# Project Proposal

Prepared for: Richard Lane, Hugh Molesworth of West Health and John Kennedy and Lal Tummala of Design Co.

Prepared by: BioComm Team 2

March 2, 2014

# PROBLEM DEFINITION

## Abstract

Often when a patient is healthy enough to leave the constant care of a hospital, they need to return to the doctor within a few weeks time to get another check up. Sometimes, patients only need to return once but they may need many more frequent check ups to ensure that their condition doesn't return, or worsen. The problem with these check ups is that they are scheduled at random times in the day and they do not accurately reflect the condition of a patient throughout the day. For example the patient may have low blood pressure at that very instant of the check up, but may have higher blood pressures throughout the rest of his or her day.

Our goal is to create an energy efficient remote vital signs monitoring system. The idea is that this system will be worn 24 hours a day by the patient and for as many weeks as the doctor requires so that the doctors can monitor the patient's physiological functions through many different parts of the day. This amounts to more data for the doctor to make a more accurate assessment of the patients health and less doctors visits for the patient which amount to less crowded and more efficient doctors offices.

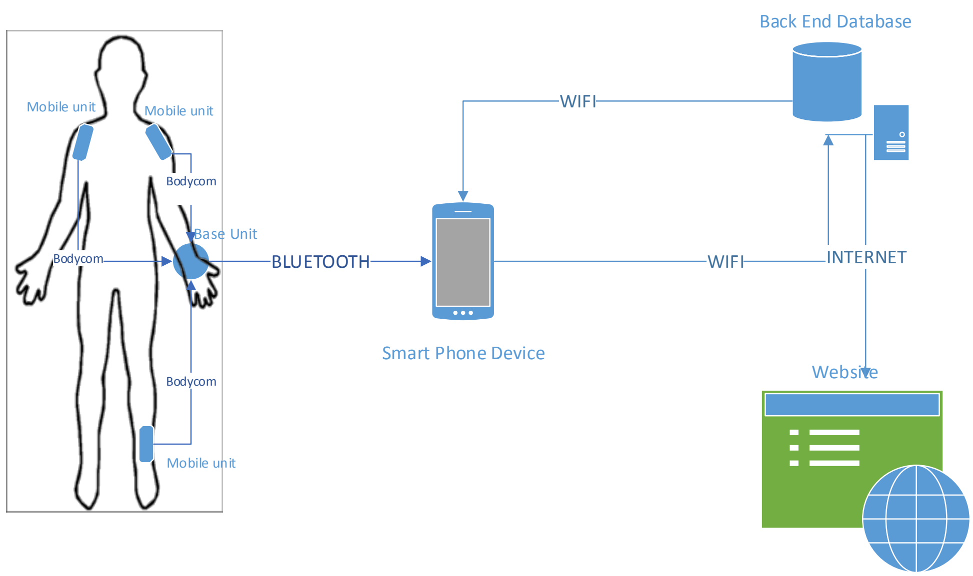
## System Description

BioComm Team 1 and Team 2 are creating a system that measures a patient's heart rate and body temperature at a minimum of every 4 hours. These measurements are taken by wireless sensor nodes disbursed across the body of the patient. The sensor nodes will communicate via the capacitance of the human skin to a main aggregator node that will be worn by the patient in the form of an armband. This main aggregator will then forward the patient's vital signs to a smartphone via Bluetooth Low Energy technology. The smartphone will then take care of forwarding the data via paths including, but not limited to, WiFi, LTE, or GSM to a back end data base. This data base then will be accessible by the doctor as the vitals are forwarded by the smartphone. As long as the patient has his or her phone on them, the vitals will be transmitted as soon as they are recorded. If not, the aggregator unit will wait until the phone is within range to transmit them. The doctor has the option to increase or decrease the frequency of sampling the data.

We want this system to be minimally invasive to the user. Therefore, the sensors will have enough energy to last about 2 weeks. The sensors will do this through an energy harvesting technique in which they harvest energy through ambient radio waves in the atmosphere. The sensors will also be equipped with a coin cell battery in case there is not enough ambient power at the time of a required measurement. The arm strap that will become the aggregator unit will be able to last a total of 2 weeks on one lithium ion battery pack. The user will be issued two lithium battery packs to simply replace the battery pack when the arm band runs out of battery. This will give the user a total of 1 month of use in the arm band.

BioComm Team 2 will be in charge of the design of a low power aggregator unit, the communication algorithm between the sensor nodes and the aggregator, a smartphone application and back end database. BioComm Team 1 will be in charge of the low power sensor nodes to obtain physiological measurements and energy harvesting. The focus of Team 2's design will be in maintaining very low power consumption and the design of the low power communication protocol. The smartphone application and database will be for demonstration purposes.

## Conceptual System Diagram



# SYSTEM DESIGN

## Background Research

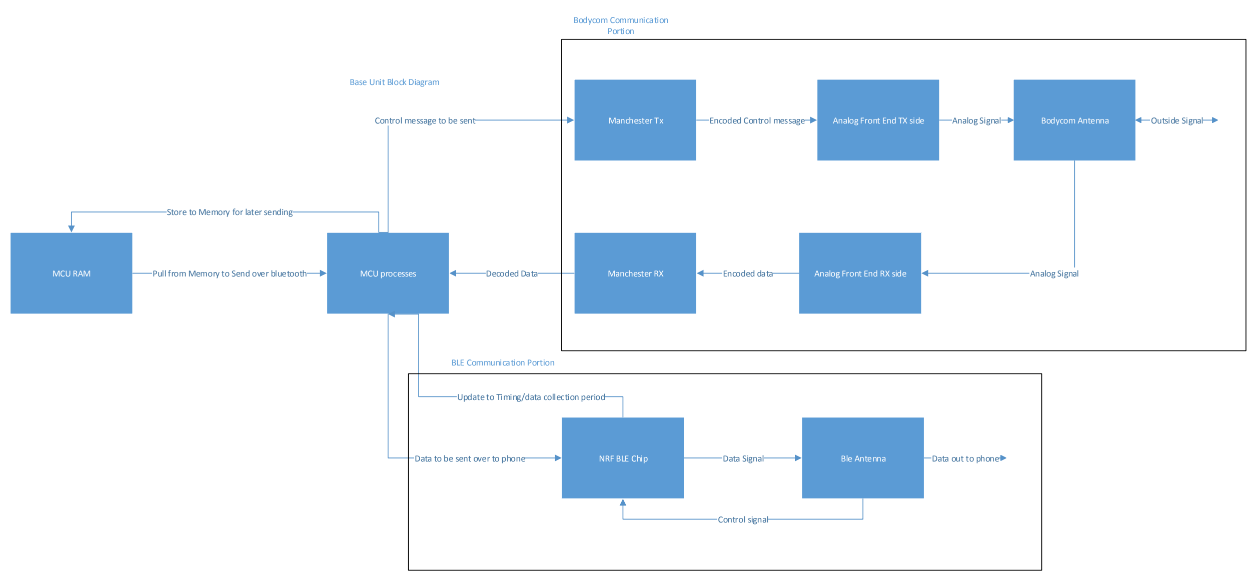
Our teams focus is to create the aggregator unit. This encompasses creating the unit to be continuously wearable for up to a months time, a communication protocol to the sensor nodes and a Bluetooth Low Energy solution to transmit data to the mobile phone and then to a backend database.

We found that as a base design we are going to use the BodyComm kit developed by MicroChip. In this kit comes a development platform to communicate to wireless nodes via the capacitance of the human skin. This platform already keeps low power design in mind, so we are going to conform to most of their reference designs. In this reference design, we are going to use a PIC16 micro controller, which includes a wakeup radio so the micro controller can be asleep when it doesn't need to process or request any data. We are also going to use a Nordic BLE chip to communicate to the smartphone.

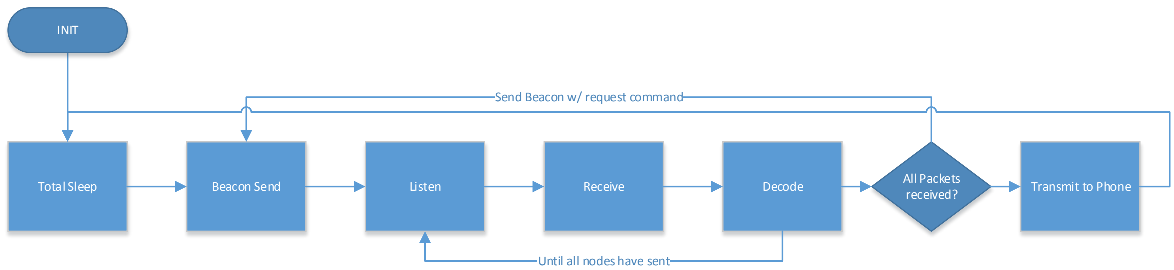
While we are using the Microchip design as a reference, we are going to significantly reduce the size of the BodyComm kit, in order for it to be comfortably wearable by a person for at maximum a months time.

We did some research on low power MAC protocols and found the BodyMac protocol. We are going to use this protocol as a baseline but we will add some of our own modifications.

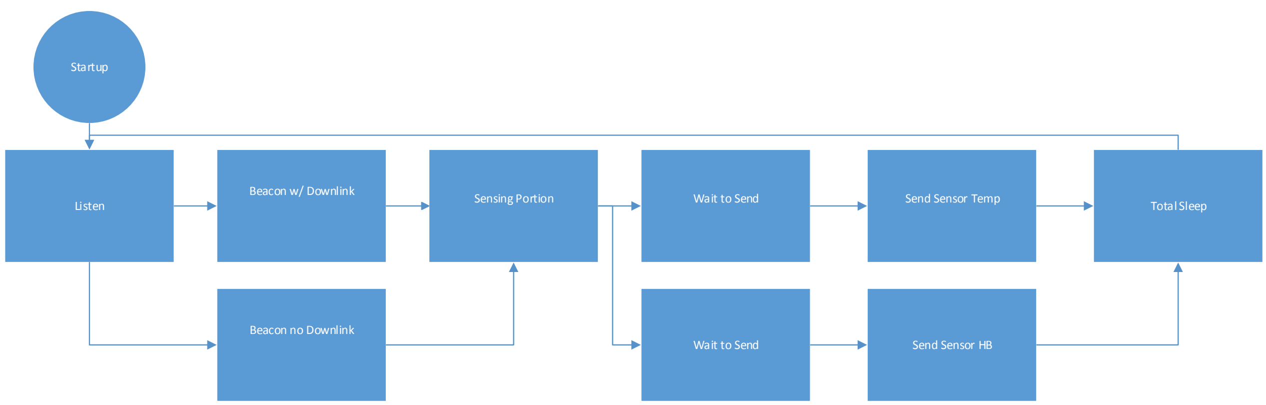
## System Block Diagram



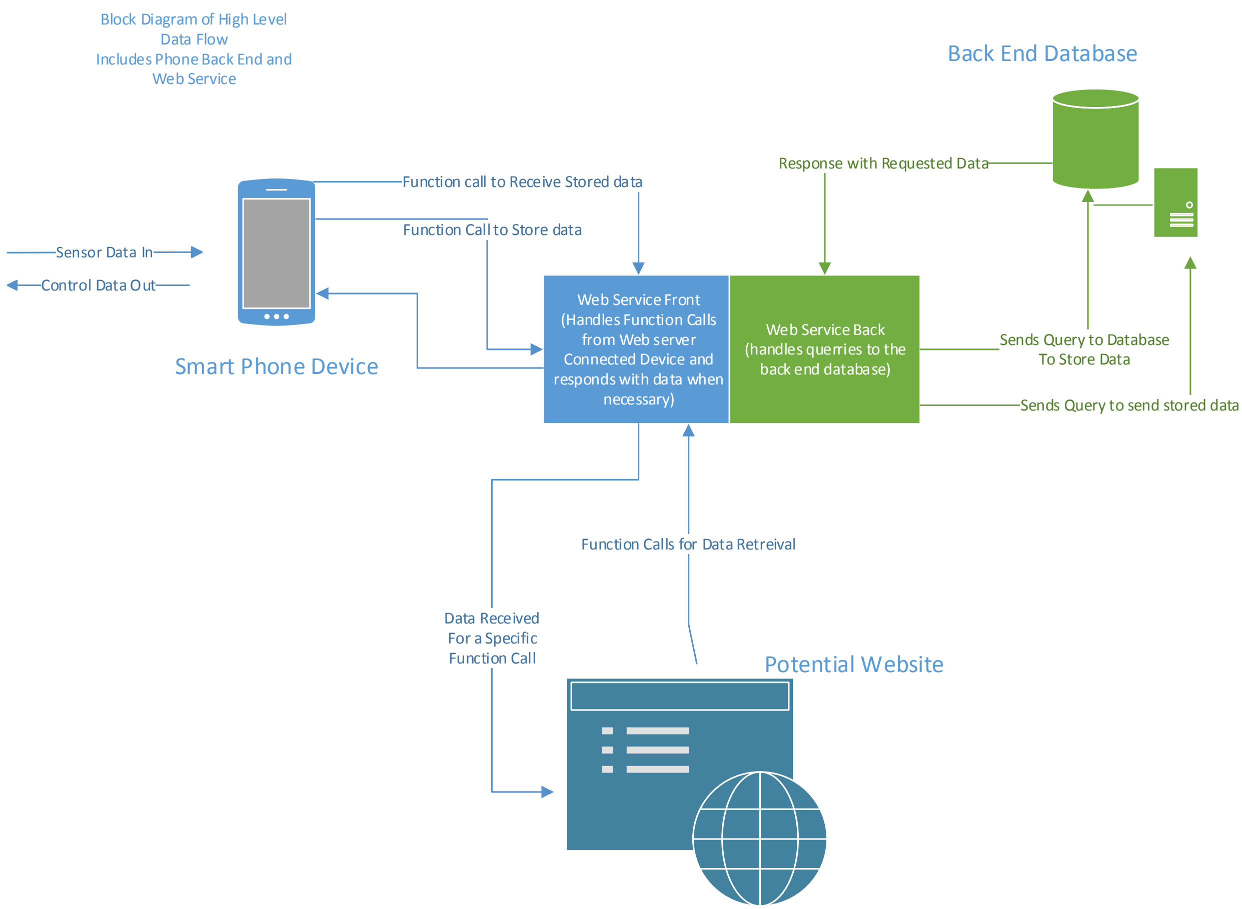
## Aggregator State Diagram




## Modified BodyMac Protocol State Diagram For Node



## Back End Database




## Testing and Procedures

1. Packet sniffing to debug communication between aggregator unit and node unit. Also to calculate packet drop rate.
2. Unit Tests
   - For all functions/API's that we have, whether it is on the mobile unit, base unit, BLE chip, phone and server we should have the corresponding unit test that determines the functionality of the function/API. In addition this test measures time and memory consumption of the API call.

3. Black Box Tests — For systems or functionalities that we have that use several API's, we shall test the functionality. Without worrying about the internals, we should test the inputs and outputs of the system and make sure they work correctly. In addition, we should test the time and memory consumption and power consumption of these systems.
4. Communication Test — Whenever we have communication between two devices or systems (example: between the mobile unit and the base unit) we shall test the communication protocol. Communication tests include the following:
   A. Load and Scalability Testing
      - Test the maximum data packet size that could be sent.
      - Test the rate at which we can send
      - If applicable, test how many nodes can be added to the commutation protocol, with the protocol retaining functionality.

   B. Performance Tests
      - How often are packets dropped
      - How much time does it take to send data?
      - How accurate is the data being sent?

   C. Regression Test — Whenever we add new functionalities to the whole system, it is important to run the testing framework as a whole to make sure that everything is working appropriately. In addition, if anyone of the team members change any implementation details, then it is important to make sure that these changes did not affect other parts of the system.

## Benchmarks & Performance Specs

1. Keep aggregator alive for 2 weeks without battery swap.
2. Expandable up to 5 nodes under power requirements.
3. Lasts 2 weeks, while sampling up to every 10 minutes
4. Communication feasible if sensor is located anywhere on the body.
5. Can hold up to 2 days worth of sensor data on aggregator unit if no smartphone present (1 hour interval sampling)

# PROJECT MANAGEMENT

## Project Plan:

Node

The plan for the project is to take incremental steps toward achieving overall system performance. This involves initially getting an individual node to transmit arbitrary data to the aggregator, and have the aggregator receive the sent data. Next, work will begin on incorporating a second node, getting it to transmit data on its own first, and then getting it to work in tandem with another node. This work shall continue until an adequate number of nodes can transmit data to the aggregator, and have the aggregator receive all of the data transmitted from the nodes.

While this work is being conducted, whenever Team 1 finalizes one of their low power sensors, work can then be started to integrate the sensor into one of the nodes. This process will be repeated whenever Team 1 produces a new sensor.

Bluetooth Low Energy

Simultaneously, work will be done to integrate a Bluetooth Low Energy module onto the aggregator unit. Initial work will be conducted to simply get the aggregator to connect to a mobile device, such as a cell phone. Once this is accomplished, the next block of work will be to get the aggregator to actively transmit arbitrary data from the aggregator to the mobile device and have the mobile device receive the sent data. The final stage of this process is to have the aggregator transmit actual data from the nodes to the mobile device.

Backend Web Database

Towards the end of system integration, once we have the bluetooth module transmitting data to a phone, work will be done to build a backend database to house data received from the aggregator. As with the nodes and the BLE, work will be done initially to get the intended mobile device to transmit arbitrary data from the mobile device to the backend database to be organized and housed. Once this is accomplished, development will proceed to where actual data received from the nodes is transmitted from the aggregator to the mobile device, then from the mobile device to a backend web database.

Mobile Device App

Once, the system is sending data appropriately from the nodes to the BLE Chip, work will be done to produce an application that will access the backend database to display the data and statistics relevant to the user on the mobile device.

Miniaturization and Energy Harvesting

After the aggregator unit is working to specification, work will be done to miniaturize the aggregator to its smallest possible form factor so that it is wearable and comfortable to the user. Also, once Team 1 finalizes their design to power the nodes using energy harvesting, that will be incorporated into the system as well.

## Milestones

- Node 1 transmits arbitrary data to aggregator, which is successfully received.
- Node 2 transmits arbitrary data to aggregator, which is successfully received.
- Node 1 and Node 2 transmit arbitrary data to aggregator in tandem with one another, which is successfully received.
- Node 1 and Node 2 transmit actual data from the sensors to the aggregator, which is successfully received.
- Aggregator transmits arbitrary data via BLE which is successfully received by mobile device.
- Aggregator transmits actual sensor data via BLE which is successfully received by mobile device.
- Mobile device successfully stores data on backend web database
- App displays data from sensors via backend database with appropriate statistics and history

## Major Integrations

- Temperature sensor integrated into node
- Pulse rate sensor integrated into node
- BLE module integrated into aggregator
- Energy Harvesting integrated into nodes

## Task Decomposition

Henok Tadesse and Yang Jiao - Bluetooth Low Energy Protocols
Patrick Belon - BodyMAC communication protocol
Michael Scherer - Web Database and BodyMAC communication protocol
Jack Powell and Thien Nguyen - Analog Circuitry

## Task Schedule

| Task Name | Duration | Start | Finish |
|---|---|---|---|
| **BioComm Team 2** | **16 days** | **Mon 3/3/14** | **Mon 3/24/14** |
| **Baseline Dev Kit** | **5 days** | **Mon 3/3/14** | **Fri 3/7/14** |
| Read & Understand Code | 1 wk | Mon 3/3/14 | Fri 3/7/14 |
| | | | |
| **Single Mobile** | **11 days** | **Mon 3/10/14** | **Mon 3/24/14** |
| **Transmit Data** | **10 days** | **Mon 3/10/14** | **Fri 3/21/14** |
| Timing | 1 wk | Mon 3/10/14 | Fri 3/14/14 |
| Arbitrary Data | 1 wk | Mon 3/10/14 | Fri 3/14/14 |
| Data Transmission from Mobile to Base | 1 wk | Mon 3/17/14 | Fri 3/21/14 |
| Successfully Transmit Arbitrary Data from Mobile to Base | 0 days | Tue 3/18/14 | Tue 3/18/14 |
| **Major Integration: First Sensor** | **5 days** | **Tue 3/18/14** | **Mon 3/24/14** |
| Transmit Read Data to Base | 1 wk | Tue 3/18/14 | Mon 3/24/14 |
| Successfully Transmit Read Sensor Data from Mobile to Base | 0 days | Mon 3/24/14 | Mon 3/24/14 |
| **Multiple Mobile** | **15 days** | **Mon 3/24/14** | **Fri 4/11/14** |
| **Individual Second Mobile** | **5 days** | **Mon 3/24/14** | **Fri 3/28/14** |
| Load Programming from Single Mobile | 1 wk | Mon 3/24/14 | Fri 3/28/14 |
| **Two Mobiles** | **10 days** | **Fri 3/28/14** | **Fri 4/11/14** |
| Timing | 1 wk | Mon 3/31/14 | Fri 4/4/14 |
| Arbitration between Mobiles | 1 wk | Mon 4/7/14 | Fri 4/11/14 |
| Have 2 mobiles successfully transmit arbitrary Data | 0 days | Fri 3/28/14 | Fri 3/28/14 |
| **Major Integration: Second Sensor** | **5 days** | **Mon 3/31/14** | **Fri 4/4/14** |
| Transmit Data from Second Mobile | 1 wk | Mon 3/31/14 | Fri 4/4/14 |
| Successfully Transmit Read Sensor Data from 2 Mobiles to Base | 0 days | Fri 4/4/14 | Fri 4/4/14 |
| **Bluetooth** | **20 days** | **Fri 3/7/14** | **Fri 4/4/14** |
| Connect bluetooth to base | 1 wk | Mon 3/10/14 | Fri 3/14/14 |
| Establish Link between Base and Cell Phone | 1 wk | Mon 3/10/14 | Fri 3/14/14 |
| Transmit Arbitrary Data between Base and Cell Phone | 0 days | Fri 3/7/14 | Fri 3/7/14 |
| Transmit Read Data from Base to Cell Phone | 0 days | Fri 4/4/14 | Fri 4/4/14 |
| | | | |
| **Backend Web Database** | **5 days?** | **Fri 3/7/14** | **Fri 3/14/14** |
| Create Database | 1 wk | Mon 3/10/14 | Fri 3/14/14 |
| Cell Phone Communication with Database | 1 wk | Mon 3/10/14 | Fri 3/14/14 |
| Transmit Arbitrary Data between Cell Phone and Database | 0 days | Fri 3/7/14 | Fri 3/7/14 |
| Transmit Read Data from Cell Phone to Database | 0 days | Fri 3/7/14 | Fri 3/7/14 |
| | 1 day? | Mon 3/10/14 | Mon 3/10/14 |
| **Major Integration: Energy Harvesting to Mobiles** | **20 days** | **Mon 4/7/14** | **Fri 5/2/14** |
| Connect Energy Harvester to Mobile | 1 mon | Mon 4/7/14 | Fri 5/2/14 |
| Operate sensors batteryless | 0 days | Fri 5/2/14 | Fri 5/2/14 |
| | | | |
| **Integrate Base into Smart Watch** | **0 days?** | **Sat 3/1/14** | **Sat 3/1/14** |
| Design new base unit board to interface with watch | | | |
| Integrate new base with watch | | | |
| Transmit data from Sensor to new Base to Watch | | | |
| | | | |
| Validation and Testing | | | |

# BUDGET

### Breakdown of Expected Costs

| Description | Quantity | Unit Price | Cost |
|---|---|---|---|
| BodyComm Kit | 1 | $ 160 | $ 80 |
| nRf51822 dev kit | 1 | $ 114 | $ 114 |
| nRf51822 | 2 | $ 5 | $ 10 |
| MCP2035 Analog Front End | 5 | $ 2 | $ 10 |
| PIC16LF1829 | 3 | $ 2 | $ 6 |
| PIC16LF1827 | 3 | $ 2 | $ 6 |
| Others | 1 | $ 100 | $ 100 |
| **Total** | | | **$ 326** |