

Smart Phone Control and Data Acquisition of Resource Effective Bio- Identification System

Battelle

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Introduction

Team Four's project is to design and build a communications module for Battelle. Battelle is a nonprofit organization that develops a variety of sensor systems for Government and industrial clients. The purpose of our project is to develop a method of communication between several sensors through the use of a Smart Phone as a common node. The main sensor that the group's design will be based around is the Resource Effective Bio-Identification System, a product of Battelle Laboratories. This sensor uses Raman Spectroscopy to determine the chemical composition of the air and sends out an alarm when a potentially harmful chemical is detected. To control this sensor, the Smart Phone controller must be able to send commands, monitor the status, and alert the operator if the sensor detects a problem. Due to budget constraints, the group will be using a computer to simulate a sensor. The team has been tasked with researching several different methods of communication between the Smart Phone and sensors. These include Bluetooth, WI-FI, radio frequency, XBee, and cellular. Furthermore, upon completion of the project the team is expected to have built the necessary circuitry, created both the Smart Phone and sensor simulation software, tested the performance and operability, demonstrate the capability, and document possible future applications for Battelle's research and design.

Background

The team will be utilizing some of the research the past semester's team completed for Battelle. The spring 2011 team already did a comparison of the iPhone and Android phones and has decided that the Android operating system works better for the needs of this projects and Battelle's overall goals. The spring 2011 team created an application that the current team will be basing some of the new interface on.

Trade Study

Part of the design objectives was to complete a large amount of background research on various forms of communication technology and their capabilities. Below is a chart describing current capabilities followed by a conceptual list of pros and cons related to each technology.

	Wi-Fi	Bluetooth	ZigBee	PRF
Frequencies	2.4GHz and/or 5GHz	2.45GHz	915MHz(US) 868MHz (EU) 2.4GHz (global)	900MHz(US) 868MHz(EU) or 2.4MHz (global)
Channels	16 @ 2.4GHz 80 @ 8GHz	79	10 @ 915MHz 26 @ 2.4GHz	16 to 79 (can be customized)
Range (Indoor)	70m	Class1=1m Class2=10m Class3=100m	20m	1000m
Range (Outdoor)	160m	100m	100m	40 miles (with high-gain antenna)
Data Rate (Max)	54Mbits/s (with12Mbits/s typical)	3Mbits/s	250Kbit/s	721Kbit/s to 72Mbit/s
Transmission Scheme	DSSS	Adaptive FHSS	DSSS	FHSS or DSSS
Power Sources	Wired	Battery/ Wired	Battery/ Wired	Battery/ Wired (industrial power source compatible)
Uses	Cable replacement, large data transfer, networking	Short distance cable replacement	Monitoring and Controlling	Cable replacement, Monitoring, Controlling, Data Transfer
Max Nodes	32	8	>64,000	Variable
Stack Size	1000KB	720KB	250KB	Variable
Transmit Power (Max)				1W

Chart obtained from http://www.bb-elec.com/bb-elec/literature/tech/Industrial%20Wireless-WP18-r0_3007.pdf

RF Circuitry

Pros:

- Long Range (one – several hundred kilometers).
- Customable to specific center and modulation frequencies.

Cons:

- Relatively expensive (about \$100-\$300/per RF transmitter)
- Large and bulky circuitry. There are many components that would be needed (inductors, capacitors, variable capacitors, antennas)
- Analog to digital and digital to analog conversion necessary to send and receive commands to and from laptop/Smart Phone.
- Possibility of an external power supply depending on the transmission range.
- Time consuming to tune inductors and variable capacitors to receive specific frequency.

Pros:

- A USB interface that runs using the XBee protocols. This allows us to circumvent source encoding and other complications that can result from the A/D conversion from the antenna signal to the phone's program.
- The range of XBee communication can be extended by adding a power boosting element to a separate antenna.
- XBee transmits through frequency agility; this is similar to frequency hopping, however if a channel change is required then the network manager can instruct all operating devices to switch to the new channel. Using this frequency shifting technique we can add multiple sensors to the network without interference.

Cons:

- Has low data rates of up to 720kBits/sec which would be insufficient if the future application requires more data to be transmitted.
- Relatively new technology that hardware developers are still working on optimizing.

Wi-Fi

Pros:

- The newest devices use the IEEE 802.11n protocol and can have a range up to 1,400 feet because the router has 3 built in antennas.

- For our needs the phone will already be Wi-Fi enabled so there is no added cost, size or software complexity because the android operating system already comes equipped to handle incoming Wi-Fi signals.

Cons:

- The device needs to be connected to an already setup Wi-Fi network for it to work.
- The power of a Wi-Fi radio is measured in dBm and the higher the dBm rating the longer the range.

Bluetooth

Pros:

- Can detect and connect to different devices without the user's involvement.
- Low cost (\$4 – \$20).
- The data transmission speed for bluetooth is between 1Mbps to 3 Mbps.

Cons:

- Short range (20-30m).

Cellular

Pros:

- Capable of using the same frequency in different areas.
- Long range if network is already set up.
- No external hardware plug-ins needed for the Smartphone.
- Minimal surplus power consumption.

Cons:

- To use a particular phone network, must pay for monthly service.
- Not useable in areas of the world where no antenna network is available.

Design Objectives

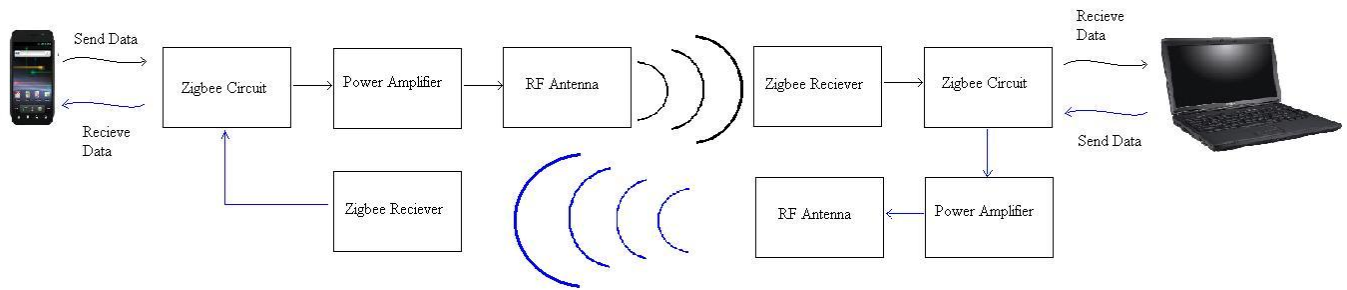
- Assess key performance parameters of Smart Phones
- Research communication systems
- Develop communication module
- Design Smart Phone application for Sensor control
- Create software simulation of actual Sensor
- Demonstrate and benchmark performance

Battelle is looking to enhance their knowledge of Smart Phone technologies and how they can integrate Smart Phones within their sensor department. There are many ways that phones and sensors can communicate and one of the primary goals of the team is to research which form of communication fulfills the needs of Battelle the best. Some factors that need to be looked at are range, cost, power consumption, size, complexity, interference, and data transfer speeds. Smart Phones have matured to the point where it is possible to use them to provide the same information and control that advanced sensor systems are currently used for. Battelle is interested in the ways that the sensors and Smart Phones can be linked and not necessarily interested in the limitations in the processing power of phones because the processing power will continue to increase over the next few years. The team will research the various ways that data can be transmitted from a sensor to a Smart Phone and then build a communication module to transmit that data. The phone will be equipped with a custom built application that will allow the end user to control the sensor, read and analyze data, and receive status updates. Once this is complete, the Smart Phone controller will be able to provide greater flexibility for using sensor systems.

Conceptual Designs Description:

Using the objectives listed above, the group has come up with three main designs that would be capable of meeting the above objectives.

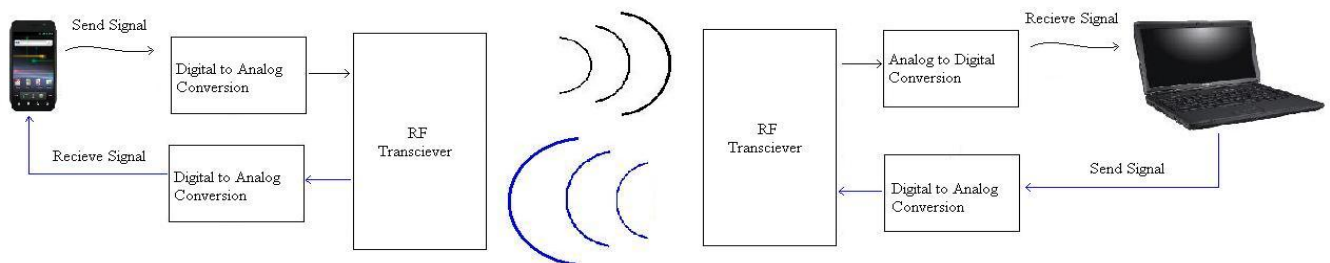
XBee Communication Block Diagram



WI-FI Communication Block Diagram



Radio Frequency Communication Block Diagram



Feasibility Matrix:

	Battelle
Operational Feasibility	The purpose of our project is to develop a mechanism in which the smart phone can be used as a station that receives signals from several sensors through a determined method of communication. In addition, the team must create software that allows for the transferring of data between the sensors.
Technical Feasibility	The team must choose one of several methods of communication between the smart phone and sensors. 1- Radio Frequency 2- XBee 3- WI-FI
Economic Feasibility	Our capital is \$500. Due to these limited resources, we will be using a computer as a stimulant for the sensors. Budget constraints limit our ability to expand our research and use a high method of technology that will most likely give us more detailed results
Schedule Feasibility	The team has until 12/9/2011 to finish the project

Selection Matrix:

Criteria	Importance	Possible Solutions		
		WI-Fi	RF	Zigbee
Power	5	9	1	9
Size	1	9	3	3
Range	5	3	9	3
Speed	1	9	9	1
Adaptability	5	1	9	9
Complexity	1	9	1	3
Cost	2	9	3	3
EMI	3	9	1	9
		137	117	145

Explanation of Important Criteria

Power – The physical location of the sensor is not conducive to frequent battery changes or the ability to be hooked up to a permanent power source. Also, the Smart Phone's normal power usage must be affected as little as possible while using it for sensor applications. Therefore, Power consumption is of high importance.

Range – The reason for designing a Smart Phone based sensor controller is to allow access to the sensor at long distances to provide safety to the user. This means Range is of high importance.

Adaptability – The sensor must be useful in a wide range of environments.

EMI – When talking to multiple sensors, the possibility for losing data through electromagnetic interference increases. A way to reduce this problem is to transmit data at multiple frequencies.

Rating Explanations

- WI-FI can only be used when there is an active WI-FI network already set up. This causes problems because the system needs to be used in places where there may or may not already be an active WI-FI network and is not possible to set up a new network. This is why the adaptability of WI-FI is very low.
- RF uses only one frequency to send data. Therefore it has poor EMI.

Results: The use of an XBee communication system will allow the team to meet the most design objectives with the allotted time and budget.

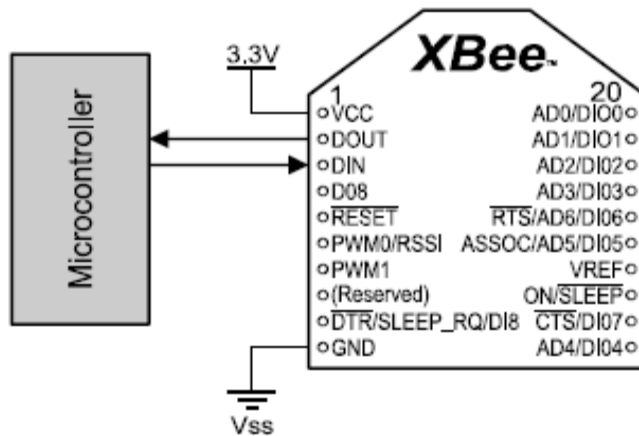
Proposed Design Solution

Design Methodology

The methodology for this project will start with the adaptation of the Xbee 802.14.4 Starter Kit to start supporting the GUI and phone's interface. Initially it is meant to communicate with a BASIC stamp and PC. This works for the sensor side but the phone will ideally only have the Xbee module attached through USB and nothing else. Once we are able to use this interface properly we will order the needed parts to complete an Xbee network of at least two sensors. More will be included at this stage to form a Zigbee mesh network if it seems feasible, otherwise this step will be re-integrated provided there is time at the end of the design process. Once the Xbee network is communicating properly two RF antennas will be constructed to send and receive the signal at greater range. Testing will be done on the antenna for range, power,

accuracy, and complexity of the signal that can be reliably transferred. Through our trade study it has been found that buying an antenna may be a more reliable option. However, if this fails, building an antenna should be feasible with the group's background in this technology. After initial designs are created, the antenna will be built/purchased and attached to the phone. Power consumption will also play a factor here as an external battery may be required as well. Creating a proper interface between the XBee antenna and the more powerful one will be the final step in hardware design. Provided we have a mesh network it may need to be multiple sets of antennas. This could potentially increase the range as the direction of conduction for the antennas can be narrowed and thusly elongated. This configuration however would almost undoubtedly require an external power source. Once the entire communication process is nearing completion the team will integrate it into the GUI that we create. This will potentially include using parts of last semesters GUI in order to integrate as much functionality for Battelle as possible. Currently, USB as mentioned earlier is the planned method of signal transfer between phone and antenna; this should remain a reliable means of transfer for the phone and Xbee while the two antennas will have their own connections. Once a properly compatible antenna is wired to the prototype phone and external antenna, a more refined version of the project can be focused on. This will include programming of the sensors (computer simulated) to give different errors and status updates. This will be controlled by a program that transmits on a never ending loop so the phone can be constantly monitoring the RF output of the sensors in order to refresh the display of GUI in a time interval we see fit. Then, the GUI will have to be altered or rewritten as mentioned earlier to allow a smooth transition from user to sensor data. Finally, if time allows, multiple sensors will be included to allow for an array to cover a much larger area. Ideally these will all be in constant communication with the phone through RF. Although, as the project finds its way to this point it may be easier to only have communication between the sensors and phone when it is required, rather than at all times and under constant refresh. In the end, a successful design team will have a robust, finished project done before Design Day. This finished project will send commands from the Smart Phone to the laptop program and send data from the laptop to the Smart Phone. The GUI will also be very user friendly.

Diagram of Available XBee Pins and Pin Functions



Pin	Name	Type	Function
1	VCC	P	2.8 V to 3.4V
2	DOUT	O	Serial data output from XBee (received data)
3	DIN	I	Serial data input to XBee (data to transmit)
4	DO8	I	Digital data Output 8
5	RESET	I	Reset module (low)
6	PWM0/ RSSI	O	Pulse with modulated output Received signal strength Indication as PWM signal
7	PWM1	O	Pulse Width Modulated output
8	(Reserved)		
9	DTR SLEEP_RQ DI8	I	Data Terminal Ready: handshaking for firmware updates (low)
		I	Sleep Request: A high places XBee in sleep mode when configured
		I	Digital Output 8
10	GND	G	Ground (Vss)
11	AD4 DIO4	A	Analog to Digital Input 4
		IO	Digital Input / output 4
12	CTS DIO7	O	Clear to send output for controller handshaking (low)
		IO	Digital Input/output 7
13	ON /SLEEP	O	Digital output, status indication: High=Awake, Low = Sleep
14	VREF	A	Analog to Digital reference voltage
15	ASSOC	O	Associated indication when joining a Network
	AD5	A	Analog to Digital Input 5
	DIO5	IO	Digital Input/output 5
16	RTS	I	Ready to Send Handshaking input (LOW)
	AD6	A	Analog to Digital Input 6
	IO6	IO	Digital Input/output 6
17-20	AD3 –AD0	A	Analog to Digital Input 3 to 0
	DIO3-DIO0	IO	Digital Input / output 3 to 0

Pin Type: P= Power, G= Ground, I= input, O= Output, A= Analog Input

Software Implementattion

The smart phone application will be developed using the Android SDK and development kit. It will be developed on Windows using the Elipse IDE with the Android SDK plugin. Since Android uses Java the application will be programmed in Java. The code will be compiled into a .apk file and loaded onto the smart phone.

The sensor application will be complied in Java and will be able to run on a computer or another smart phone.

Building Plan

The order the team constructs parts for our design is one of purpose and function. The first step is to acquire our Nexus phone. The next step is to order the XBee 802.15.4 RF starter kit. Once assembled, this will allow all team members to start working on and testing the code as well as to become familiar with the interface. From here, more XBee parts may be ordered if needed. Once the XBee interface is complete, the next parts to be ordered will be those for the power boosting antenna circuit. The ECE shop should have the majority of the parts that will be required to build such an antenna. Then, integration of the two can take place as well as the possibility of additional nodes.

Benchmarks

Listed below are the main benchmarks that must be completed for the project to succeed. The three underlined are the critical benchmarks that must be completed before any more progress can be made. Inability to complete these steps in a timely manner will result in a need to redesign the communication module or risk project failure.

- a. Successful data transfer from XBee to laptop.
- b. Successful data transfer from XBee to Smart Phone
- c. Successful data transfer between laptop and Smart Phone using XBee.
- d. User friendly Smart Phone application completed.
- e. Simulated sensor created with laptop.
- f. Complete, functional control and monitoring of sensor with Smart Phone.

- g. Increased range of XBee transceiver successful through amplification of signal.

Risk Analysis

Risks associated with this project weigh heavily on the choice to use external transmission technology. However, the software aspect will have problems as well.

External transmission technology

- Access to the data retrieved from the USB ports on Smart Phones may be restricted making XBee or RF transmission technology impossible to implement in Smart Phones.
- External hardware may reduce the phone's battery life by amounts not feasible for current battery technology. In addition, the longer range technologies will reduce battery life even further.
- Smart Phone developers put the majority of their efforts into improving phone capabilities on their own communication networks. This means that technological improvements between external transmission hardware and Smart Phones may not advance the same as other technologies do.

Software

- The programming code used by the Spring 2011 Battelle group may not be adaptable to the use of the XBee transceiver.
- With Smart Phone technology always rapidly changing, accessing the registers needed to acquire the USB Smart Phone data may also change. In some extreme cases it may become restricted as well.

Project Management Plan

Personnel

Non-Technical Roles

Name	Non-technical Role	Details
Dr. Christopher Ball	Sponsor	N/A
Professor Tongtong Li	Faculty Advisor	N/A
Jacob Sawicki	Manager	Schedule meetings Report to facilitator: summaries of meeting agendas and attendance, progress and problems on the project, expenditures, etc. Project task list and timeline Budget Group processing Project management- including Gantt chart for planning, scheduling, task assignment
Kevin Gleason	Webmaster	Unix directory maintenance Web page coordination CD-ROM writing Use of imaging and video hardware/software, such as digital camera, scanner, video camera, etc.
Phillip Horny	Document Prep -	Software tools - Microsoft Word, Adobe Acrobat Coordinate the preparation of written reports Coordinate peer-editing of documents Maintain documentation portfolio

ThamerAlajlan	Presentation Prep	Software tools - Microsoft Powerpoint, Adobe Acrobat Coordinate preparation of oral reports Coordinate peer evaluation of presentations Maintain documentation portfolio Coordinate the preparation of posters showing the design projects at the term end
Andreas Dixon	Lab Coordinator	Coordinate ordering of parts for the team Insure the lab stays clean and orderly Report problems noted with the lab equipment to the ECE shop

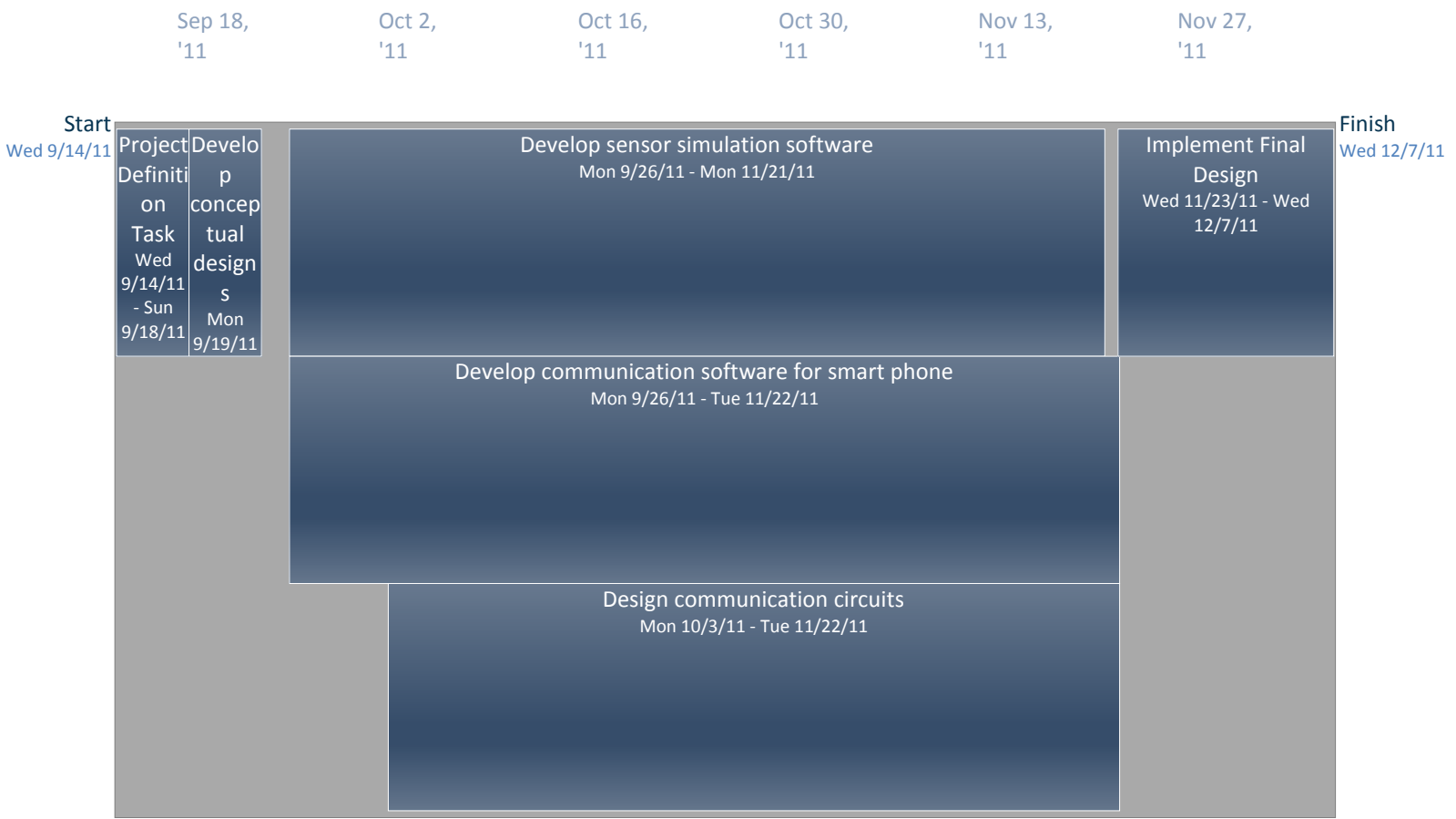
Technical Roles

Name	Technical Role	Details
Dr. Christopher Ball	Sponsor	N/A
Professor Tongtong Li	Faculty Advisor	N/A
Jacob Sawicki	Programmer	Develop sensor simulation software
Kevin Gleason	Programmer	Develop communication application for the Android smartphone
Phillip Horny	Hardware Designer	Research XBee Communication Determine feasibility of signal strengthening Design power amplifier for XBee signal Build preliminary communication circuits Build and test final communication circuits
ThamerAlajlan	Hardware Designer	Research XBee Communication Build preliminary communication circuits Build and test final communication circuits
Andreas Dixon	Hardware Designer	Research XBee Communication Order XBee components Build preliminary communication circuits Research high frequency antennas Order components for power amplifier and antennas Build and test final communication circuits

Resources/Facilities

The team has access to the 2221 lab which contains all of the equipment necessary to test the hardware. In addition, the team will be using the laptop provided by the ECE department to simulate a sensor as well as an android-based Smart Phone that was purchased by the Battelle team during the spring semester. Free Eclipse software necessary to program in Java language will be downloaded from the Internet. Java is the language used to program an android phone.

Proposed Schedule



Budget

Each team is allotted a \$500 budget. Battelle has offered to pay for any reasonable and needed expenses beyond this point if they occur. For this project, there is only one main expense, the XBee transmitter or receiver units that will be purchased. In the previous semester, an Android Smart Phone was purchased for the Battelle project. This year the same phone can be used for the project, cutting out a major expense.

Proposed Budget			
Items	Amount	Price (Each)	Price (total)
XBee Transmitter/Receiver Units	2	\$34	\$68
USB Connector	2	\$20	\$40
USB to Mini-USB	1	\$1-\$2	\$2
Amplifier Parts		Minimal	Minimal

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