyzer and a spectrum analyzer. The spectrum analyzer was used to view if the spectrum was changing at higher frequencies. In addition, the transmitter had to output power when transmitting high (or a one), and output zero power when transmitting low (or a zero). By setting the input into the transmitter as VCC or GND, the output power at the two stages was verified.

The GPS was tested using the Arduino. The Arduino was an easy-to-use hardware, and it was used in most cases for development of prototypes. The Arduino as other microcontrollers is composed of several digital and analog inputs and outputs and interfaces all connected to a microcontroller. One of the advantages of using the Arduino was that developed programs were easy loaded to the Arduino board making it easy to run the code.

The software used for the Arduino was easy to download and most importantly was free. The software package was found in the Arduino official website and contained a library to use the GPS-Shield, a variety of codes that explained how use the GSM and GPS module, and some design and schematics of Arduino board and GPS-Shield. This microcontroller board was based on the Atmega328 with 14 digital input/output pins, a16MHz ceramic resonator, 6 analog inputs, a USB connection, an ICSP header, a power jack, and a reset bottom. The board operated on an external supply of 6 to 20 Volts. However, it important to keep in mind that with less than 7 Volts, the 5 Volts pin may supply less that 5 Volts and the board was unstable.
The hardware installation was just connecting all parts to the right socket. Since the GPS patch antenna looked up in the sky, the GPS shield was placed as topmost shield. Also from directory Arduino development environment was required to load the drivers needed to the Arduino board.

Finally, we plotted each coordinate received from the GPS on Google Maps. Google Maps was a great user-friendly mapping technology that was provided key information of the location of the people been tracked. Also, Google Maps gave the option to change at any time in a search to switch from Satellite view and see aerial views. For the purpose of testing, a worksheet with sufficient data with latitude and longitude was saved on excel document to be plotted on Google Maps. The latitude and longitude was obtain directly from the GPS module and processed by the Arduino, but decimal degrees were the coordinates we used for testing because these coordinates were easily used in spreadsheets.

6.2 Indoor Tracking System Testing

The testing is one of the important phases in a project, especially in an engineering project. The testing will determine if the prototype design will function as intended. Thus, a careful test plan must be followed in order to assure the success of the prototype. We are going to use the information about each part on the datasheets in order to program the testing device using the same information. We will take advantage of using the materials

in the computer labs at the ENG I building to test the project. The parts require a certain voltage to function properly. For example, the microcontroller requires a voltage between 1.8 volts and 3.6 volts; the XBee requires a voltage about the same range (2.1 Volts – 3.6 volts). However, the reader requires a voltage between 7 VDC and 24 VDC. We will design some circuits at the lab to see how these devices will be connected in order to work as intended. The test we perform will include voltage readings and current readings. We will use different voltages and monitor the outputs. Mostly, we are going to use the oscilloscope with 2 channels and dual power supply for the 24 VDC (the maximum voltage that will be used in the RFID part) and 3.6 volts for the other parts such as the microcontroller and the XBee transponder. After setting all the components, we will test the whole system by having a person wear the tag and leaving the area to see how the components will react or if they function as we intended.

6.3 Base Station Testing

In order to test the Stellaris LM3S8962 the Stellaris evaluation board was used. Equipped with 10/100 Ethernet controller, a fully integrated Stellaris chip, microSD card, CAN bus connector, 30 I/O break out header, and a graphics display screen this board was fully capable of testing not only the chip but the Ethernet controller and RJ-45 jack as well. We made use of the sample programs that came with the board to test out the different functions the base station would perform. We coded and tested the communication between the base station and the GPS-device separate from the communication between the base station and the web application. Once we were satisfied with the performance of each program, we combined them and tested the system as a whole.

First, the Xbees were tested separately from the system by first verifying that they could transmit and receive data by connecting both modules to the computer via X-CTU. Once this was established the range of the RF transmitters was determined by setting one device, programmed to transmit hello world, in a static location while the other moved until communication was lost.

6.3.1 Base Station and GPS Device

We used a sample program that came with Stellarisware to test out the UART. Once we learned how it functioned, we modified it to take constant data from the GPS device. We used the X-CTU terminals to see the GPS-device output on the screen and for testing purposes we used the board's LCD screen to see the input. One of the libraries that was crucial to our implementation of data transfer between the devices was the use of the uartsdio.h library by Texas Instruments. This library allowed us to use a ring buffer to handle the incoming data from the GPS device without overloading the Stellaris's receive buffer. We tested the communication at various speeds to make sure that the Stellaris could handle the incoming data. Once we were satisfied by the performance we integrated it with the code for the web-app communication.

6.3.2 Base Station and Web-Application

For the communication between the base station and the web-application we had to use the TCP protocol using lwIP. Stellarisware came with a sample program that hosted a small server on the Stellaris board. First, we familiarized ourselves with the code, which

was extensive. We then started modifying functions to see how the program reacted to the changes. Once we were able to understand how the code was set up to host the server, we created a new version of the program and modified the functions that allowed us to make the connection to the server. We use the board's LCD to know the IP address being used by the board and hard-coded that IP address on the web-application function that made requests to the small server on the board. We used CGI-like functions on the board to process the request sent by the web-application and send out a generic html page response that used Server Side Include (SSI) to populate the fields on the page with updated values. We made used of Wireshark and Firefox's Firebug plugin to monitor the network and provide troubleshooting. We simulated GPS data being sent to the application and monitored how the data was been received on the web-application. Once we were satisfied with the results, we integrated the code with the GPS-device communication code.

6.4 Web Application Testing

Testing of the web-application was done at every stage. Using Web2py as a framework provided some useful tools that allowed us to test the application without having to deploy it on a public server. Web2py allowed us to host a local server for testing and previewing purposes. This tool was extremely beneficial throughout the developing and testing of the application. Although web2py offers an online editor to edit the code, it was not very convenient to manage the whole application. Jetbrains's PyCharm IDE proved to be very advantageous to manage the code by offering an intelligent editor with code completing, error highlighting, and code analysis among other features. It also offers support for modern web development frameworks, including web2py.

We created several test cases to test out the different functions of our web-application.

6.4.1.1 User Login Test Cases

We tested the application's response to valid and invalid inputs to make sure that it acted accordingly following the cases below:

- **Action:** Input a valid Gmail username and password and press Login
  Expected Outcome: Successful login, user is taken to main menu screen
- **Action:** Input an invalid Gmail username and press Login
  Expected Outcome: An error message prevents successful login and prompts the user for valid input
- **Action:** Input a valid Gmail username and invalid password and press Login
  Expected Outcome: An error message prevents successful login and prompts the user for valid input
- **Action:** Press Login button with empty fields
  Expected Outcome: An error message prevents successful login and prompts the user for valid input
- **Action:** Press Forgot Password button
  Expected Outcome: Application is send to the background and the Google website is launched where the user can retrieve their password

6.4.1.2 Navigating the Main Menu Test Cases

We tested the response of the application to the different buttons pressed on the main menu screen by the user.

- **Action:** Press button to access personal information
  Expected Outcome: User is redirected to screen containing personal information
- **Action:** Press button to access GPS device information
  Expected Outcome: User is redirected to screen containing information pertaining the device
- **Action:** Press button to view the About Us section
  Expected Outcome: User is redirected to screen containing the About Us section

6.4.1.3 Inputting New Data Test Cases

This test case took place in the Personal Information section and tested that the user could change the information that was previously saved in the database.

- **Action:** Press Update Information button
  Expected Outcome: Textfields appear allowing the user to delete existing data and input new data
- **Action:** Input new data and press Save button
  Expected Outcome: The user receives a confirmation message that data has been saved and the screen goes back to "viewing" mode. The user will be able to see on the screen the updated information at this point. The Google App Engine database and web application will also reflect the changes made
- **Action:** Input new data and press Cancel
  Expected Outcome: The application reverts back to "viewing" mode without saving any changes

6.4.1.4 MCU Request Test Cases

During this case, we tested to make sure that the application responded appropriately to the user's request for updated information about the GPS tracking device. First, we tested the response of the application to the request without sending it to the MCU to make sure that the application was working properly. For this we used Firebug to monitor the network status when the request was sent out. Then we tested to make sure that the application was able to correctly send the request to the MCU at the base station. We first tested the Python function separately from the web-application. We created a Python script to send the GET request to the base station and to print out the response on the screen. Once we saw that response received was the one expected, we tested the function within the web-application following the test case below:

- **Action:** Press Request Update button
  Expected Outcome: The data displaying the coordinates is updated with the new coordinates received from the GPS device.

6.4.1.5 Emergency Scenario Test Cases

We tested the response of the application to the user's interaction and to the MCU's interaction separately. We manually set off the emergency status on the application to see

if it responded correctly. Then, once the testing confirmed that the application function was working correctly, we had the MCU set off the alert status on the application to make sure that the application was registering the requests and warning the user.

- **Action:** Application receives a change to the alert state to ON from base station
  Expected Outcome: Web application sends a text message notifying the GPS device left the premises
- **Action:** Application receives a change to the alert state to OFF from base station
  Expected Outcome: Application sends a text message notifying the GPS is back in the premises.
- **Action:** Application receives GPS coordinates from base station
  Expected Outcome: The map shows the updated location of the GPS device

6.4.2 Google App Engine

The Google App Engine will be used for both the web application and the database storage. Google provides different tools and resources to perform testing on both web applications and datastore. A service stub is one of the tools that are available and the one we will use the most during the testing phase. It allows us to simulate the behavior of the service without running it on the actual server or the datastore. In order to do this, a JUnit 4 Jar file will need to be added to the testing classpath. This file can be found on the Google Developer's website at no cost.

6.4.2.1 Database Testing

The database was created using the High Replication Datastore (HRD). Google provides a library for the sole purpose of testing HRD databases. The following two libraries will be added to the code file to allow us to write tests while developing the application:

```
import com.google.appengine.tools.development.testing.LocalDatastoreServiceTestConfig;
import com.google.appengine.tools.development.testing.LocalServiceTestHelper;
```

We also tested the database functionality when testing the user application.

7 Administrative Content

7.1 Project Milestones

The milestones associated with this project were split into different parts to separate the nature of the work that will take place during the year. The project was separated into three phases, based on the time available to us to complete the project. The first phase is from January to April, the second phase is from May to August, and the third and final phase is from September to December. This arrangement was agreed upon by the members of the group to be the most beneficial for each member and for the project.

The first phase encompasses the whole semester of Senior Design I and the beginning and end of the phase were chosen to guarantee that. The main focus of Senior Design I is the research, design and documentation of the project and thus the milestones were chosen to align with the deliverables that have to be presented at the end of the semester.

We will schedule biweekly meetings to stay updated on the progress of everyone in the group.

Figure below depicts the timeline of phase I and the milestones that were set forth by the group. The milestones chosen are the due dates for different deliverables that we have to turn in as a group. The figure does not show the biweekly group meetings that were scheduled.
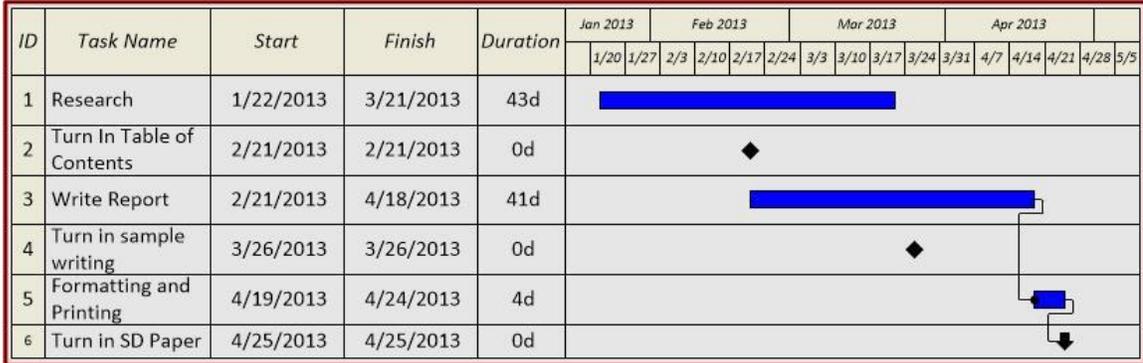
ID	Task Name	Start	Finish	Duration	Jan 2013	Feb 2013	Mar 2013	Apr 2013
1	Research	1/22/2013	3/21/2013	43d				
2	Turn In Table of Contents	2/21/2013	2/21/2013	0d				
3	Write Report	2/21/2013	4/18/2013	41d				
4	Turn in sample writing	3/26/2013	3/26/2013	0d				
5	Formatting and Printing	4/19/2013	4/24/2013	4d				
6	Turn in SD Paper	4/25/2013	4/25/2013	0d				

Figure 60: Phase I Timeline

The second and third phase will deal with the construction and testing of the prototype. Phase II will involve the acquisition and testing of the individual parts of the prototype to make sure that everything is working correctly before construction begins.

Figure 47 below depicts the timeline for this second phase. There are not any milestones integrated in this phase because it takes place during the summer and most members will be away on internships. This is a rough draft to let us see what the time we are working with is and what we need to accomplish during this time. We will hold monthly meetings via phone/Skype conference calls to keep everyone updated on each person's progress.

ID	Task Name	Start	Finish	Duration	May 2013	Jun 2013	Jul 2013
1	Acquire parts	5/13/2013	6/21/2013	30d			
2	Parts Testing	6/24/2013	8/9/2013	35d			
3	Build GUI – mobile app	5/27/2013	7/5/2013	30d			
4	Build GUI – web app	7/1/2013	8/12/2013	31d			
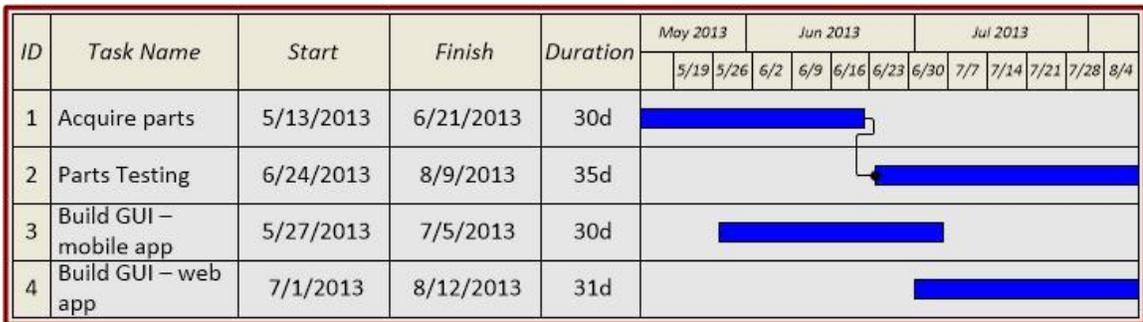
Figure 47: Phase II Timeline

The third and last phase will cover the semester of Senior Design II. During this phase, the Smart GPS System will be built, integrated and tested. The project is comprised of 4 modules: GPS module, RFID module, Base Station module, and User Interface module.

Figure depicts the timeline for Phase III. The modules will be worked on separately but their start time and finish time will overlap to give us time to finish in a timely manner.

The first module we will focus on is the Base Station module because this is the command center. Once the parts are integrated and the code for the MCU is finished, testing of the module will take place and the GPS module will begin construction at the same time. Our group will split in two to maximize efficiency. Once the first group is done testing the Base Station module, they will join the second group to finish the GPS module. At the time specified on the timeline, the group will again split in two where the first group will finish the GPS module testing and the second group will start building the RFID module. After the GPS testing is done, the integration of the Base Station module and the GPS module will take place. The people that lead those two modules will be in charge of the integration and testing. Once the RFID module is finished testing, we will integrate it to the other two modules and test the whole system.

The user applications, built during Phase II, will have test scripts already ready to be tested with the base station. After each module testing, the applications will run some tests with the base station to make sure that everything works properly. If there are major issues found that prevent the application from running, the code will be dealt with immediately. On the other hand, if there are minor issues found that do not affect the connection between the application and the base station, they will be written down to be dealt with after the prototype has been finished.

ID	Task Name	Start	Finish	Duration	Aug 2013	Sep 2013					Oct 2013			Nov 2013		
					8/25	9/1	9/8	9/15	9/22	9/29	10/6			11/3	11/17	11/24
1	Assemble Base Station	8/19/2013	9/8/2013	21d	███											
2	Integrate parts	8/19/2013	8/25/2013	7d	█											
3	Program MCU	8/28/2013	9/3/2013	7d		█										
4	Establish Web Server on MCU	9/6/2013	9/12/2013	7d			█									
5	Test module	8/28/2013	9/10/2013	14d		██										
6	Assemble GPS Module	9/6/2013	9/26/2013	21d			███									
7	Integrate parts	9/6/2013	9/12/2013	7d			█									
8	Program MCU	9/16/2013	9/22/2013	7d				█								
9	Test Module	9/17/2013	9/30/2013	14d				██								
10	Integrate Modules 1 and 2	10/1/2013	10/7/2013	7d					█							
11	Test Functionality	10/3/2013	10/7/2013	5d					█							
12	Assemble RFID Module	9/26/2013	10/16/2013	21d					███							
13	Integrate parts	9/26/2013	10/2/2013	7d					█							
14	Program MCU	10/5/2013	10/11/2013	7d						█						
15	Test Module	10/7/2013	10/20/2013	14d						██						
16	Integrate Module 3 to prototype	10/21/2013	10/27/2013	7d							█					
17	Test Functionality	10/23/2013	10/27/2013	5d							█					
18	User Interface Module	8/19/2013	10/31/2013	74d	███████████████											
19	Beta Testing	11/1/2013	11/8/2013	8d								█				
20	Reserved for updates if issues found during Beta test	11/9/2013	11/15/2013	7d									█			
21	Prepare for final presentation Do final testings	11/16/2013	12/2/2013	17d										██		

Figure 62: Phase III Timeline

7.2 Budget and Expenses

The project is being entirely financed by the members of the group. The total cost will be divided evenly among the group members.

7.2.1 Bill of Materials

Since this is a self-financed project, we tried to select parts that are low cost and still allow us to fulfill our specifications. Unfortunately, some of the parts are not cheap, so we tried to balance it out by eliminating unnecessary costs from other areas, such as the user interfaces. Both Google App Engine and Android offer free tools and resources to develop applications and store data online.

We have separated the expenses by areas to allow us to see the breakdown of costs independently from other modules. During Phase II, we will look for way to bring down the costs wherever possible. The following expenses are related to the Outdoor Tracking System:

Part	Tentative Vendor	Price
GPS Module	SparkFun	$ 59.95
Microcontroller	Ebay	$ 21.00
Microcontroller	TI	$ 4.78
PCB	4PCB	$ 16.00
LCD	SparkFun	$ 24.95
Recharge Circuit	Sparkfun	$ 15.00
Buck Regulator	Linear Technology	$ 2.06
Rechargeable Battery	AliExpress	$10.85
Patch Antenna	Ebay	$ 5.00
	Sub-Total	$159.59

The following expenses are related to the Indoor Tracking System:

Components	Part number	Quantity	Price/unit (1ku = per 1000)	Total
Readers	RI-RFM-007B	1	260 1ku	~ $0.26
Microcontroller	CC430F5123	1	2.5 1ku	~ $0.0025
Antenna	RI-ANT-S01C	1	115 1ku	~ $0.115
XBEE pro zb	XBP24BZ7SIT-001	1	$37.95	$ 37.95
RS-232	2881078	2	$23.99	$ 47.98
			Sub-Total	$ 85.93

The following expenses are related to the Base Station:

Components	Part Number	Quantity	Price	Total
TI Microcontroller	Stellaris LM3S8962	1	$14.12	$ 14.12
RF Module	XBee 900 Pro	2	$42.95	$ 85.9
RJ-45	Pulse J3011G21DNL	1	$7.69	$ 7.69
T I Ethernet Controller	TLK100	1	$4	$ 4
AC Adapter	PW-CT-9V	1	$10	$ 10
DC Barrel Power Jack	PCB Mount	1	$0.20	$ 0.20
Antenna	A09-HASM-675	1	$29.91	$ 29.91
			Sub-Total	**$ 164.86**

7.3 Roles and Responsibilities

We have split the project into four modules to make it more manageable to work with and have assigned a lead person to each module. Each module lead is responsible for the completion of that particular module and is considered the Subject Matter Expert (SME) in that area. We did it this way to distribute responsibilities evenly across the group and, more importantly, to make sure that no module is neglected. Each module performs an important function within the whole Smart GPS System and we do not want to run the risk of overlooking any requirements associated with a neglected module.

Even though there is a lead for each module, when building the prototype, the group will work together on each module as described in Section 7.1.

The following diagram, Figure , shows the distribution of work among the group. Some of the bulleted tasks are found in more than one member, these tasks will have those particular people focused on them because they share the knowledge to complete the tasks. We believe that this will speed up the process to complete each task.
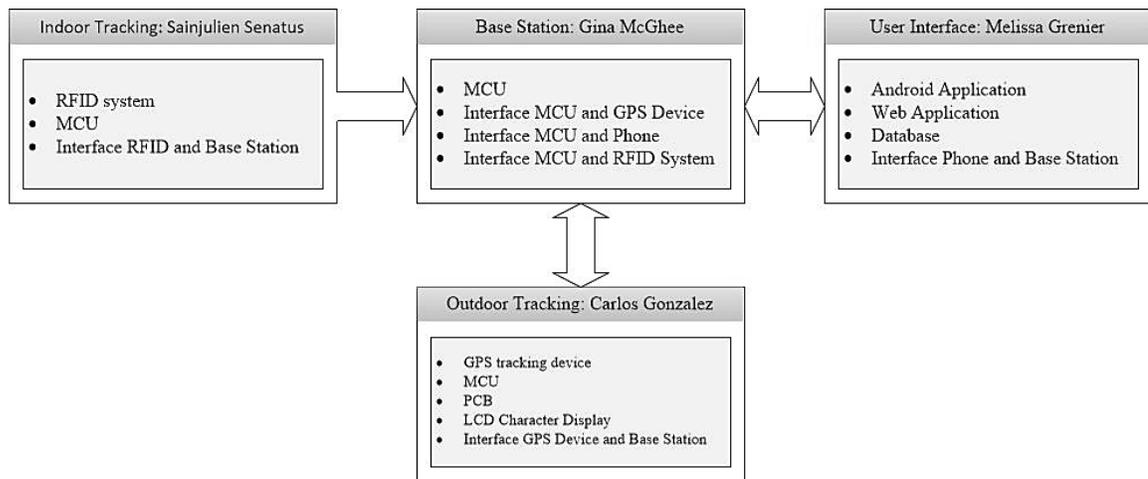
Figure 63: Distribution of Labor

8 Conclusion

In conclusion, the project was successful although modifications had to be done. We had to implement the geo-fence by the GPS device because there were some delays with the RFID component by the time the final presentation rolled around. Even with this change, in essence, the project worked as planned. The GPS device is able to alert the base station when it has left the perimeter which is then passed to the web-application where measures to notify the emergency person are taken.

This project was very involved and let us put to practice what we have learned throughout our undergraduate career. It allowed us to learn new technologies and programming languages.

Appendix A – Permissions

Geoff's Projects Permission Request

Untitled Message

Send | Options... | HTML

- Draft autosaved at: 1:02 PM

From: Carlos A Gonzalez
To... projects@geoffg.net
Cc...
Bcc...
Subject: Permission

Tahoma | 10 | **B** *I* U

Hello,

My name is Carlos Gonzalez and I am an Electrical Engineering student currently working on a Senior Design project at the University of Central Florida in Orlando, FL. I am working on creating a GPS tracking device for our design and I would like to request permission to use on of the figures in our documentation.

I would like to request permission to use the "EM-408 GPS Module" from this link: http://geoffg.net/EM408.html

Thanks,

Carlos A. González
Electrical Engineering Student
Outreach Coordinator 2012 -2013
Society of Hispanic Professional Engineers (SHPE)
University of Central Florida
carlos.gonzalez@knights.ucf.edu
(407) 600-2198

GPS Information.Org Permission Request

Permission

Send | Options... | HTML

- Draft autosaved at: 1:12 PM

From: Carlos A Gonzalez
To... spam@mehaffey.us
Cc...
Bcc...
Subject: Permission

Tahoma | 10 | **B** *I* U

Hello,

My name is Carlos Gonzalez and I am an Electrical Engineering student currently working on a Senior Design project at the University of Central Florida in Orlando, FL. I am working on creating a GPS tracking device for our design and I would like to request permission to use on of the figures and tables in our documentation.

I would like to request permission to use the "Outputs for GPS graphs and tables" from this link:

http://www.gpsinformation.org/dale/nmea.htm

Thanks,

Carlos A. González
Electrical Engineering Student
Outreach Coordinator 2012 -2013
Society of Hispanic Professional Engineers (SHPE)
University of Central Florida
carlos.gonzalez@knights.ucf.edu

Sparkfun Permission Requests
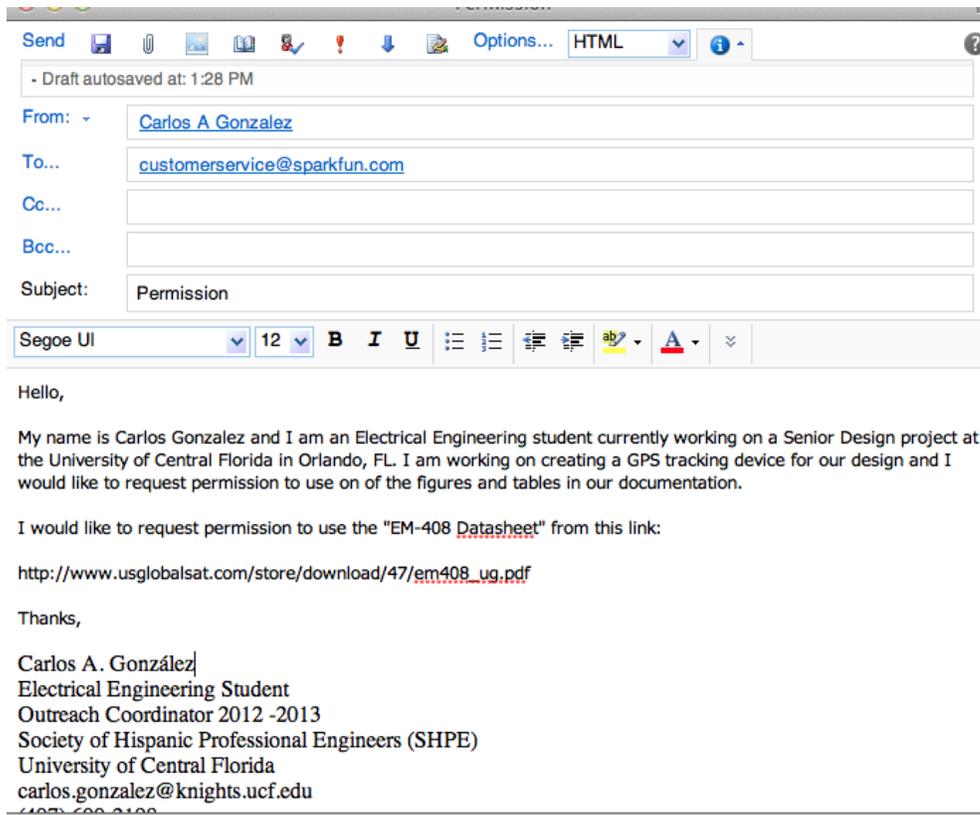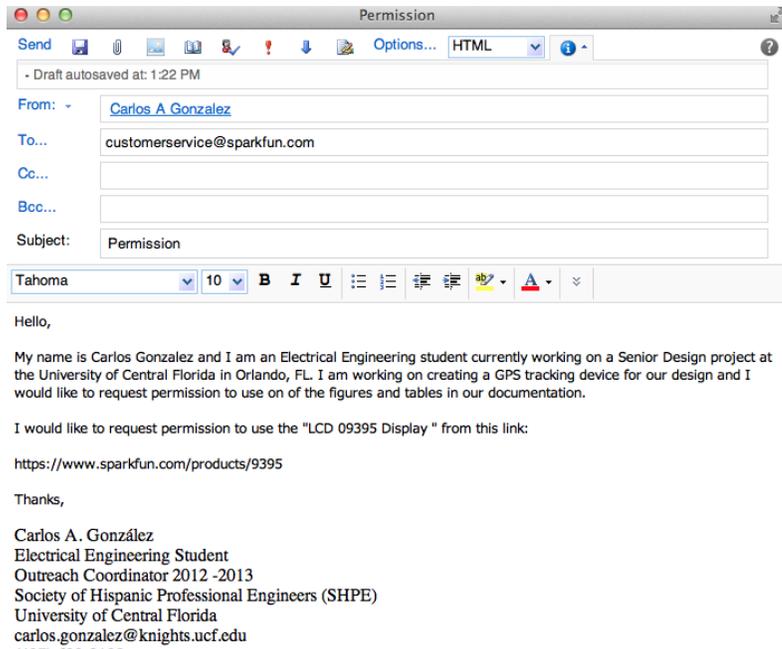
Texas Instruments Permission Requests

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rfidsupport@ti.com
Thursday, April 04, 2013 2:32 PM

↩ ↩ ↪ Actions ▾

To: ☑ ssenatus@knights.ucf.edu
Cc: ☐ SSENATUS@HOTMAIL.COM

Hi Sainjulien,

Sure, to be honest, as long as its for Educational/non-profit use, the marketing team is alright with you using the images and content. But here, I want to show you the official Copyright page with the details, and their contact if need be:
http://www.ti.com/corp/docs/legal/copyright.shtml

I hope this is helpful!

Regards,

Billy Owen
TI Applications Support
Americas Customer Support Center

Engage in the
TI E2E Community Support Forums
TI E2E™ Ask questions, share knowledge, explore ideas
Community and help solve problems with fellow engineers

http://www.ti.com/e2e-support

copyright infringement

Bassuk, Larry [l-bassuk@ti.com]
Wednesday, April 24, 2013 3:11 PM

Thank you for your interest in Texas Instruments. We grant the permission you request in your email below.

On each copy, please provide the following credit:

Courtesy Texas Instruments

Regards,

Larry Bassuk
Deputy General Patent Counsel &
Copyright Counsel
Texas Instruments Incorporated
214-479-1152

Gina McGhee
Wednesday, April 24, 2013 3:09 PM
Sent Items

To: copyrightcounsel@list.ti.com

To Whom it may concern,

I am currently an electrical engineering student at the University Of Central Florida and would like to request permission to display some of the diagrams, schematics, and figures illustrated in the data sheet for the CC3000 to aid in depicting said part as it will be used within my senior design project. None of the information I wish to use is for profit and all serves to to better explain that manner in which the CC3000 will work within the projects design. This endeavor is purely academic and does not seek to generate a profit in anyway.

Thank you,

Gina McGhe

Bassuk, Larry [l-bassuk@ti.com]
Wednesday, April 24, 2013 3:11 PM

Gina McGhee
Wednesday, April 24, 2013 2:54 PM
Sent Items

To: copyrightcounsel@list.ti.com

To Whom it may concern,

I am currently an electrical engineering student at the University Of Central Florida and would like to request permission to display some of the diagrams, schematics, and figures illustrated in the data sheet for

TLK100 Ethernet Controller to aid in depicting it as it will be used within my senior design project. None of the information I wish to use is for profit and all serves to to better explain that manner in which TLK100 will work w the projects design. This endeavor is purely academic and does not seek to generate a profit in anyway.

Thank you,

Copyright Infringement

Gina McGhee
Wednesday, April 24, 2013 2:48 PM

To: pr@microchip.com

To Whom it may concern,

I am currently an electrical engineering student at the University Of Central Florida and would like
to request permission to display some of the diagrams, schematics, and figures illustrated in the data sheet for the
PIC32 Micro-controller to aid in depicting said part which would be used within my senior design project. None of
the information I wish to use is for profit and all serves to to better explain that manner in which..... part will work
within the projects design. This endeavor is purely academic and does not seek to generate a profit in anyway.

Thank you,

Gina McGhee

copyright infringement

Gina McGhee
Wednesday, April 24, 2013 2:57 PM

To: pr@microchip.com

To Whom it may concern,

I am currently an electrical engineering student at the University Of Central Florida and would like
to request permission to display some of the diagrams, schematics, and figures illustrated in the data sheet for the
ENC28J60 Ethernet Controller to aid in depicting said part as it will be used within my senior design project. None o
the information I wish to use is for profit and all serves to to better explain that manner in which the Etherne
Controller will work within the projects design. This endeavor is purely academic and does not seek to generate a prof
in anyway.

Thank you,

Gina McGhee

Google Permission

About Android   Get the SDK

Except as noted, this content is licensed under Creative Commons Attribution 2.5. For

Appendix B – Figures and Tables Index
Figures Index

Tables Index

Appendix C – Sources

General Sources

http://www.webmd.com/brain/autism/news/20121008/autism-wandering-common-serious-concern?page=2

http://www.pocketfinder.com/

Outdoor Tracking Module Sources

http://www.oxts.com/default.asp?pageRef=76&newsID=267

http://www.GPSinformation.org/dale/nmea.htm

https://www.sparkfun.com/products/8975

https://sites.google.com/site/reeetech/inverter/solar-charge-controllers

http://www.ti.com/product/bq24193

www.eecs.ucf.edu/.../g10/.../Final%20Documenatation%20Paper.pdf

http://www.splung.com/content/sid/3/page/batteries

http://batteryuniversity.com/learn/article/serial_and_parallel_battery_configurations

http://www.batteryspace.com/batteryknowledge.aspx

http://worldwidescience.org/topicpages/c/concentrated+aqueous+lithium.html

www.jhuapl.edu/techdigest/TD/td2804/Srinivasan.pdf

http://michaelbluejay.com/batteries/rechargeable.html

http://batteryuniversity.com/learn/article/how_to_prolong_lithium_based_batteries

www.linear.com/docs/4120

http://www.tpub.com/neets/book7/27j.htm

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http://www.ti.com/product/tps78001

www.ti.com/lit/ds/symlink/lm1117-n.pdf

www.linear.com/docs/4137

http://www.scribd.com/doc/126185089/MSP430-Microcontroller-Basics

http://www.freebsd.org/doc/en/articles/serial-uart/

http://www.societyofrobots.com/member_tutorials/book/export/html/35

http://www.i2cprotocol.com/

https://www.sparkfun.com/products/9395

http://www.ti.com/tool/ccstudio

Indoor Tracking Module Sources

http://ww1.microchip.com/downloads/en/DeviceDoc/21299E.pdf

http://www.asentrix.com/rfid.htm.

http://www.idtechex.com.

http://www.rfidjournal.com/

http://www.mouser.com/

http://www.everymanbusiness.com/equipment-supplies/rfid-system/

http://www.synometrix.com

http://www.freepatentsonline.com/

http://www.ti.com/solution/rfid_reader

http://www.smartcodecorp.com/

http://www.centrenational-rfid.com/rfid-frequency-ranges-article-16-gb-ruid-202.html

http://www.rfidbuzz.com/news/2005/epc_class_1_generation_2_rfid_tag_specification

http://www.gaorfid.com

http://www.broadcom.com/

Base Station Module Sources

http://www.microchip.com/stellent/idcplg?IdcService=SS_GET_PAGE&nodeId=1406&dDocName=en545713

http://en.wikipedia.org/wiki/PIC_microcontroller#Code_space

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http://ww1.microchip.com/downloads/en/DeviceDoc/39662e.pdf

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