A Wireless, General Purpose Tamper Detection System with Mobile User Notifications

Group Members:

Group number: 7
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Motivation:

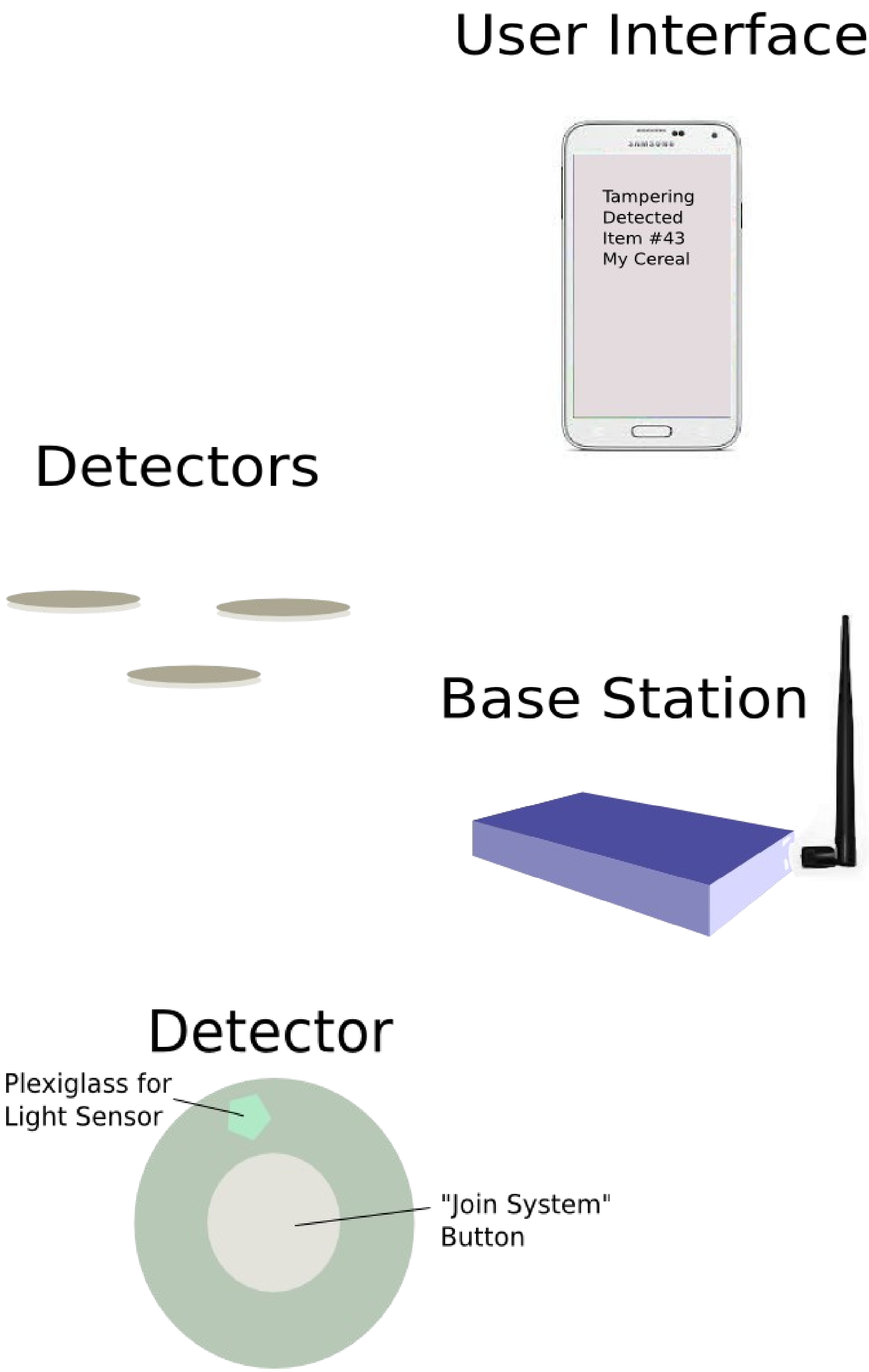
There are plenty of objects around a household which you may not want other people to touch. These may range from the serious, for instance, pharmaceuticals, a safe, or a gun cabinet, to the mundane items, like my goal of preventing someone from eating all my breakfast cereal. The goal here is to solve all of these problems. This can be done by building a wireless, low cost, and easy to use tamper detection system which can be placed on a variety of items and can notify you on your phone when that item has been interacted with.

A major application of this technology may be for parents who are concerned with which items their children are interacting with. If this was the systems true niche, it might be tempting to dub the detectors “don't-touch-me's”. The ability to know that your child has just picked up or moved something they're not suppose to and then to call them seems, although a devastating blow for the inner child inside all of us, a thing of value to the concerned parent. As such, the system should be consumer friendly and not require much, if any, networking knowledge to set up and should then require minimal interaction to maintain. Its user interface should be easily understood as well. Some more technical details follow.

Aside from being low cost and easy to use, it should be small and light weight (ideally enough so to adhered to some flat surface), battery powered with a long battery life, and easily adjusted so that it can effectively detect the tampering of any object in several ways (detecting motion and/or a change in light would be the primary means). The system as a whole should be expandable. In other words, there should be an option to add more detectors to a system when needed. Low-battery notifications seem necessary. Additional features might include an off-line mode which can record data while the device is unable to directly notify the user. Encryption can also be provided if it was desired for some purpose.

In terms of what exists that is similar to this, it can be said that although there are products for specific items such as gun cases, doors and windows, etc..., a quick on-line search turns up no results for such a small, general purpose device as this one. Moreover, the cost off these devices is typically several hundred dollars. A preliminary estimate of the cost of our system gives no indication of why it should cost this much.

Envisioning:



Requirements:

Scalability:

Up to 10 detectors can be used in a system.

The user should be able to push a button on the detector to have a new detector join the system. The user should be able select the detectors threshold settings during this process.

Communication:

The detectors must use wireless communication and work within a range of 15.42 m(50 ft) from the base station unobstructed.

The base station must receive and transmit data between the detectors wirelessly. The base station must use the 802.11 protocol (wifi) to communicate data with an access point. The final step of sending data to the user can take place over the Internet or through an access point.

Define a tampering event as a trigger threshold being crossed more than a minute apart in time from any other crossing of a trigger threshold.

Power Usage and Charging:

The detector must be able to operate wirelessly for 720+ hours(30 days) with one or less tampering events being detected.

The re-powering process for the detector can use wires, but should charge to an operating voltage in less than 10 hours.

The base station must be powered from standard North American wall power(120V, 60Hz).

Notification:

The system must notify the user(connectivity permitting) of low power at least once while the detectors are within the range of 15% to 0% of needed operating power remaining. This must happen before a detector runs out of power.

A tampering event must trigger a notification for the user as long as network connectivity is available between the base station and the user and the detectors are within the communication range of the base station. In the case where network connectivity between the user and base station is not present, the base station should store this notification and deliver to the user when possible.

Sensitivity Settings and Trigger Thresholds:

A detector must be able to recognize when its dynamic acceleration crosses the user selectable variable threshold, g_threshold. The value of the variable g_threshold is selected from the set {off, .1, .2, .3, .4, .5, .6, .7, .8, .9, 1} [g] or equivalently [m/s^2]. Static acceleration (e.g. gravity) should not trigger a tampering event.

A detector must be able to detect when illuminance crosses the variable threshold lux_threshold. The user selectable lux_threshold is selected from the set {off, .1, .5, 1, 2, 3, 4, 5, 7.5 , 10, 20} [lx] or equivalently [lm/m^2].

The detector will have an magnetic which when removed from the outside of its casing will cause a trigger threshold to be crossed. The option to turn this feature will be given to the user as well.

Size and shape:

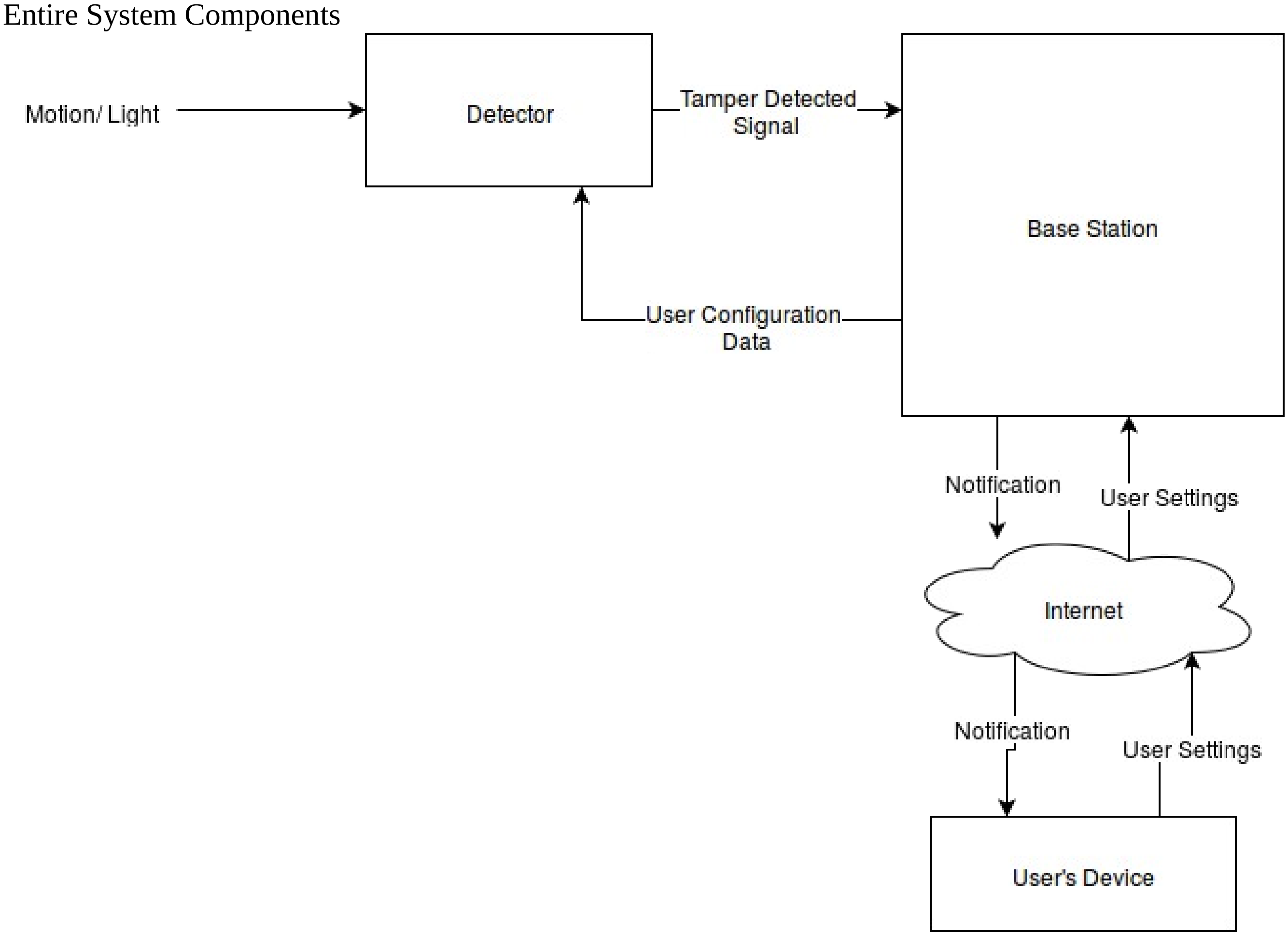
The detector can physically be of one of the two forms(not including the magnet):
-A disk less than 70 mm in diameter and less than 15 mm in height
-A rectangular with sides less than 70 mm in length and a height less than 15 mm.

Mass:

The detector must be less than or equal to 50 grams in mass(not including the magnet).

Block Diagrams:

Entire System Components



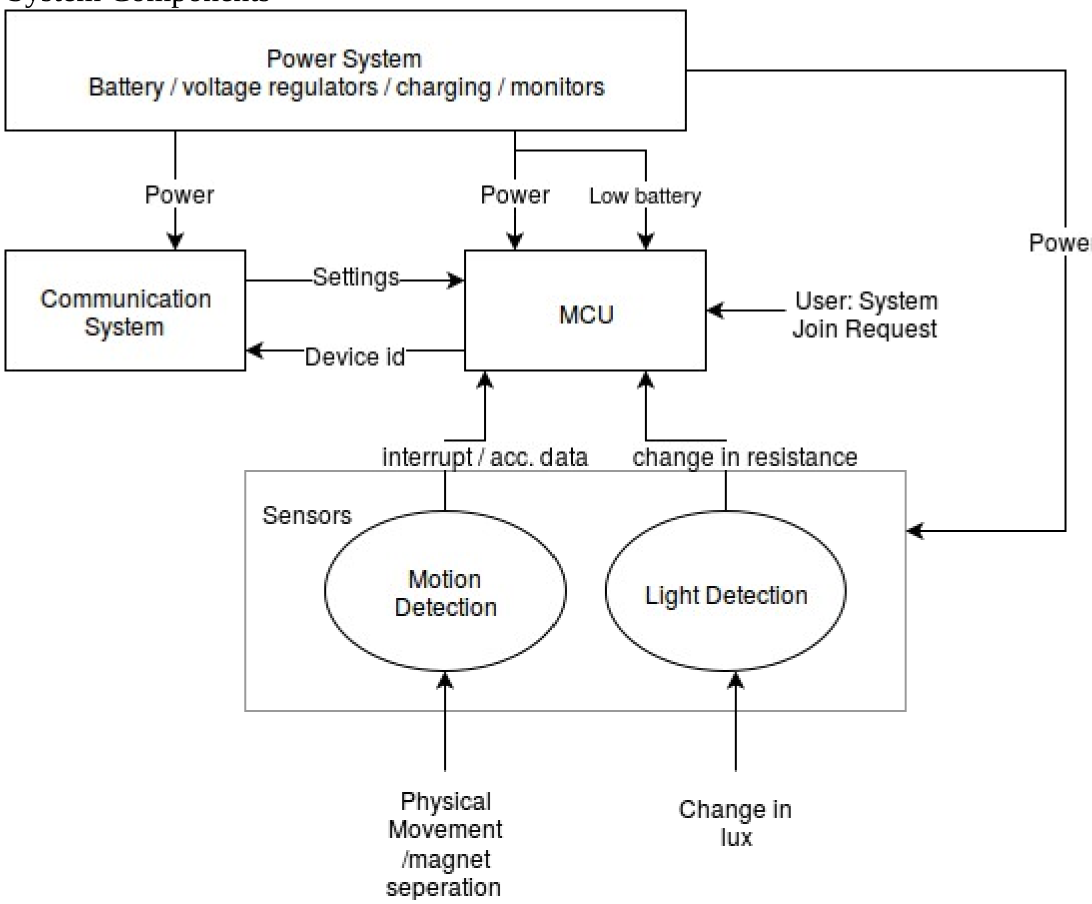
Detector:

Responsibility: All group members at this level of abstraction
Status: Research

Base Station:
Responsibility: All group members at this level of abstraction)
Status: Research

User's Device(Interface):
Responsibility: Daniel Gibney
Status: Design, it's going to be an Android app.

Detector System Components



Power System:
Provides power to all other components of the detector. Also contains parts needed for recharging and low battery detection .
Responsibility:
Status: Research

Communication System:
Provides wireless communication to and from the microcontroller. Includes ICs and antennas, and supporting components.
Responsibility:
Status: Research

MCU:
Coordinates sensor data and communication system operation. Determines if sensor data causes a notification to be sent.

Responsibility: Daniel Gibney

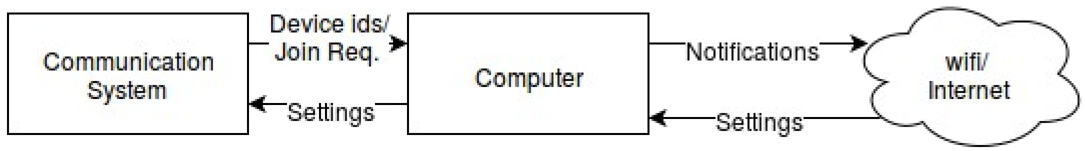
Status: Research

Sensors:
Contains two subsystems. One to detect motion and the movement of the magnet. The other is to detect a change in light.

Responsibility:

Status: Research

Base Station System Components



Communication System:
Provides wireless communication to and from the microcontroller. Includes ICs and antennas, and supporting components. Can likely be the same communication system as on the detector.

Responsibility:

Status: Research

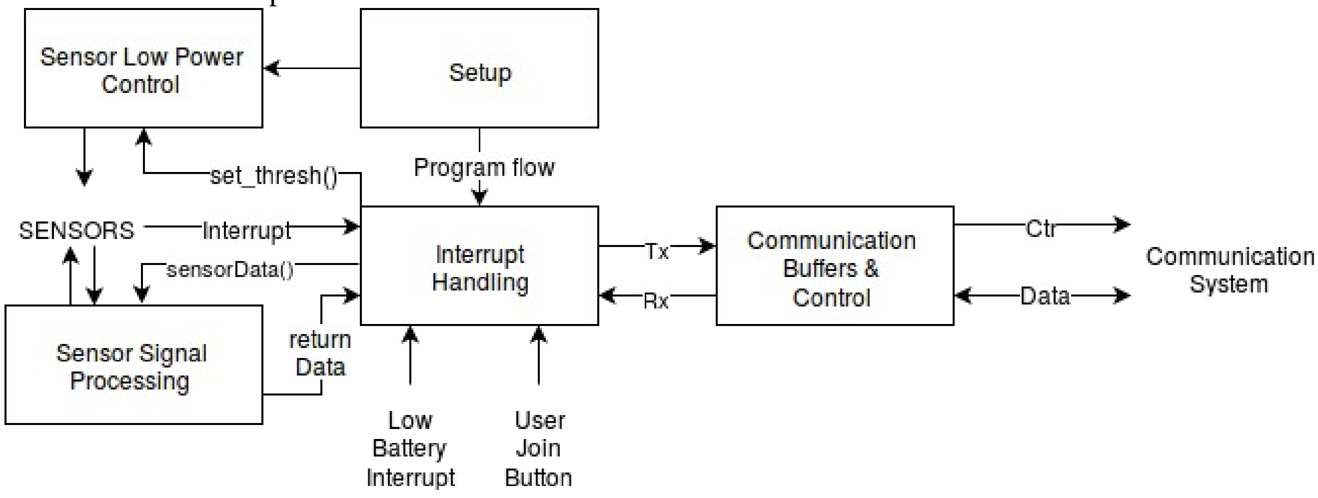
Computer:

Responsibility: Daniel Gibney

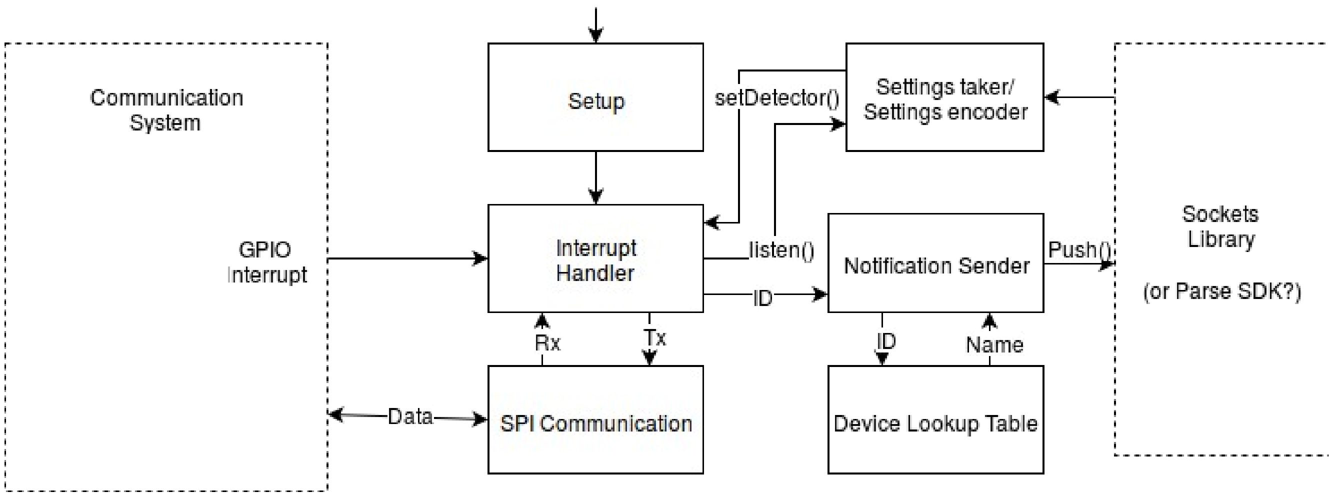
Status: Development (application development)

Software Systems:

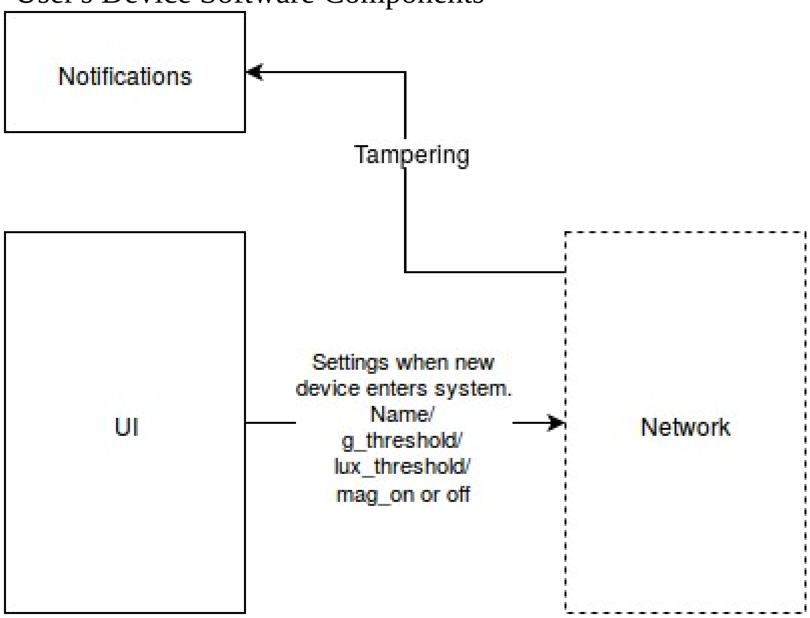
MCU Software Components:



Computer Software Components:



User's Device Software Components



Estimated Project Budget and Financing:

The following list indicates which parts will likely be needed and for what function. It also indicates some of the prices found on-line for these parts.

Detector Parts:

Wireless Communication:

Option 1(Preferred): NRF24L01+ 2.4GHz communication (uses SPI to microcontroller)
NRF24L01+ (with development board for initial prototype)
$ 4.00
NRF24L01 (lone IC for final prototype)

$3.50

Option 2: Digi Zigbee communication module. Contains crystal and antenna(this may be used in the prototyping process, however there seems to be no stand alone ICs for this option)

XBP24-Z7WIT-004
$19.00

Option 3: Building Zigbee communication system ourselves.
This would be the most challenging as it would entail designing the crystal and the antenna system. It would also delay the creation of a functioning prototype by the most amount of time.

RF Transceiver IC:

FREESCALE MC13202FC (Uses SPI to microcontroller)
$7.00
Requires

Qfn32 Qfn40 to Dip32/40 Adapter PCB(for prototyping)
$3.28
16MHz Crystal NX3225SA
$0.72
Surface mount → needs PCB adapter
Antenna Design: requires LNA and trace or ceramic antenna

Microcontroller:

ATMEL ATMEGA328-AU $3.15

Power:

The battery system will have to be design to provide for recharging of the battery and some sort of mechanism to detect when the battery is almost out of charge.

Battery rechargeable lithium ML-2020/F1AN, 3V 45mAh Coin, 20.0mm
$2.68
Battery Management MAX17048G+T10(to monitor remaining battery charge)
$2.64
Voltage Regulator(for recharging battery) MIC5205-3.0YM5 TR
$0.62
Other discrete components
Micro-USB type B connector ZX62D-B-5PA8
Capacitors/ Resistors
~$3.00

Sensors:

Fast Vibration Sensor Switch (To bring detector out of sleep mode)
$0.95 x 2 = $1.90
Photo-resistors(50 pack)
$2.00
Digital Potentiometer
$1.00
Reed Switch ORD325-1520 (For detecting when the magnet is removed) (10 pack)
$8.50

Magnet NDFEB 10X5X1.9MM (10 pack)
$9.10
Adafruit Triple-Axis Accelerometer - ±2/4/8g @ 14-bit – MMA8451 (for prototyping)
$7.95
Accelerometer MMA8451Q IC (for final prototype)
$1.12

Board:
2 custom 4-Layer PCBs
$210.00 @ sunstone.com

Enclosure:
Hammond Manufacturing 1551JTBU
$2.00 x (number of detectors built)
Ice breakers (candy) Case?

Base Station Parts:

Detector communication:
For option 1)
NRF24L01+ with development board(for initial prototype)
$4.00
lone IC (for final prototype)
$3.50

For options 2 and 3) TI CC2531 USB Dongle ZigBee Adapter
$14.83

Computer:
Raspberry Pi Model B+ (SPI through the GPIO, push notification through USB wifi adapter)
$29.95
Ultra-Mini USB Wireless LAN 802.11N
$7.99

Enclosure:
Raspberry Pi B+ / Pi 2 Black Enclosure
$8.95

Estimate of costs

1. Cost to Prototype (2 detector without power system and base station):
Arduino Pro-mini = $20
NRF24L01+ x 3 = $12
Sensors = $30
Shipping = $30 // assumed shipping cost for initial batch of parts
Total = $82

2. Cost to add Power system(for 2 detectors)

Battery = $ 6
Components = $ 14
Total = $20 // shipping included above

<u>3. Cost to build final Prototype (2 detectors, PCB, all ic's, enclosures, etc...)</u>

3 microcontrollers(1 extra)	= $ 10	
PCB	= $210	// over half the cost!
Enclosures	= $ 15	
Additional Shipping	= $ 30	
Total	=$ 265	

Estimated overall total cost = 82 + 20 + 265 = $367 ~ $400

Initial Project Milestones:

For semester one, our major milestone is to have a prototype with two detectors working entirely, but using the development boards. By working entirely, I mean that there is wireless communication between the detectors and the base station, all sensors on the detectors are operational, and the base station is communicating with the user. By using the development boards has much as possible in the beginning we can be sure our conceptual ideas of how the product works are sound and that all of our code is working. This will make trouble shooting easier during semester two since it will eliminate a certain set of problems from our search space.

During semester two, our major milestone will be to have the same functionality, but without the development boards. This means having our ICs soldered on our custom built PCBS and using the power system. It also means having the PCBs neatly placed inside their respective enclosures. Since the development boards chosen provide schematics, we will have a good starting point for implementing our own PCBs, although the power system may require a bit of work.

Itemized Milestones/Objectives

1. Power system design complete
2. Sensor system design complete
3. Wireless communication between detector units(or dev-board simulating detector)
4. Sensors working on detector
5. Sensor driven notifications working between detector and computer
6. Ability to join system through button(bypassing user app)
7. Ability to change settings on detector through computer
8. PCB layout complete
9. PCB board soldered
10. Notifications working between computer and user device
11. Fully functional user application
12. Finished product