BFound

Scholarship Report

Scholarship report for my 2013 electronics project, BFound, which is a Windows Phone based item finder system.

Background

During a conversation, my client expressed his frustration over losing his keys. He said that his niece usually wanders off with them and hides them in some unknown place. After countless hours trying to retrieve the old set of keys, my client is usually required to get a new set of keys made. He finds this as not only an unnecessary "waste of time" which greatly reduces the productivity of my client but also results in a huge amount of anxiety, stress and unnecessary spending as he would have to get a new set of keys made. In some instances, he has to get the locks replaced because replacement keys can't be made for certain existing locks. This situation inspired me to come up with a solution as it is something that is faced by everyone on a regular basis.

An eBook called "How to Find Lost Objects" by Professor Solomon contains a few handy tips to finding lost or misplaced items such as remembering to keep the keys in a specific place each time or hanging them around your neck, but is nothing more than information and tips that could be taken into consideration when looking for lost or misplaced items. According to the National Association of Professional Organizers, people on average spend a year of their lives searching for lost or misplaced items. Also Americans, collectively waste 9 million hours every day looking for lost or misplaced items. After all of which most lost or misplaced items are not found.

> "The quickest way to find something you've lost or misplaced is to purchase another just like it" —GEORGE BERGMAN

As the above quote suggests, purchasing another is the quicker and easier option however it incurs a cost which may or may not be considered huge but it is an unnecessary spending. When I enquired at Smart Services in Westfield St Lukes, I was told that the general price on the market for cutting keys is $NZD 10 per key where the average set of keys contains 10-12 keys valuing it at $NZD 100 - $NZD 120. This however, doesn't account for certain keys which have inbuilt remote transponders such as car keys. According to AutoKey, these types of keys by themselves can be valued between $NZD 20 - $NZD 1500 therefore increasing the total value of the set of keys. This spending doesn't and cannot account for the time wasted or the anxiety and stress experienced while searching for the lost or misplaced keys. Among the most common misplaced or lost items are also wallets, rings, scissors, notebooks, important documents and many more. Although my client initially didn't express to me his concern for losing these other items, I have made sure by consulting him that extending the use of my device to help find any item would be essential as it extends the use of the device making people more open to integrating the device into their lives.

My initial concept involved a futuristic approach to solving the issue where an x-ray type image would show up on the user's mobile phone in real time showing them exactly where the item they are looking for is. Although this would be a very ideal solution, this system cannot be built with existing technology and would require such technology to be invented. Since my knowledge, experience and time are very limited, it would be highly unlikely for me to be able to invent such a system and attempting to do so in the time available may have a great effect on my academics and also my health therefore, I have decided to innovate with existing technologies.

Key Stakeholders

My first and most important stakeholder is my Client as my project is being designed to address the situation faced by my Client on a regular basis. Throughout my project, I will be talking to my Client frequently to get his opinion on potential features of the device and also possible changes to the

original plan. This situation faced by my client is very common as people usually misplace items whether it be knowingly or unknowingly and end up going through a lot of anxiety, stress and waste valuable time while trying to retrieve these items.

My next and equally important stakeholders is Murray, an acquaintance, who usually complains that he is getting old because he keeps forgetting where he keeps things. When I mentioned my project to Murray he was very excited and said "I'd definitely buy that." He said that this device could potentially save him a lot of time and effort and also save him from the anxiety and stress encountered during the retrieval process. This is a situation faced by many of the elderly as they tend to forget where they keep things. Although the forgetfulness faced by my stakeholder is not very serious, there are many people who suffer from diseases such as Alzheimer's or any other form of dementia who usually go to the extent of turning the house upside down in order to find the item of interest. Since the situation faced by my stakeholder is quite common, Murray is representative of the elderly and also those who suffer from diseased such as attention deficit disorders, Alzheimer's or any other form of dementia.

My next and equally important stakeholder is a mother of two young children, who regularly misplaces things all around the house as she is constantly chasing her children. She finds that having to retrieve these items becomes a task on its own and is very stressful and time consuming. During this time, she is unable to monitor or attend to her children making it very difficult to focus on either task adding to the amount of stress encountered. She expressed to me that she is late to important events quite often due to the fact that all her things are involuntarily scattered throughout the house. When I told my stakeholder about my project, she said that this device could potentially be a "life saver" as she would no longer have to turn up late to important events and also, she wouldn't have to deal with the anxiety and stress trying to retrieve these items usually bring. She also said that she could potentially be saving a lot of time and money because in many cases, after countless hours of searching for the misplaced item, she is often buys another such item to replace the original only to find the original item a few days later This is a situation faced by many people who cook on a regular basis therefore my stakeholder is representative the general public but mainly of mothers with young children.

I will be speaking to all my key stakeholders on a regular basis, at least once during each major stage of my project. I will however, be talking to my client more frequently. I will be doing this so that I can get their opinion on potential features and also possible changes to the original plan.

This project is mostly based on the software which might be a major challenge for me as I am not a highly skilled programmer nor do I have complete knowledge of any particular programming language. Also this project will require me to work on multiple development platforms some of which I have never used before therefore adding to the difficulty and complexity of the project. The limited amount of time also creates a challenge because I need to be able to finish my project within the given amount of time using the resources available to me

Conceptual Statement

My client has expressed to me that he has misplaced numerous sets of keys on several occasions. This device, an Item Tracking device, would simplify situations such as my clients while providing a convenient and stress-free method of searching for misplaced items. This device is intended for everyone but is especially useful for the aged and those with some form of dementia.

Physical and Functional Attributes

The physical and functional attributed of the device are detailed below. This device will feature:

- **Light** is triggered through the smartphone to make locating the item easier.
- **Buzzer** is triggered through the smartphone to make locating the item easier.
- **Red status LED** signals whether there is an active Bluetooth connection or not.

Specifications

For the device to be fit for purpose, it has to meet the specifications of my client and stakeholders. These specifications are detailed and justified below. Having discussed the required functionality of the device, my client and stakeholders specified that:

- the device must be very easy to use and require minimal maintenance. This is especially important as it is a device that is intended for all age groups where people from certain age groups might not have the patience to try things out in order to get the device working.
- the device must function with as less user input as possible. This is to avoid confusion as many buttons add to the complexity of operation.
- the user must be able to see exactly what the BFound tag is doing from their smartphone. This is so that the user is informed of the functions being performed by the device.
- it would be nice if the device could be controlled via voice commands. This would make operating the device much easier and user friendly therefore saving time and making it more useful. Although this was a suggestion made by my client and stakeholders, they weren't forceful for me to implement this functionality urgently.

Existing Solutions

The main purpose of my project is to design and develop a system which is easy to use and relatively inexpensive that solves my client's issue of misplacing his keys. There are many such solutions already available on the market which will be explained in detail below. Most of the products detailed below work on the same concept as the "locator" button on the base of a cordless telephone which can be used to locate the handset.

The first generation of products that aimed to tackle this issue activated a light and a sound when the user clapped or whistled. These products were more popularly known as the Whistle Key Finder. Their range was limited to the how loud the user could clap or whistle. Also these products were easily triggered falsely as they had difficulty determining what a clap or a whistle was therefore resulting in poor performance. It is due to this poor performance and reliability that these products were not very popular and were therefore discarded from use.

Figure 1

The Key Ringer is described as the "most advanced remote control locator and lost key finder" which uses Radio waves to communicate between the remotes therefore has a relatively large range of about 200 feet or 60 meters and each remote is said to have a battery life of approximately 24 months. The product is sold as a pair of remotes which retails for $USD 29.99 however if multiple items are tagged with the remote controls, the activation of one remote activates the buzzer and flashing lights on all of the remote devices which all then have to be manually turned off until the

item of interest is found. This is a drawback even though it reduces anxiety and makes finding items much more efficient as it takes a lot more time to find the object of interest than it should.

Figure 2

The Click 'n Dig! comes in different variants starting at $USD 29.95 and also follows the remote control concept which works on radio frequency and has an operating range of about 60 feet. Each variant of the device comes with a transmitter and a number of color coded receivers which have inbuilt buzzers and flashing lights that can be activated. Pressing a colored button on the transmitter activates the buzzer and flashing light on the corresponding receiver. The product webpage shows the approximate battery life of each transmitter and receiver to be 3-12 months depending on usage. Although this device is much more efficient in finding objects, it is limited in the number of objects that can be found using one transmitter and requires the user to remember the color that corresponds to the item they are looking for. Also each transmitter only works with specific receivers therefore limiting the usage and application of the device further.

There are many other products on the market such as EZ-Find!, Find One Find All Key Finder and LOC8TOR Plus Pack all of which follow the remote "locator" concept and work on radio frequency with each being slightly different than the other in terms of features. For example, LOC8TOR Plus Pack which gives a user an approximation of how close they are to the tagged object of interest. All of these devices however require the user to have a proprietary transmitter with them which not only increases the cost of the whole system but also creates a sense of extreme dependency on that transmitter.

A much more modern approach to this issue is taken up by the Find My Keys! iPhone app which assists the user in remembering where he/she last put their keys by giving them a list of places where they had found their keys previously. These events have to be recorded into the app by the user. Although this app is a step towards a smarter approach it is no more than a list and is very limited in functionality that is helps to remind the user of where they might have kept their keys rather than helping them find/locate them. Also this app is limited to the iPhone or iOS based devices which is a drawback in the age when there are many other mobile operating systems.

Figure 3

After thorough research into the context of the issue, I have decided to solve this problem while taking into account the existing modern day technology and trying to integrate my solution into the user's lives seamlessly. My solution for this problem is to design an object tracking device which essentially works like a metal detector. The keys to be tracked are tagged with a small chip and can be located using a smartphone app. The smartphone app gives the user controls to set a buzzer to assist them in manually finding their keys while the option of setting an LED allows for easy location is dark areas such as cupboards. I have decided to integrate my device into the already existing smartphone as it eliminates the requirement of having to carry a special transmitter around. With smartphones becoming seemingly popular which is evident through the latest news that smartphone sales in Q1 of 2013 surpassed that of feature phones, I thought that integrating my device into smartphones is a smarter approach towards solving the problem than making a

proprietary transmitter for device. Integrating my device into a smartphone also means that it can be implemented very easily by users with minimal costs as people usually have their smartphones with them 96% of the time. Since my client uses a Windows Phone device, my solution has to be based on the Windows Phone platform in order for it to be fit for purpose.

Windows Phone 8 development platform

This project is mostly based on the software which might be a major challenge for me as I am not a highly skilled programmer nor do I have complete knowledge of any particular programming language. Also this project will require me to work on multiple development platforms some of which I have never used before therefore adding to the difficulty and complexity of the project. The limited amount of time also creates a challenge because I need to be able to finish my project within the given amount of time using the resources available to me.

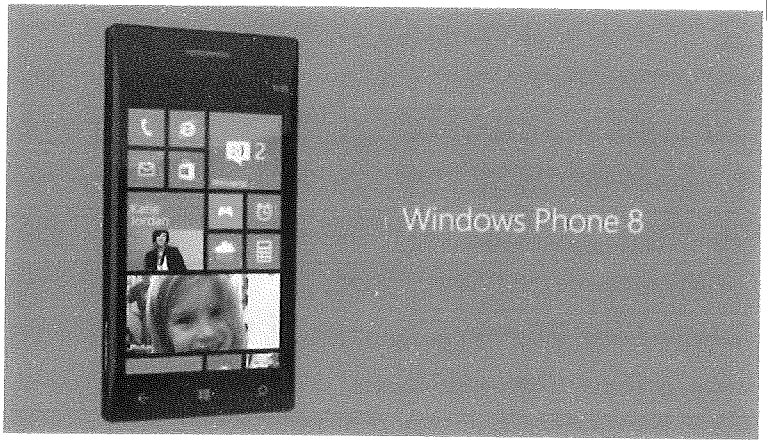


Figure 4

I recently got a Windows Phone device for which I began experimenting with the App development opportunities of the platform and seeing that such a product would be the first of its kind on any mobile platform, I decided to contact a local company, OptimizerHQ asking for assistance with developing the phone app. Also, since the Windows Phone platform is a relatively new platform to the market, there are very few tutorials on how to develop apps on the platform. With no experience in developing apps for the Windows Phone platform, I decided to email both my phone manufacturer Nokia and Microsoft requesting assistance with developing the phone app for my project.

While waiting for replies from OptimizerHQ, Nokia and Microsoft, I spent time doing more research into alternative ways to have control of these remote tags and also researching on how to make the BFound tags themselves.

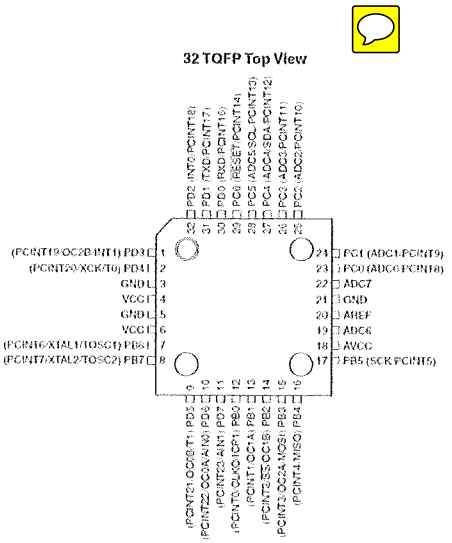
Microcontroller

A microcontroller is essential to have included in the design of the BFound tag as it allows processes to be executed under given conditions or control from the BFound Beta Windows Phone app. This allowed me to design a self-reliant tag that was able to react to commands received from the phone app and perform the specified task. Although many different families of microcontrollers are available on the market such as Atmel, ARM, PICAXE etc., I have decided to develop the BFound tag on the Atmel based microcontroller mainly due to my familiarity with programming that family of microcontrollers and also because of the hardware features available on the platform. The price, availability, size and feature set of the microcontroller was also taken into consideration before

choosing the microcontroller that would be used in the BFound tag. The software written for the BFound tag was done in C due to my familiarity with that programming language although it could have also been done in BASIC or Assembly, but since C is a high level programming language that has low level features, it is my preferred choice.

While selecting the microcontroller to use for the BFound tag, I had to take into consideration the power requirements, hardware features, physical size, availability and also the price of the microcontroller.

Many different development platforms were used during the trialling and testing stage of the BFound tag which include the Arduino, Atmega16 microcontroller and Atmega48 microcontroller before finally settling with the Atmega328P microcontroller. My initial development began on an Arduino as it is a very easy to use development platform which requires barely any low level register configurations. The main purpose of using the Arduino development platform was to try and establish a Bluetooth communication with the Windows Phone 8 device. Once this I was able to establish a connection, I shifted over to the Atmega development platform as this is the platform on which the final prototype will be based on.



The Atmega328P in the TQFP package was chosen for the final prototype of BFound because the physical dimensions of the microcontroller allowed for the final prototype of the BFound tag to remain as small as possible while maintaining full functionality. Also, since the microcontroller has a very low power consumption, it allows for the batteries running the device to last much longer while the 32KB programmable flash memory makes the device future-proof as it can be upgraded to the latest firmware without having to make any hardware changes to the device. This microcontroller also allowed for UART communication which is a requirement for the BFound tag as that is the only way to establish communication between the HC-06 Bluetooth module and the microcontroller. Another reason why the Atmega328P was chosen for the device was because of its cost efficiency therefore decreasing the overall cost of each tag while maintaining full functionality.

The TQFP package of the Atmega328P microcontroller ended up being that was used in the final prototype of BFound tag. The Atmega328P is an 8 bit microcontroller manufactured by Atmel which is essentially the same as the Atmega48 but with a larger programmable flash memory. The microcontroller I have used in my final prototype is the PicoPower variant of the Atmega328 microcontroller which means it can run on very low power. The Atmega328 has a 32KB programmable flash memory, 1KB static RAM and 512 bytes of EEPROM. The flash memory has an endurance of 10,000 write/erase cycles and the EEPROM of 100,000 write/erase cycles. The Atmega328P is a 28 pin microcontroller of which 23 pins are I/O (Input/Output). The I/O lines are divided into three 8 bit ports which are designated as PORTB, PORTC and PORTD. This microcontroller runs at a maximum speed of 8MHz with the internal RC Oscillator. The microcontroller also has a number of peripherals built in like USART and SPI. Each of the IO pins is assigned an alternative task which relate to the built in peripherals as shown in the pin diagram. This information and diagram was extracted from the Atmega328 datasheet.

Through the conversation I had with my client and stakeholders, I realised that the chances of Microsoft, OptimizerHQ or Nokia getting back to me offering assistance with my project are very slim. Therefore I decided to choose one of my concept ideas based on the research considering the negatives and the positives of each concept. This way I would make some progress with my project but I am still keeping a lookout for their replies. Based on the advice I received from my clients and stakeholders, I decided to resort to my concept and attempted to self-learn how to develop apps for the Windows Phone platform using the Visual Studio for Windows Phone 2012 IDE.

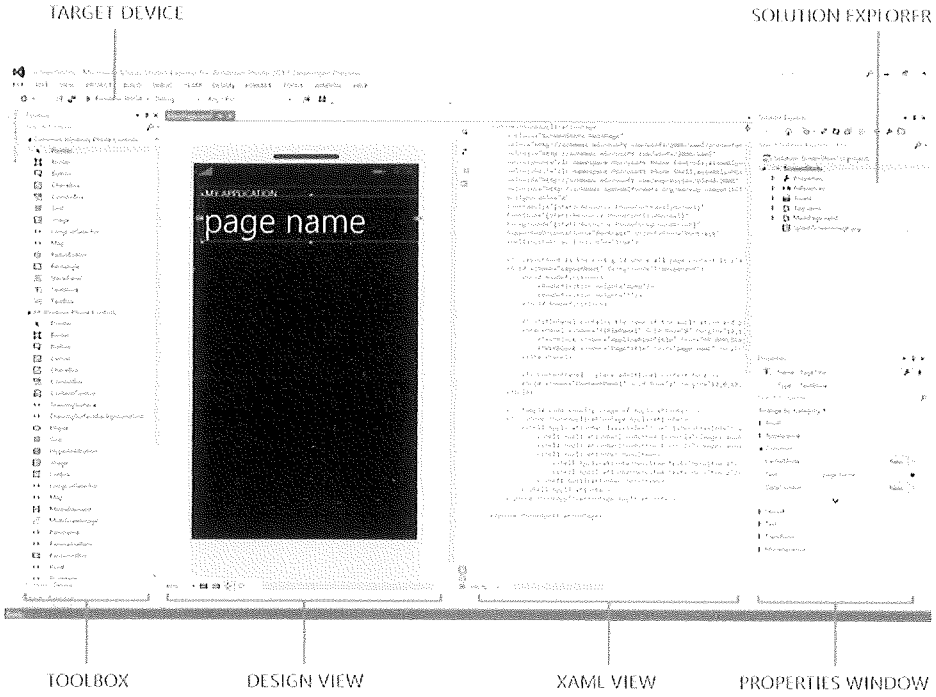


Figure 5

Although this concept requires the use of the Windows Phone platform, I decided to work on it as this concept was the most forward thinking and was entirely different to any of the products already available on the market. This concept was approved by both my client and my stakeholders as they said it was the most easy to use, low maintenance and cheapest solution they have ever seen to this issue.

Wireless communication

The Radio Frequency circuit plays a very important part in the functioning of the system as it is through this method of communication that the BFound tag and BFound Beta Windows Phone app communicate. Many different radio frequency technologies were considered for use in the BFound tag before deciding to use Bluetooth in the final prototype. The main alternative to Bluetooth that I considered was the Zigbee communication protocol.

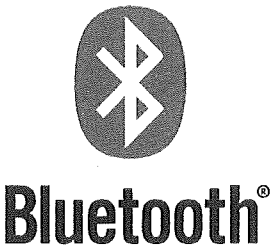


Figure 6

Bluetooth, which was standardized as IEEE 802.15.1, was originally conceived as a wireless alternative to RS-232 communication. With Bluetooth communications providing a way to connect and exchange data between many devices such as mobile phones, telephones, laptops, printers, GPS receivers, game consoles and many more through a secure 2.4GHz short-range radio frequency bandwidth, it is a low cost and very popular wireless communication standard. Since Bluetooth is designed for low power consumption, it is used for short range communication, up to 100m, but the range is power-class dependent and has theoretical data transfer speeds of up to 24Mbps.

Bluetooth would be an ideal option for my system as it is low cost, has low power consumption and is already inbuilt into many of today's devices however; the range of Bluetooth is not very large which may be an issue. Also while the theoretical data transfer speeds of Bluetooth are rather high, they are not very important for the functioning of my system.

Figure 7

Zigbee is a very low cost and very low power wireless mesh networking standard which has a very large range 10-1000m. This standard is internationally standardized as IEEE 802.15.4 and operates in 3 different radio bands around the world – 868MHz in Europe, 915MHz in the US and Australia, and 2.4GHz in the rest of the world. This standard was created to be cheaper than standards such as Bluetooth while having a lower power usage and a larger range. This however comes at the cost of data transfer speeds as the Zigbee standard has a defined rate of 250Kbps. Also, Zigbee can activate from sleep mode in less than 15ms therefore resulting in a very low latency making the devices very responsive compared to Bluetooth whose wake up delay is about 3 seconds. Devices following the Zigbee protocol are intended for use in embedded applications that are general-purpose, inexpensive and are capable of self-organizing a mesh network that can be used for industrial control, embedded sensing, medical data collection and other such applications.

The Zigbee standard is proprietary and is not found in many of the common household devices such as smartphones, tablets and other such devices therefore increasing the difficulty of implementing the standard within my system. The standard is very low power and much cheaper than Bluetooth with a very large range making it an ideal standard to use within my system. Although the data transfer speeds of the Zigbee protocol are rather low, it is not a very important factor to be considered for my system. Implementing the Zigbee protocol however would mean that user require an external device to be carried plug in to their smartphones therefore increasing the complexity, decreasing the usability of the device and hence defeating the purpose of the system.

After looking at and comparing the specifications of each wireless communication standard, I have decided to use Bluetooth as it is a more popular protocol and is widely present in devices such as mobile phones, laptops and other such devices. Although Bluetooth has a smaller range and higher wake up delay time than Zigbee, it better fits the purpose as it integrates very well into the users' smartphone without requiring any external device to be plugged into the smartphone. I have taken this decision of choosing to implement Bluetooth into my system over Zigbee based on feedback from my client and stakeholders all of whom said they would rather have a shorter range as it is

physically more practical to look in a smaller area while also eliminating the need for having to carry an external device to plug into their smartphones with them to find the item of interest. My client and stakeholders were happy for me to design a Bluetooth based system even though it requires me to design a phone app that is based on Bluetooth. Also designing a Bluetooth based system means that I am more likely to complete making the device in the given time frame. Since the communication subsystem is the most complicated and most crucial, I need to be very cautious in my selection of Bluetooth modules. The Notification subsystem of the device doesn't require many components which keeps the interfacing to a minimum. I will also need to use an LCD screen throughout the development of my device as it is a requirement of the assessment therefore, I will be using it for trialling and testing purposes where I will be able to debug my software much more easily. Since my client and stakeholder wanted an easy-to-use device with as few buttons as possible, basic components such as the buzzer and LEDs need to be added for the user to be able to see different states/processes as they are triggered.

Bluetooth Module

Through my research about the wireless communication protocols and my talk with Mr Nazaruk, I decided to use a Bluetooth based system in my device as Mr Nazaruk suggested that trying to invent a system as in my original concept would be extremely difficult and time consuming. There are many previous projects on the web which make use of Bluetooth communication. These projects also include details such as how they set up a connection with the Bluetooth device and how they communicated with it. These details however were about the Android platform therefore requiring me to establish a Bluetooth connection on my Windows Phone through a trial and error process.

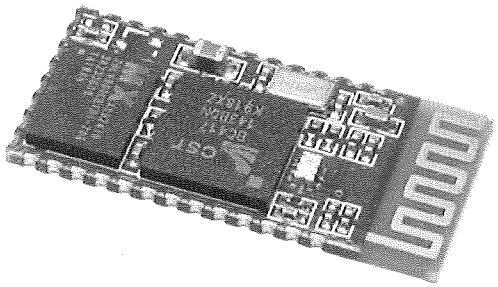


Figure 9

While selecting the Bluetooth module to use for the BFound tag, I came across two relatively cheap Class 2 Bluetooth modules both of which had a serial interface but the communication protocol each of them used was different. The HC-06 Bluetooth module that is interfaced to the microcontroller of the BFound tag contains a 2.4 GHz radio. The Bluetooth radio operates at a frequency range from 2400-2483.5MHz as this frequency is in the globally unlicensed Industrial, Scientific and Medical (ISM) short-range radio frequency band. Bluetooth is a very popular form of wireless communication which allows for data exchange over short distances and uses a radio technology called frequency-hopping spread spectrum that splits the data and transmits it in groups on up to 79 frequencies. The HC-06 Bluetooth module supports UART (Universal Asynchronous Receiver/Transmitter) communication while the HopeFM RFM70 Bluetooth module supports SPI (Serial Peripheral Interface) communication. Although both UART and SPI are serial communication protocols, they are different in the way they achieve this data transmission.

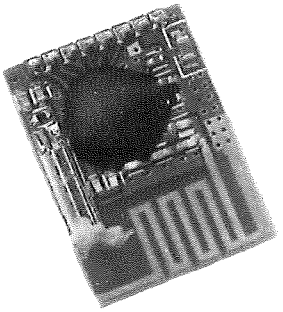


Figure 8

SPI is a synchronous serial communication protocol in which the data transmitted is synchronised by a clock line. UART however, is different because it doesn't have a clock line which is why it is called UART (Universal Asynchronous Receiver/Transmitter). In UART, a start bit and a stop bit are used to

synchronise the data transfer. The HC-06 Bluetooth module communicates with the microcontroller via the standard UART protocol which is compatible with 3.3V-5V TTL (Transistor-Transistor logic).

Having never used SPI before, through research, I found that it is very fast and easy and is especially useful when connecting multiple devices together. The main difference between SPI and UART is that SPI requires clock synchronization lines therefore requires more connections to the microcontroller. This can have an effect on the design of the PCB as a greater number of connections to the microcontroller results in decreased flexibility of the placement of the module, therefore resulting in the BFound tag being larger in size. Also, since I have no prior experience with using SPI, I will be required learn to use the protocol and also write my own SPI library if I am unable to find one that works. This means that I will have to spend a lot more time on the trialling and testing stage which might decrease my chances of finishing the project within the given amount of time. Although both the HC-06 and RFM70 Bluetooth modules are very similarly priced, the HC-06 Bluetooth module was readily available for order while the RFM70 Bluetooth module was out of stock. Through client and stakeholder consultations, I have decided to use the HC-06 Bluetooth module as opposed to the RFM70 Bluetooth module as it is readily available and is based on the UART protocol. The UART protocol is one that I have experience with and have managed to develop my own library making it a lot easier for me to get working resulting in less debugging of the code and hence increasing my chances of finishing the project on time. Also, since the HC-06 Bluetooth module uses the UART protocol, it only required 2 connections to the microcontroller, RxD and TxD. Since there are only two connections to the microcontroller as opposed to the 4 connections required when using SPI, it will make designing the PCB a lot easier and will allow the overall size of the BFound tag to remain as small as possible. Since the use for serial communication in the BFound tag is to create a communication link between the microcontroller and the Bluetooth module, there is no significant advantage of using SPI over UART therefore after client and stakeholder consultations, I have decided to use the UART based HC-06 Bluetooth module.

In the meantime, I received replies from both Microsoft and OptimizerHQ. Both replies had negative responses. The CEO of Nokia, Stephen Elop, however provided me with the contact details of a Nokia developer located in Australia. When I told my client and stakeholders about this, they were surprised. Therefore based on my clients and stakeholders choice, I decided to work on my concept.

Prototype development

Building the circuits on the breadboard was a relatively simple task however, referring back to that same circuit while drawing the schematic diagram on EAGLE was challenging as there were many devices that were interfaced to the microcontroller in a small space, making the breadboard look like a complex mess of wires. During this stage, I had multiple talks with my client and stakeholders, showing them the state of the prototype and explaining to them the function of device. Since all the components were tightly packed together on two long breadboards, my client and stakeholders often complained about the mess and the complexity of the circuit. They suggested laying out the circuit on more breadboards. This way, it would be easier for them to understand when I explain to them and is also easy for me to figure out rather than having to refer to the schematic and double checking connections.

I had to keep changing the pin connections of the devices that were interfaced to the microcontroller to get the best pin configuration. Also I had to spread the circuit out on to more breadboards so that my client and stakeholders would see and listen to the progress of the device.

Before starting any programming work, I had to choose which programming language I was going to use for making this device. I have a choice between using BASCOM-AVR which uses the original Windows BASIC compiler and C. BASCOM-AVR is a very useful IDE as it has most of the libraries already built in whereas AVR-GCC requires libraries to be added otherwise written to make use of certain hardware components. Considering all the positives and negatives of each programming language, I chose to do this project using the C programming language as it is a high level language with low level features. Since I have already worked with this programming language in my project last year, I feel more confident in programming in C rather than BASIC. Also, the phone app that I am required to write is to be written in C# therefore using C will maintain consistency across both systems therefore making it easier for me to research and implement one family of programming language. During the beginning few weeks of this stage, I made sure to test out all the communication protocols I thought I would be using based on the datasheets of the components I was using and research on the internet. This meant that I wouldn't have much difficulty debugging any future errors that relate to these communication protocols. There were many previous projects making use of Bluetooth communication for which the program code was freely available online. This made it easier for me to implement Bluetooth communication in my device. For the Windows Phone app however, there was barely any help available online since this platform is relatively new therefore adding to the difficulty of the system.

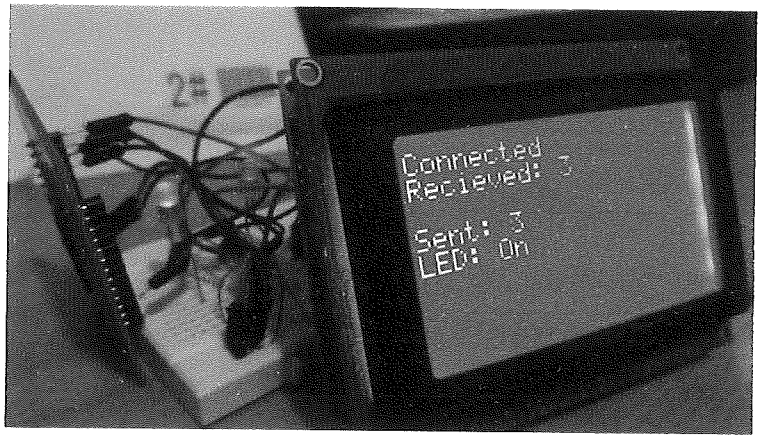
During a recent talk with my client and stakeholders, I decided to make the device more future proof by including an option in the BFound tags where their firmware can be updated remotely through the user's phone. This way, the device will not need to be replaced regularly therefore decreasing the maintenance costs and also contributing to the decrease of e-Waste. This however, does increase the complexity of my device while maintaining simplicity for the end user. The Windows Phone app caused me the most trouble as I wasted a lot of time trying to establish a connection between the BFound tag and the phone. Once I figured this out however, I was faced by another difficulty which prevented me from obtaining RSSI information about the established Bluetooth connection between the phone and the BFound tag. When I told my client, stakeholders, they were confident that there must be an easier way. I realised that I could contact Vaughan Knight whose contact I was given by Nokia CEO, Stephen Elop requesting assistance about obtaining RSSI information of the established Bluetooth connection. My client and stakeholders were also approving of this as they were confident that it will help me finish the project on time.

I should have contacted Vaughan Knight about obtaining RSSI information of the Bluetooth connection as I knew that I would have to implement this feature into the Windows Phone application at some point of time. This would have saved me a lot of time as I wouldn't have to await a reply in order to progress further.

The software that was written for the BFound tag prototype was changed multiple times to suit the development platform hardware at each stage and also to update the functionality of the tag while fixing bugs.

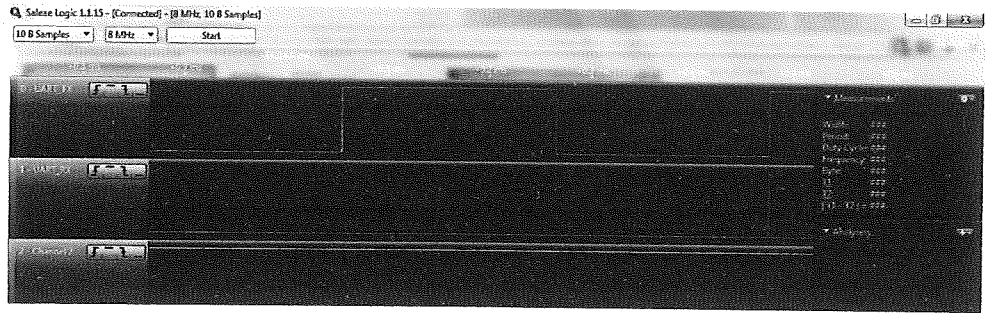
Towards the earlier stages of software development for the BFound tag, a simple logic was employed where the device would perform the task specified by the user. The user however is not informed of whether the task specified by the user has been completed or not. This is not a very efficient or stress free way of performing specified tasks as the user is unaware of what is happening

therefore resulting in the device not being fit for purpose. Through client and stakeholder consultations, I decided to incorporate an echo feature where the BFound tag echoes the command it receives back to the Phone app therefore allowing the user to actively see what has happened. This acknowledgement feature adds redundancy to the system therefore making it more reliable. On receiving the acknowledgement, the Phone app changes its button state to display the status of each notification component on the BFound tag therefore keeping the user informed hence making the system more user friendly and interactive.



During the trialing and testing stage of the BFound tag's software, my client discovered a very major flaw in the design of the device which meant that he had to keep changing batteries very often. When the user set the "Light on" through the phone app, and then quits the app, the light on the BFound tag still remains on therefore wasting battery power and attracting unnecessary attention. This issue was solved by using an interrupt vector for INT0 which detects a change in state of the Bluetooth connection status pin from High to Low. Since the Bluetooth connection status pin follows a square wave pattern with a period of 102ms when not connected, the interrupt vector for INT0 detects this change in state and when the user disconnects the phone application from the BFound tag, the Light is automatically set off. This is a very important feature that was pointed out by my client which increased the power efficiency of the BFound tag. Also, after this client and stakeholder consultation, I have decided to let the buzzer sound 8 times when the sound is set from the phone app as this is much less noisy and don't cause as much disturbance to people in the vicinity as if it were to keep sounding until the item is found by the user.

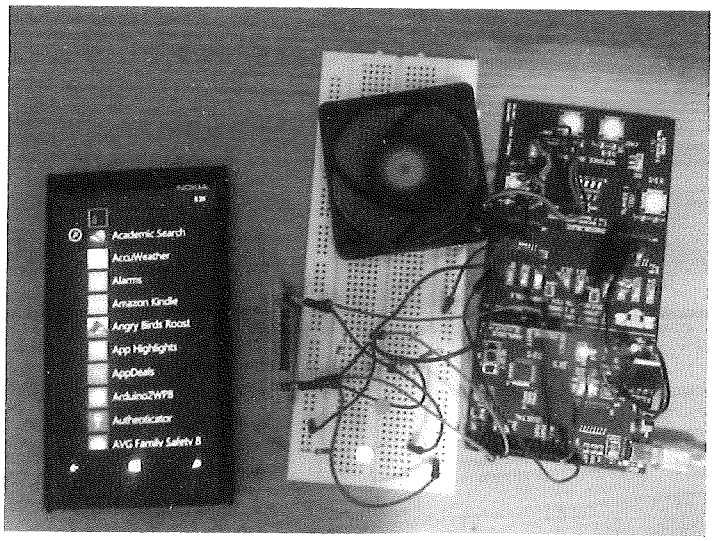
Throughout the trialing and testing process, I also used a logic analyzer to help me debug UART communication issues between the Bluetooth module and the microcontroller. Using tools such as the logic analyzer made this process much easier rather than using the LCD screen or other output devices such as LEDs. An example of the signal received and transmitted when the Light is set on through the phone app is shown in the image below.



Since I had finished writing the software for the BFound tags that worked, I had to work on optimising it so that it is efficient and is bug free. I should have done this while writing the software for the tags. This would have saved me a lot of time. Although, I am waiting for a reply from Nokia's Vaughan Knight, it is vital that I work on optimising this code in order to make use of the available time in the most efficient way possible. This will ensure that I complete the project on time.

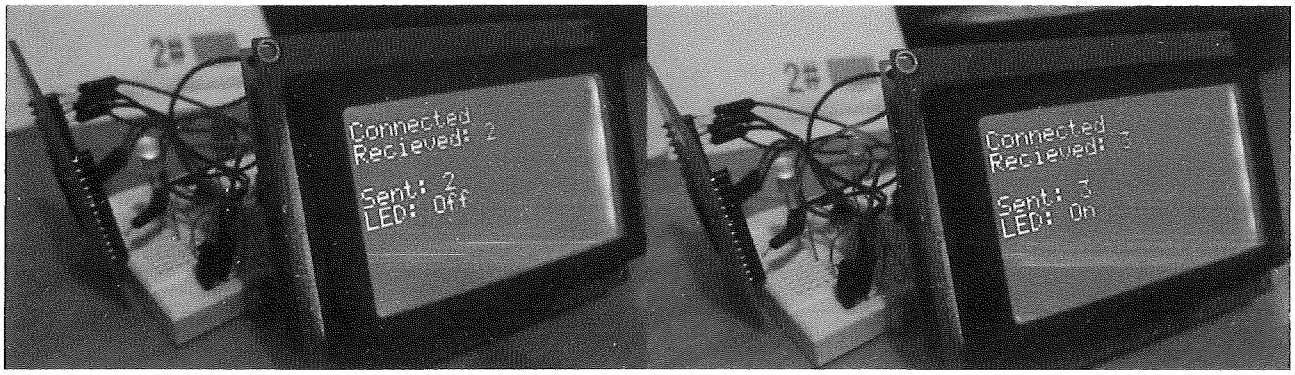
During the trialing and testing process, I worked on with many different microcontrollers, starting with the Arduino board, then the ATMEGA16 before finally basing my final prototype on the ATMEGA328P.

My initial testbed was an Arduino to which I interfaced an LED and a fan as well as the HC-06 Bluetooth module. The reason why I chose to do my initial trials on the Arduino was because of it is a very easy to use development platform which contains almost all of the required libraries to carry out a task. The image below shows my initial test bed which I used to learn how to establish a connection between my Windows Phone app and the target device to enable communication between the two.

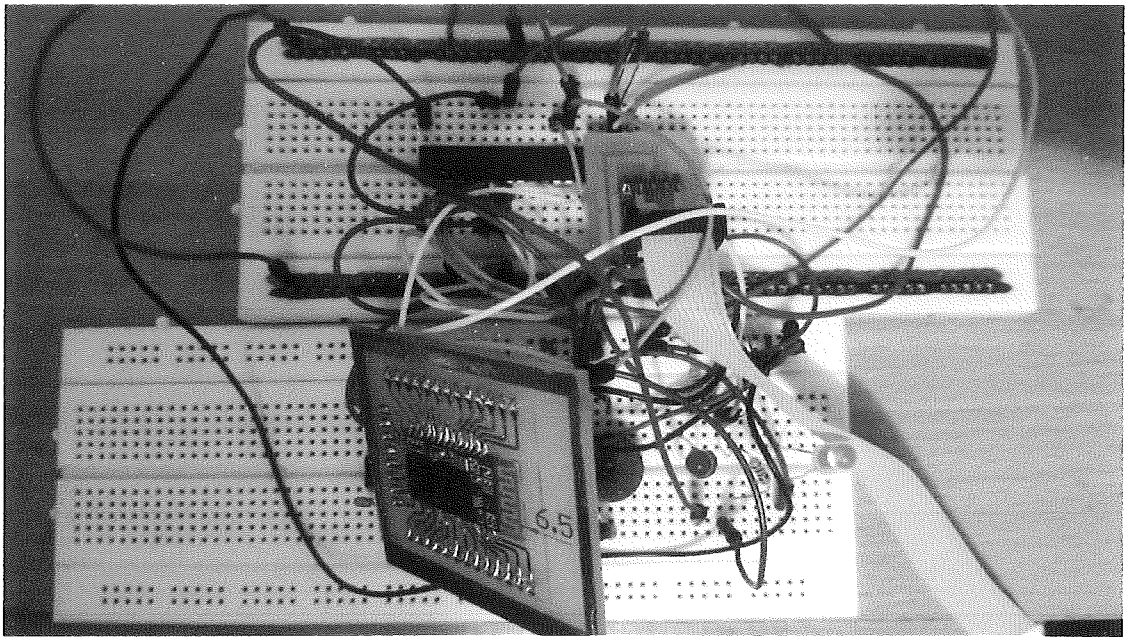


The Arduino provided me with a very easy to use platform through which I could develop my entire project however, Arduino boards are usually quite big therefore using this platform will not allow me to achieve the size and form factor that is required for this project therefore decreasing the device's portability and hence making it unfit for purpose. Since this initial trial worked on the Arduino platform, I have attempted to port this over to the ATMEGA16 microcontroller to which I have interfaced an graphics LCD screen to allow me to be able to debug any errors in a much easier way.

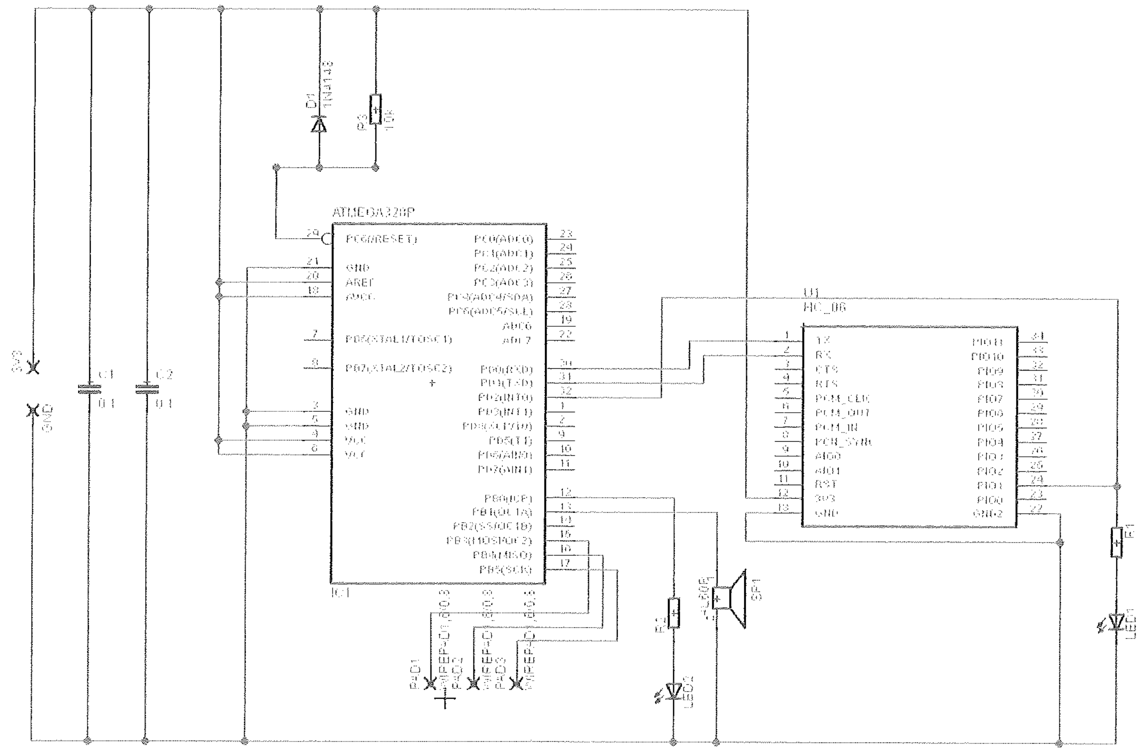
The Atmega16 based test bed is pictured below. This test bed features a graphics LCD screen for advanced debugging capabilities, an LED for easily locating the device in darkness as on the final prototype and a buzzer for locating the device easily through sound also as on the final prototype.

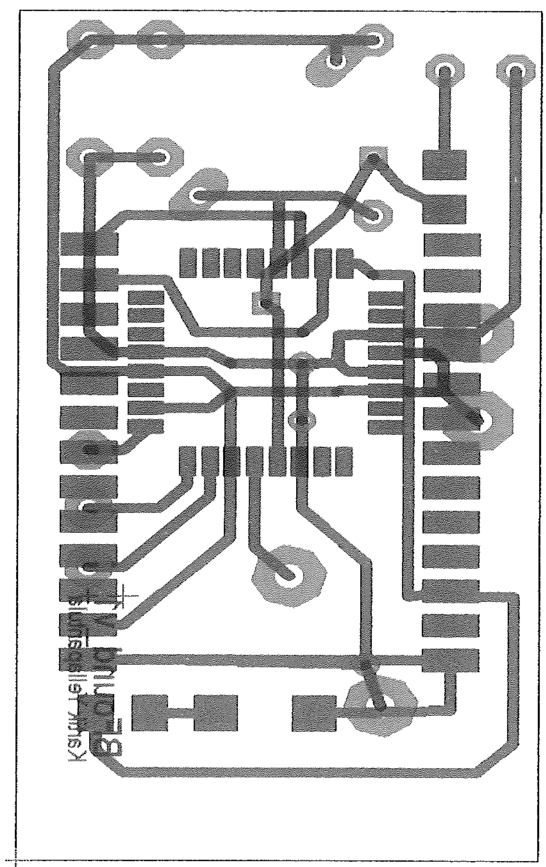


The Atmega16 based prototype allowed me to create software as it were for the final prototype as the final prototype is also based on an Atmel 8-bit microcontroller. I could have easily used this as my final prototype but again, due to this test bed being quite large in size, I will not be able to achieve the form factor that is required for this project therefore decreasing its fitness for purpose as it is not very portable. During the final trialing and testing stages of the prototype, I built a test final prototype using an Atmega168 chip which is exactly the same as an ATMEGA328P except in a different package and with a smaller amount of memory. An image of this prototype is shown below.

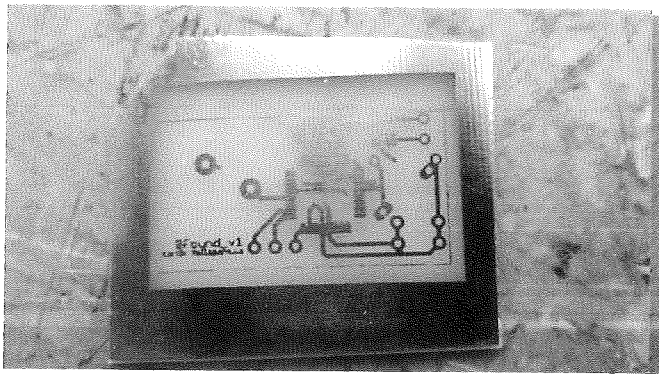


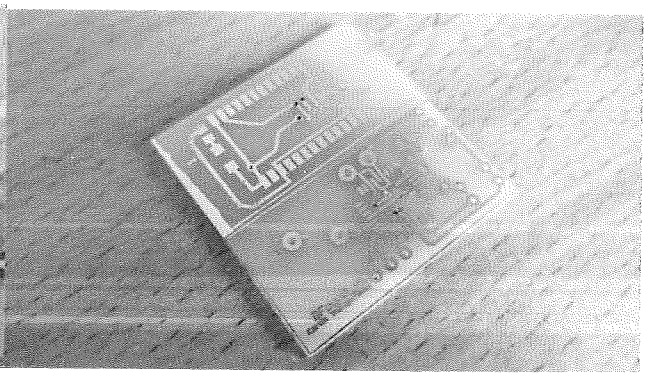
The breadboard layout of the Atmega168 based prototype was the basis on which I designed the schematic and PCB (Printed Circuit Board) layout for the final prototype of the BFound tag. The schematic and PCB (Printed Circuit Board) layout for the final BFound tag are shown below and was designed using EAGLE.

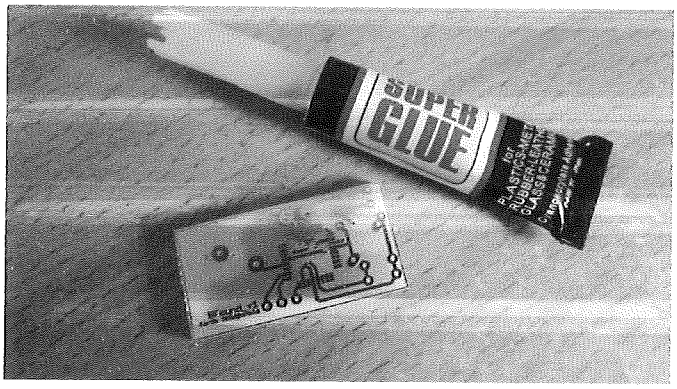

ATMEGA328P
IC1
U1
HC_06



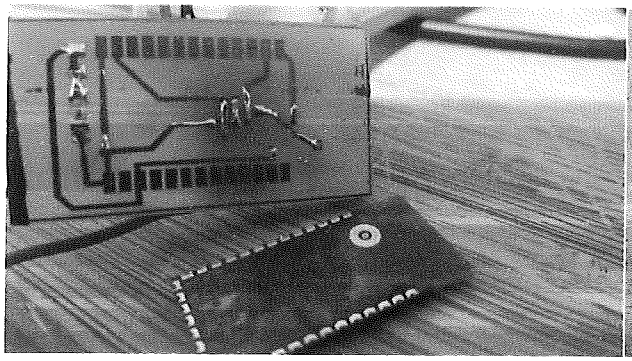
The process of putting this prototype together can be seen through the series of images below. This process was quite challenging as I didn't have access to double sided PCB which is why I have used two single sided PCBs and stuck them back to back using Superglue to achieve the double sided PCB affect. Although this doubled the thickness of the PCB, it had no effect on the overall fitness for purpose of the device.

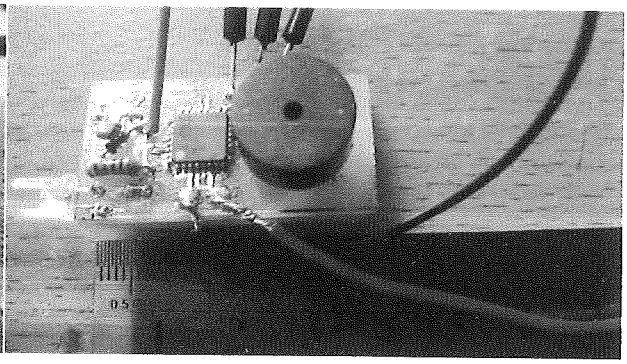


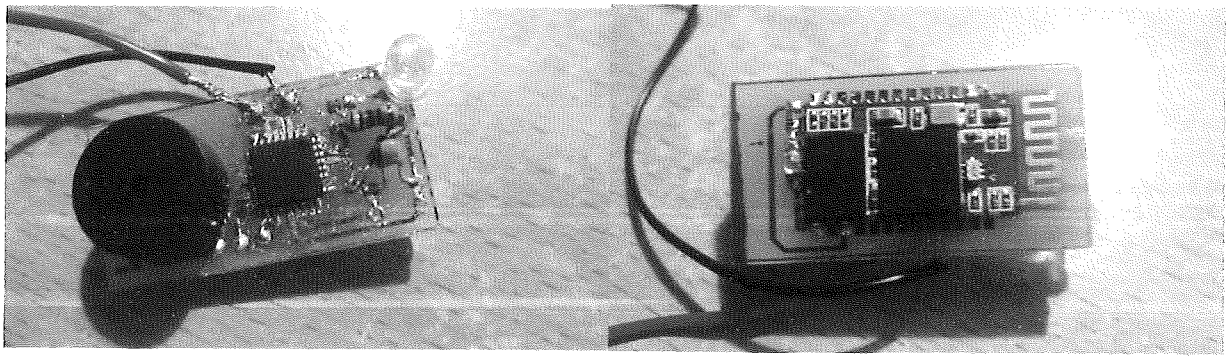




Soldering the components onto the PCB was especially challenging as I didn't have the correct equipment to do so. The size of the components especially the Atmega328P microcontroller made soldering the most difficult task while developing the final prototype of the BFound tag.







This final prototype of the BFound tag is quite small with dimensions of approximately 40mm in length, 20mm in width and 18mm in height. The overall height of the BFound module could have been much less however, surface mount buzzers and high intensity white LEDs were out of stock at both school and online electronics stores. After consultations with my client, stakeholders and Mr Nazaruk, I have decided to use the components available to me to increase my chances of finishing my final prototype of the BFound tag in time therefore allowing me to produce an outcome that is fit for purpose.

Software

During this stage, I put together each part of what would be the optimised code of each BFound tag and flashed it to the finished hardware prototype of the BFound tag. I also worked on the Windows Phone app. I received a reply from Vaughan Knight who advised me that RSSI information for Bluetooth connections is not currently supported by the Windows Phone platform and said that he will contact me when it is enabled in a future update.

I was easily able to integrate and put together the parts of the software starting of the BFound tags and also the Windows Phone app, the beta of which I have published to the Windows Phone Store. I have tested this phone app on two different devices, the Nokia Lumia 920 and the HTC 8S where the app worked flawlessly on both devices. During recent talks with my client, stakeholders and Mr Nazaruk where I explained to them the lack of support for RSSI information in the Windows Phone platform which is why I will not be able to implement a distance indicator between the user and the BFound tagged item. Through discussions with my client, stakeholders and Mr Nazaruk, we agreed that my device would be fit for purpose without the distance indicator feature. When explaining the limitations of the prototype without the distance indicator feature, my client and stakeholders felt that adding that feature would be the most ideal thing to do next in terms of developing the concept further however; they weren't forceful for me to implement that technology by the due date of this project and understood the limitations of the platform the phone application was being developed on. This would mean that my chances of finishing on time are much greater than if I had to look for workarounds to implement the distance indicator feature into the phone app.

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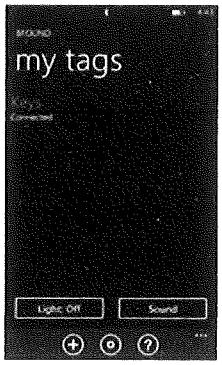
tools + productivity

BFound Beta

Control Center for BFound tags



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Reviews

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Version

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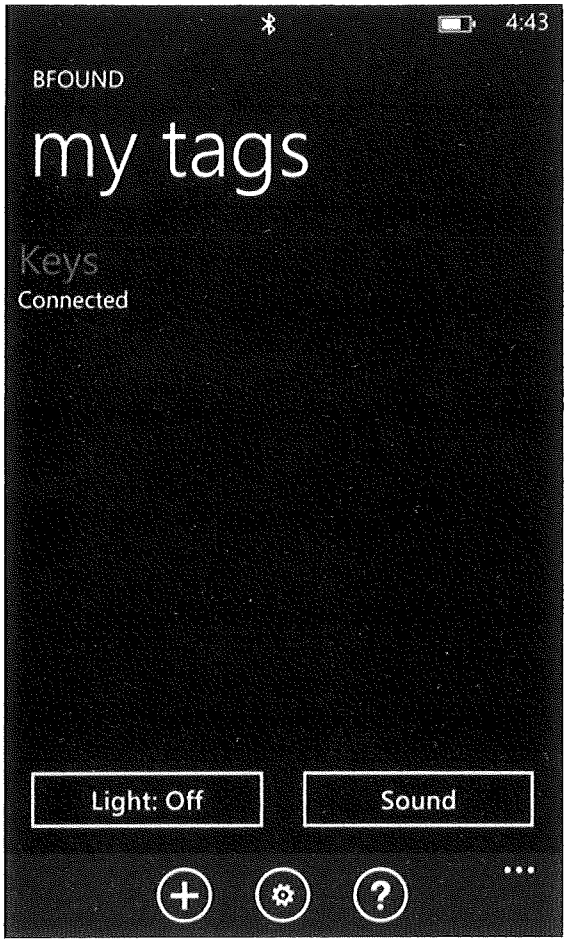
Beta



A beta version of this app has been submitted to the Windows Phone store where it can be downloaded by anyone to trial out. A screenshot of the main user interface of the application is shown below. This app has been designed with simplicity in mind and follows the Windows Phone Modern design language very closely.

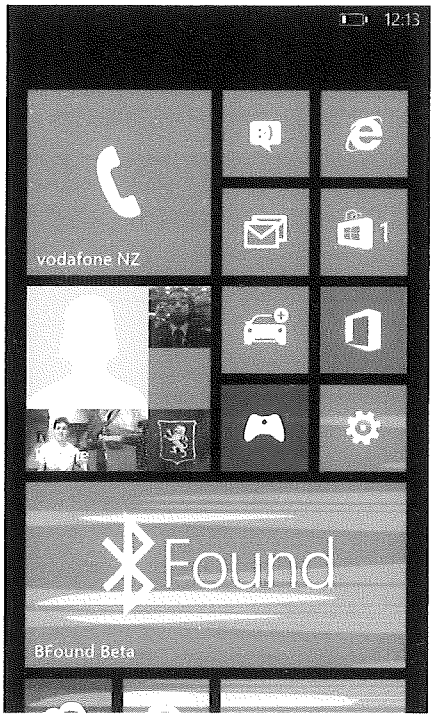
The BFound Beta app which is hosted on the Windows Phone store can be downloaded at the following link or by scanning the QR code as shown above.

http://www.windowsphone.com/s?appid=649e7fec-5483-45d1-9ee1-1a41525fc84c

I realised that I should have thought about and tried developing the BFound app on the Android platform as well which would have allowed me to incorporate all the features I had in plan for the system. This however, wouldn't have deemed my solution as fit for purpose as my client uses a Windows Phone 8 device.

During this final stage, I was able to make my phone app code more efficient while adding graphics and creating a logo for the app as requested by my client and stakeholders. My client and stakeholders were happy with the outcome however they requested that in the future, they would like to see the device being updated regularly with new features that would make the BFound tags more users friendly, customizable and easy to maintain. They requested a custom sound feature as they found that when

multiple people in the same area are trying to look for a lost or misplaced item, it was very difficult to locate their item. Also they were concerned about the security of their items which when tagged show up with the items name such as "MyItem2." Also, since the passcode is a 4 digit pin, anybody with wrong intentions within the range of their item would be able to hack their tag and obtain the item. This security threat was something that my clients and stakeholders wanted me to fix as soon as possible as it could result in other major issues. Also, the BFound tag is not designed to be water proof therefore exposing the tag to water will destroy the BFound tag making the item it is attached to undiscoverable and hence unfit for purpose.



While in the final testing stage, I made sure to have the system tested out by my client and stakeholders in ideal everyday usage conditions with the device attached to a set of keys for a week where they received a fairly decent amount of physical wear. The keys were unintentionally left in jacket pockets which were kept in cupboards, left in drawers and many other unusual places. In all these situations, my client and stakeholders were able to successfully retrieve the keys within 5 mins of realising that they had misplaced them. They did however notice that as there were more obstacles between the set of keys and my phone, the connection range decreased considerably. Through these tests I was able to conclude that my device has a communicating range of 10m to 50m with very little battery drain. I expect the BFound tags to last approximately 1200 hours of use which is a theoretical estimate which is based on the battery drain recorded during that one week of use. My client, stakeholders and Mr Nazaruk were all very happy with the final prototype and wanted me to develop this concept further and said that they can see great potential for such a device in the market. They believed that the final prototype of the device was fit for purpose and were very happy with its functionin

I should have focused more on the security of the system as it raises very important concerns. Although, the security of the system was not a specification given by my client or stakeholders, it

doesn't affect the fitness for purpose of the issue but it is something that definitely needs to be developed.

A video of how the BFound system works and the user's interaction is available on YouTube at http://www.youtube.com/watch?v=nFk08pMs-uM

Gadgets such as BFound might have a significant impact on society's attitude towards putting things in the right place. This is because such a device gives people a sense of security and might result in them becoming careless about where they keep their things.

In the future, devices such as BFound could be superseded by technology which enables users to have items appear in front of them on demand. As said in the quote by George Bergman, it is easier and quicker to replace an item than to try and retrieve it. Thus such technology which has been showcased in numerous Sci-Fi films is likely to be the technology that replaces the need for an item finder device such as BFound. Since such on demand technology hasn't been developed yet, devices such as BFound are likely to be relevant and fit for purpose for quite a while.

Although the outcome is fit for purpose even with a relatively less secure device, I will continue attempting to make the device more secure so that it can be used worry free. Due to the limited amount of time available and limitations in the platform, I had to make certain compromises on the features of the Windows Phone app into which I was unable to incorporate a distance indicator feature, cloud synchronisation of all the BFound tags to allow access from any device, Nokia City Lens type tracking through the SDK, voice control and many other features. The main compromise I had to make however was on my initial plan of making a system that produces an xray type image which would show up on the user's mobile phone in real time showing them exactly where the item they are looking for as designing such a system would be very difficult although it would have been fit for my client and stakeholders purpose. I will however, continue working on the suggestions made by my client, stakeholders and Mr Nazaruk during the late stages of the project as a way to further develop the system.

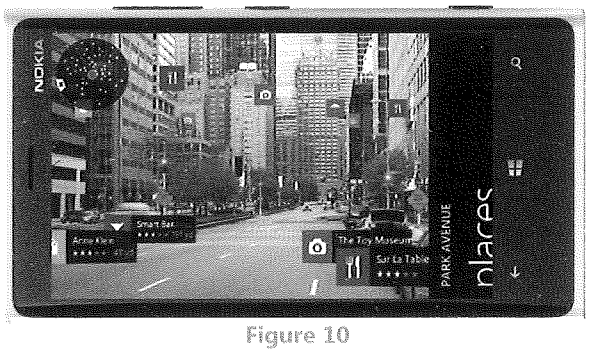


Figure 10

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Figure 2 - http://dealspl.us/Automotive_deals/p_click-n-dig-key-finder-4-receivers-wireless-rf-item
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Figure 4 - http://www.louesfera.com/2012/09/06/vistazo-a-windows-phone-8/windows-phone-8-e1340217410861/
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Figure 7 - http://sanscontact.wordpress.com/2010/08/23/par-dela-la-rfid-et-la-nfc-les-autres-technologies-du-sans-contact/
Figure 8 - http://2.bp.blogspot.com/-ANqBbReXkt4/T99Bw9aJWDI/AAAAAAAAAI0/eBYdC4Yr5Eo/s1600/HC-06.png
Figure 9 - http://newzealand.rs-online.com/web/p/bluetooth-modules/7312795/
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