THE OHIO STATE UNIVERSITY

Wireless Animal Containment

TI Competition

Alena Abukovich, Candace Castillo, Chris Mitchell, Ante Tomicic, Suhayl Elkhammas

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Senior capstone project for group FIDO: The goal of this project was to design and implement a wireless animal containment system which enforced wireless boundaries through voice communication rather than shock.

Executive Summary

Introduction: The purpose of this project is to design a wireless animal containment system that does not require a lot of set up and enforces the user's boundaries through voice commands instead of shock. The system will also be capable of sending tracking information to the user's handheld device to make it possible for the user to know where their pet is at all times.

Background: There are already wireless containment systems on the market today. The difference between these already existing systems and the system in design is that the already existing systems require set up posts to define the boundaries where as the new system will have the boundaries programmed into the collar. The old systems also enforce the boundaries through shock instead of a voice command. Many of the older systems also do not have a tracking option.

Design Overview: Our system design is composed of three main components. First is the hand held device, the second is the remote tracking device, and the third is a GPS receiver module. The design overview section describes in detail how these three components will work together. It also includes a flow chart of system operation and a block diagram of system interactions.

Report of Work: The design and implementation of the wireless animal containment system has been divided into two quarters. In ECE 582 (AU08), the design and relevant background information was gathered. In ECE 682 (WI09), the implantation of the design took place.

Resources: The group, FIDO, is comprised of five fifth year Electrical/Computer Engineering Students: Alena Abukhovich, Candace Castillo, Chris Mitchell, Suhayl Elkhammas, and Ante Tomicic. The group will also be advised by the course Professor Steven Bibyk and the course teaching assistant Drew Milley

Schedule: The schedule was designed keeping in mind spiral design flow. For the most part, the group was kept on schedule minus some minor setbacks in the integration of the three components of our system.

Cost: The cost of the design was $49.00 for the microcontroller, $11.99 for the recordable speaker, and $3.50 for the DC/DC converter for a total of $64.49. The GPS receiver module was received for free from Wi2Wi for evaluation.

Design Review: Summarizes the overall design, to explain what the system design is composed of. Changes have been made since the beginning and initial plan of the project to accommodate issues due to feasibility.

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Introduction

Purpose

The purpose of this project was to design a wireless animal containment system that uses voice commands instead of shock to contain an animal in a defined area. The design incorporated a user interface in which the user can input boundaries to keep their pet and record their voice message to be played if the animal steps out of bounds. Through a microcontroller/GPS interface, the animal is monitored. As soon as the animal steps outside of the user defined boundaries, a little speaker in the collar will play the recorded message to the dog and instruct it to return to its allowed area. The system also was designed with a receiver which reported to the pet owner if and when the animal leaves its allowed area. The GPS system on the dog collar was designed to keep track of the dog and report its location to the receiver so the owner will know the location of the dog at all times.

Problem Statement

As animals are being seen as more and more a part of the family, the importance of keeping them safe is rising as well as the need and popularity of wireless animal containment systems. Most current systems include a collar which is put on the dog and posts which are used to define the boundaries in which to keep the dog. When the dog crosses past the posts, a shock is sent to the dog, scaring it back into the allowed area or even father out of the defined area. This may be seen as cruel to some pet owners. The current systems also pose the problem that once they are placed in the yard, in order to move it and use it elsewhere, the user must collect the posts and transport them, then reposition them in the new place. This can be quite a hassle if you take your dog with you to a lot of places. Although, these current systems serve the purpose they were created for, a less abrasive and more transportable system can be created.

For this project, our group explored the possibilities of designing a system in which, instead of shocking the dog a message is played instructing the animal to return to its specified allowed area and creating a system that keeps track of the boundaries without the use of posts. Through the use of a microcontroller and GPS interface on the collar of the dog, it is possible to create a system which does not require the use of posts. This allows for a more transportable system. The user will have the freedom to input the boundaries of the dog directly into the collar. A small speaker in the collar can also replace the shocking system in the collar. Instead of being shocked for leaving its boundaries, the user can record their voice onto the collar and have that play instead.

A problem that may occur with this system is that the dog may not listen to the command without the physical reinforcement. To fix this problem, the GPS/microcontroller system on the dog's collar was designed to send a signal to a receiver displaying its position to the user. With these changes, the ultimate goal is to create an adaptation of current wireless animal containment system that is more portable and animal friendly.

Scope

In ECE 682, the design of the wireless animal containment system was altered a little. The detachable keyboard was removed and replaced with a USB interface to a computer. The LCD screen was also removed because of the use of the computer. The rest of the design remained the same. At the end of the quarter, the group demo was of microcontroller communication as well as of the GPS receiver module being used.

Background Information

The Global Positioning System (GPS) is a satellite-based navigation system consisting of a network of 24 satellites placed into orbit by the U.S. Department of Defense. These GPS satellites perform two defined orbits per day around the earth, transmitting signal information down to earth. GPS receivers obtain the signal information and apply triangulation to calculate their location accurately. Triangulation is the method of determining the location of a point by measuring angles to it from known points at either end of a fixed baseline. To simplify, the GPS receiver compares the time a signal was transmitted by a satellite with the time it was received. The difference in time informs the receiver how far the satellite is from the receiver. Now, with distance measurements from a few more satellites, the receiver can determine its position.

A GPS receiver must have clear communication with at least three satellites to calculate latitude, longitude, and track movement. To determine three dimensions, latitude, longitude, and altitude, there must be four or more satellites in view. Once position is established, other calculations such as speed can be computed. GPS receivers have become very popular and with improvements in technology become smaller, more accurate, and more economical.

There are several products available that perform location tracking through GPS. Also there are many animal containment products which do not use this technology, in fact most do not. Most animal containment devices do not track the pet. They simple require the user to set up post boundaries to confine the pet, which trigger the collar when passed. These animal containment devices are often advertised as invisible fences ($90-$350). In the design of our animal containment system, we will use GPS technology, which is used for many tracking applications.

Many GPS tags that are available are the size of small cell phones, and vary in price based on processing speed and functionality. The P-Trac Micro is the smallest GPS tracker available at this time, measuring two inches wide and one inch thick ($449.95). This device is able to track indoors and outdoors using cellular Assisted Global Positioning Systems (AGPS). AGPS technology uses local cellular towers to triangulate a location, unlike standard GPS which needs to locate a satellite in space and identify an exact location. The standard GPS process can take up to a couple of minutes to acquire location information, while AGPS acquires a location using cellular towers that are continuously receiving satellite location data from space. Therefore it only takes AGPS a few seconds to pull data from the cellular satellites to determine GPS location. The advantages presented by AGPS include faster obtainment of device location, decrease in needed processing power, and the GPS location is able to be obtained indoors or outdoors accurately. The common consumer concern is that, like many GPS location devices there are monthly charges for real-time online tracking services. A non-GPS available alternative is The BrickHouse Locator ($189.95).

The BrickHouse Locator is an all-in-one device, providing guidance and tracking information through a hand held receiver rather than through web browsers or cell phone interfaces. This product assists the user in locating their tagged children or valuables, and also alerts the user if the tagged item is out of its user defined range. If used as a child locator, there is an extra safety precaution, which allows the person wearing the tag to press a panic button to alert the user or parent of an emergency. The features provided by this product are very innovative and user friendly, which provide an example for future products. There is an on screen directional display and audio guidance that leads the user to their tagged items. The BrickHouse Locator with its discrete homing tags, can detect tags as far as 600 feet away.

To distinguish our idea from the countless animal containment systems available in stores and online, we have decided to use GPS technology and add an audio feature that plays a recorded message when activated. This feature can be utilized when a tagged pet approaches set boundary limits, which then activates the audio message. The recorded message can consist of anything such as a sound, voice command, or even song. Recordings such as “Get back here” or the yelling of the pet’s name can be recorded in the guardian’s voice to prevent the tagged object from leaving the area defined by the user. This type of reinforcement will prove to be more effective and animal friendly. There is a thirteen second self-recordable module available online ($11.99), which is commonly used for personalized greeting cards and presentation folders. This simple device can be integrated in our design approach to make our project more unique and functional. Recordings are usually encoded from a wav or mp3 format, which proves to be rather simple. Other technology incorporated in our project includes the Texas Instruments MSP430F2274 microcontroller, Texas Instruments CC2500 RF transceiver, Texas Instruments TPS62100 and the Wi2Wi W2SG0004 GPS Module SDK.

TI MSP430F2274

The MSP430F2274 is a compact, energy efficient microcontroller that consists of all the hardware and software (Integrated Development Environment and SimpliciTI) necessary to develop a wireless project. An emulator included in the MSP430 is used to program and debug an application in-system. The emulator interface may be utilized to download and debug target applications, and can transmit serial data to your PC while in or out of a debug session. The MSP430F22x4 combines 16-MIPS performance with a 200-ksps 10-bit ADC and 2 op-amps and is designed for low-power applications (ti.com). This product can be found in conjunction with the CC2500 in the TI MSP430 ez-RF2500 microcontroller unit.

TI CC2500

The CC2500 is a low cost transceiver designed with low power wireless applications in mind. Capable of operating in the 2.4 GHz spectrum, it can transmit data from 1.2 kBaud to 500 kBaud achieving maximum data transfer rate of 500 kbps, if required by the application. As designed, the CC2500 provides all of the necessary hardware requirements to handle data buffering, packet handling, burst transmission, clear channel assessment, link quality, and wake-on-radio features. It is also RoHS compliant, containing no antimony or bromine. This product can be found in conjunction with the MSP430F2274 in the TI MSP430 ez-RF2500 wireless unit.

TI TPS62100

The TPS62100 is a multimode synchronous Buck converter with adjustable output providing DC/DC conversion ranging from an input of 2.5V to 9V and an output range of 0.8V to 8V. The TPS6210x family of products can be configured to run at multiple frequencies: 300 kHz, 600 kHz, 1 MHz or 2 MHz. By using the dual function SD/SYNC input pin, the circuit can be synchronized, or set to run at a fixed frequency. Due to the design of the TPS6210x family, it has a highly efficient at both low and high output currents.

Wi2Wi W2SG0004 GPS Module

The W2SG0004 is a highly sensitive, ultra-low power, SMD (11.2mm x 12mm x 2.5mm) type 20-Channel L1 GPS receiver. It is designed for battery powered portable devices and is a full radio receiver solution. The W2SG0004 permits fast and trouble-free integration into standard or custom applications. The device has features making the output data format selectable as latitude, longitude, altitude, speed, heading, and time. This tool uses NAVSTAR GPS L1 signal. Some other features of this module include:

- Permits use of either passive or active antenna
- Supports E911 mandate
- Support for NEMA and SiRF Binary™ Protocols

Design Work

System Design

Our system design is composed of three main components. First is the hand held device, the second is the remote tracking device, and third is the GPS receiver to provide coordinates for the remote tracking device.

The hand held device will be used to initiate a tracking on the remote device, as well as display the read out given by the remote tracking device. It will contain a toggle switch to initiate the search, a connection to TI Sensor Monitor software to present the information to the user, and a microcontroller with a wireless transceiver to communicate with the remote tracking device.

The remote tracking device will be a unit which is placed on the device which is to be tracked. It will contain a GPS receiver to retrieve the signal and determine the location. It will also contain a microcontroller to control the GPS's searches, as well as relay the information between the GPS receiver and the hand held device. The microcontroller will have a small speaker attached to it to emit a sound to the animal when it steps out of bound. This microcontroller will be continually powered so that it can receive a signal from the hand held

Detail Design

For both the hand held device and the remote tracking device, we have chosen to use the TI MSP430 ez-RF2500. This package came with a demo that allowed for wireless communication between the two devices. We have been able to modify this code so that it is able to transmit and receive the appropriate data for our project. We have also acquired a demo GPS SDK from Wi2Wi for this project.

The software for the hand held device has been configured so that it will establish the communication with any remote device within its range and manage this connection. A framework for this to functional fully has been laid out. Once implemented, it will continually look for any new remote device in the area, establish a connection, and then wait for further instructions from the user. If a user chooses to, the framework has the functionality to transmit data to set the remote device with a coordinate and boundary for the device to be contained within. The framework also has the functionality to wait for the user to toggle a switch, and request the current location of the remote hand held device. Once the information is received, it will present it to the user via TI Sensor Monitoring software.

The software for the remote device has been configured to continually attempt to establish communication with the hand held device. Once it has done so, it will sit in an infinite loop waiting on a series of conditions to occur. If it receives information from the hand held device requesting to set the boundary location, it will set that, then periodically check the coordinates to ensure the device is still within its range, if not, it will activate the prerecorded sound. The framework for the remote device also includes the capability to receive information from the hand held device requesting the current location. If this is done, it will retrieve the location from the GPS unit, and transmit it back to the hand held device.

The SDK for the Wi2Wi has allowed us to explore all the possible options for utilizing its potential. While we did not have adequate time to fully test all of these options, we were achieve and understanding of its capabilities and limiting factors. One of the capabilities we found particularly useful with this GPS unit was the ability to communicate via a UART connection, which the microcontrollers have as well. This should allow for a simple connection between the two devices. One of the limiting factors we have discovered with the GPS unit is its necessity to have a clear view of the sky for an accurate GPS location to be obtained.

While the framework for the software has been planned out and coding of certain pieces has been completed, more work still needs to be done for a fully functional system to be active. Also, more time needs to be dedicated to the GPS unit to understand all the components of the SDK so we can use it as effectively and efficiently as possible.

Structure and Physical Descriptions of Hardware and Software

Figure 1 shows an outline of the flow of the system from when a location request is sent all the way to retrieving the data.

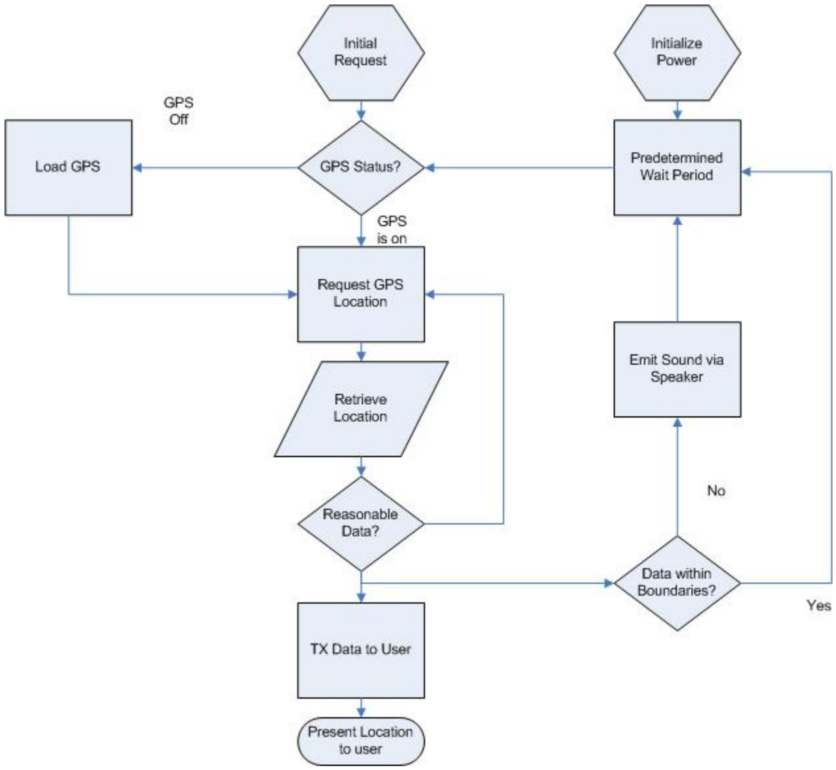

Figure 1: Wireless Animal Containment System Flow Chart

Figure 2 is a block diagram of how the system described in the design approach will fit together. There will be three parts: a remote device which is placed on the dog's collar, a handheld device for the pet owner, and a GPS receiver. The remote device has three parts as well: the microcontroller, the GPS, and a small speaker. The microcontroller is the part of the system that will attach to the keypad. It will also be responsible for the wireless communication between the collar and the pet owners hand held device. The hand held device will also have a microcontroller which will be responsible for receiving the signal from the remote device as well as receiving search commands and displaying received location to the user.

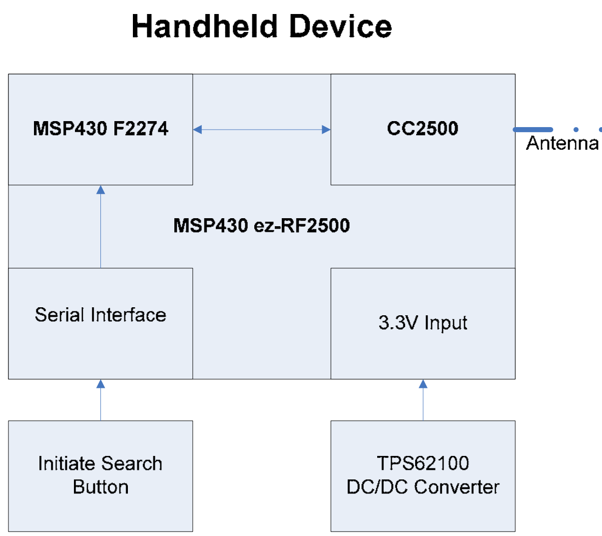

Figure 2: Wireless Animal Containment System Design, Handheld Device

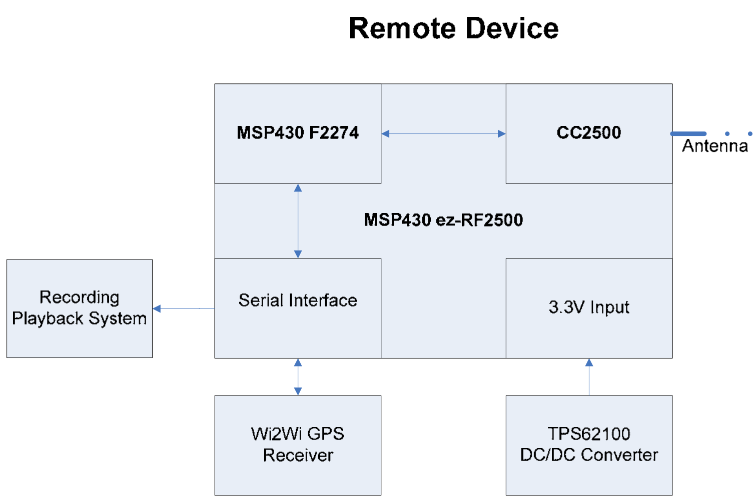

Figure 3: Wireless Animal Containment System Design, Remote Device

Report of Work

Throughout the quarter there were many tasks assigned, the following is a list of dates of when tasks were assigned, when tasks needed to be completed by, and what was accomplished for that period.

<u>1/18/2009</u>

- Ordered the TI – Microcontrollers.

- Set up and get familiar with the microcontrollers.

<u>1/21/2009</u>

- Alena assigned to speak with SiRF to get the chip.
- Everyone work on microcontroller.

<u>1/26/2009</u>

- Order recorder and keypad.
- Need Price of LCD and order that part.

<u>2/2/2009</u>

- Design has changed, need approval on new design.
- Begin implementing design.
- Still get familiar with microcontroller.

<u>2/9/2009</u>

- Figure out how recorder will interface with the microcontroller, need data sheet.
- Update power point slides.
- Brainstorm what code we need to write to implement everything.

<u>2/16/2009</u>

- Alena asked to borrow development board for free, and to get the data sheet for the SiRF chip.
- Research other options incase problems arise, in case we can't get development board.
- Need to get all coding done before we meet to interface parts together.

<u>2/23/2009</u>

- Got the development kit, need to set it up.
- Coding is still in progress.
- Integrate recorder, microcontroller, and GPS receiver.
- Consider end of quarter demo, and begin preparing.

2/28/2009

- End of quarter demo, prepare poster.
- GPS needs clear signal, work on finding suitable location.
- Compile all status reports.
- Work on final draft of our documentation.

3/5/2009- 3/9/2009

- Final wrap up of everything!

4/6/2009

- Discussion continuation of project for TI competition
- Review specs of design
- Come up with work schedule timeline

4/13/2009

- Research device specs
- Begin working on code for transmitting data

4/20/2009

- Continue working on code

4/27/2009

- Continue working on code
- Debugging and testing

5/4/2009

- Debugging and testing
- Begin Updating Final Report

5/11/2009

- Testing
- Update Final Report

5/18/2009

- Update Final Report

5/27/2009

- Final Rap up of report

Resources

Personnel

Alena Abukhovich, Candace Castillo, Chris Mitchell, Ante Tomicic, and Suhayl Elkhammas will be doing all the research and the writing on this project. All group members are in their senior year of the ECE program at The Ohio State University. Professor Bibyk and Drew Milley will provide any guidance necessary with regard to the project.

Alena Abukhovich

The student is in the fifth year of education pursuing degree in Electrical Engineering major specializing in Control Systems and Digital Signal Processing. The student has taken a few courses that could contribute to the project design: introduction to logic design, electronic analysis, design and simulation, and introduction to microcontrollers. An internship experience at Rimrock Corporation provided a great foundation for technical writing experience describing machinery sequence of events and operation, as well as testing and evaluating products for possible use in electrical control systems.

Candace Castillo

This member is a fifth year student majoring in ECE with a specialization in computers. She has taken three courses and two labs dealing with digital logic and microcontroller programming. This experience will be helpful in design implementation. She has also had several internships in which she participated in a design project where she needed to come up with a design, build, and report results. In her internships, she also was able to gain a lot of experience in technical report writing as well as presenting. This will also be helpful for the project in design reporting.

Chris Mitchell

This member is a fifth year Electrical & Computer Engineering student, specializing in Computer Engineering. He has completed three courses and two labs on digital logic, design and microcontrollers.

Through multiple internships, he has gained a wide range of experience from debugging issues in existing hardware to designing and producing software packages. The digital logic, design and microcontroller classes will be beneficial to the development of this project, while the project management skills acquired from the internships will help with the organization and structure of the project.

Ante Tomicic

This member is a fifth year ECE student, with an emphasis in power and communications. He has taken two courses regarding digital logic and design, where microcontrollers were first introduced to him. In addition, in an internship at Rockwell Automation this student was professionally trained on the Micrologix family of microcontrollers and was put into an engineering sales position. Two control and digital signal processing courses along with a circuit design course conclude his relevant engineering knowledge for this project.

Suhayl Elkhammas

This member is a fifth year ECE student, specializing in Computer Engineering. The student has experience in various programming languages, as well as, programming a microcontroller. The student has taken technical writing courses which will be useful for the report write up. The student conducted experiments to measure the behavior of Electrical Circuits and designed and built systems using parallel interfaces, timing operations, analog to digital conversion, and keyboard interface and scanning.

Facilities and Equipment

The facilities used for the project are located in Caldwell Lab at the Ohio State University. Personal Computers were used for testing purposes; the group met in the Caldwell Lab as well as arranged the meetings outside the lab throughout the quarter.

Schedule History

The team completed documentation in December 2008. All the necessary parts have been ordered and received in January-February 2009.

The schedule for the Winter Quarter 2009:

Begin design approach in January 2009

- Week 1-4: facility set-up, beginning the design approach, ordering the parts from the TI's website
- Week 5-6: completing the design for review and starting the system integration, midterm presentation
- Week 7-8: completing the system integration, receiving the GPS kit and the self recordable and speaker module, getting familiar with the GPS system
- Week 9-10: complete testing, presentation, final report

Finalize Design and Documentation by March 2009

The team could not get all the parts to work together. However, the GPS system was studied thoroughly and the team members managed to link the remote device to the hand-held unit of the microcontroller.

Costs

<u>For the given design the following parts have been ordered:</u>

5x TI-MSP430 -$49.00 each (used TI part voucher for to obtain part)

1x SiRF GSD 3tw – got the part at no cost (original price $700)

5x Voice Recorder 6-second self recording and speaker module - $11.99

<u>The components necessary for final design implementation:</u>

1x TI-MSP430 -$49.00 each (used TI part voucher for to obtain part)

1x SiRF GSD 3tw – got the part at no cost (original price $700)

1x Voice Recorder 6-second self recording and speaker module - $11.99 (for a pack of 5)

Design Review

From beginning to end of the project, our system design incurred many changes. Changes were based on the feasibility of the project. The final and overall system design is composed of three main components. First is the hand held device, second is the remote tracking device, and third is the GPS receiver. The hand held device will be used to initiate a tracking on the remote device, as well as display the read out given by the remote tracking device. The remote tracking device will be a unit, which is placed on the device that is to be tracked. For both the hand held device and the remote tracking device, we have chosen to use the TI MSP430 ez-RF2500. The demo that came with this package, allowed for wireless communication between the two devices. We have been able to modify this code so that it is able to transmit and receive the appropriate data for our project. We have also acquired a demo GPS SDK from Wi2Wi for this project. The GPS receiver is used to retrieve the signal from the tracker and determine the location.

Software for the hand held device has been configured so that it will establish the communication with any remote device within its range and manage this connection. The software for the remote device has been configured to continually attempt to establish communication with the hand held device.

Appendix A: Code for Handheld Device

```
void HandleInputs()
{
 //Handles inputs from the user intructing what to do.
 bool dataToSend = false;
 decimal msg[4];
 if (BSP_BUTTON1)
 {
  //Set GPS coordinates
  msg[0] = 0;
  //Need to implement a system to allow users to input dynamic data
  msg[1] = 0.0;
  msg[2] = 0.0;
  msg[3] = 1;
  dataToSend = true;
 }
 else if (BSP_BUTTON2)
 {
  //Activate search request
  msg[0] = 1;
  dataToSend = true;
 }

 if (dataToSend)
 {
  if (SMPL_SUCCESS == SMPL_Send(linkID1, msg, sizeof(msg)))
  {
    //Data sent properly.
    BSP_TOGGLE_LED2();
    BSP_TOGGLE_LED1();
  }
 }

}
```

NOTE: Additional code handling the linking of the microcontrollers was provided by TI and can be obtained from
http://focus.ti.com/analog/docs/techdocsabstract.tsp?familyId=936&abstractName=slaa325

Appendix B: Code for Remote Device

```
void processIncomingFramed(decimal latitude, decimal longitude, decimal radius)
{
 // process all frames waiting
 for (i=0; i<sNumCurrentPeers; ++i)
 {
  if (SMPL_Receive(sLID[i], msg, &len) == SMPL_SUCCESS)
  {
   if (msg[0] == 0)
   {
    //Indicates GPS coordinates should be set
    latitude = msg[1];
    longitude = msg[2];
    radius = msg[3];
    BSP_TOGGLE_LED1();
    volatile int i;
    for(i = 0; i < 0x5FFF; i++){}
    BSP_TOGGLE_LED1();
   }
   else if (msg[0] == 1)
   {
    //Indicates the object should check current coordinates, if outside of perimeter, play sound
    decimal coordinates[2];
    coordinates = GetGPSLocation();
    if (!WithinRange(coordinates, latitude, longitude, radius))
    {
     PlaySound();
    }
    BSP_TOGGLE_LED2();
    volatile int i;
    for(i = 0; i < 0x5FFF; i++){}
    BSP_TOGGLE_LED2();
   }
   else
   {
    //Received invalid data, flash flights
    BSP_TOGGLE_LED1();
    BSP_TOGGLE_LED2();
    volatile int i;
    for(i = 0; i < 0x5FFF; i++){}
    BSP_TOGGLE_LED2();
    BSP_TOGGLE_LED1();
   }
}
```

```
void PlaySound()
{
 //Activate power to trigger sound to begin playing
 volatile int i;
 for(i = 0; i < 0x5FFF; i++){} //Shut off power to card, should continue playing from indepenant power source
}

bool WithinRange(decimal[] coordinates, decimal latitude, decimal longitude, decimal radius)
{
 var R = 6371; // radius of the earth in km.
 var dLat = (coordinates[1]-latitude).toRad();
 var dLon = (coordinates[0]-longitude).toRad();
 var a = Math.sin(dLat/2) * Math.sin(dLat/2) +
       Math.cos(coordinates[1].toRad()) * Math.cos(latitude.toRad()) *
       Math.sin(dLon/2) * Math.sin(dLon/2);
 var c = 2 * Math.atan2(Math.sqrt(a), Math.sqrt(1-a));
 var d = R * c;
 if (d > radius)
 {
  return true;
 }
 else
 {
  return false;
 }
}

decimal GetGPSLocation()
{
 //Activate GPS controller and retrieve current GPS location
 //To be implemeted at a future date.
 return {"0.000","0.000"};
}
```

NOTE: Additional code handling the linking of the microcontrollers was provided by TI and can be obtained from
http://focus.ti.com/analog/docs/techdocsabstract.tsp?familyId=936&abstractName=slaa325