IoT Sensor Integration and Back-end Development for Sequoia

Design Document

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1 Introduction

1.1 Acknowledgement

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1.2 Problem and Project Statement

Problem Statement

With a large number of baby boomers becoming older there is a large need for systems to monitor the health of our senior citizens. Most senior citizens have habits that they follow every day, and a lot of information can be learned about them from these habits. The goal of the Sequoia project of our clients company is to put sensors in seniors homes to monitor their habits, and be able to tell when a senior might be ill based on changes in habits before they are showing other symptoms.

Project Statement

Our group's specific goal of this project is twofold. First we will add a smart outlet that will track when different appliances are being used to the suite of sensors that is already in place for the system. Second we will use a wearable device such as a smartwatch to track the the location of the senior within the apartment and use the sensors already on the smartwatch to monitor their health in more traditional ways.

1.3 Operational Environment

The sensor network will be placed in the senior's apartment or home to collect data data on their habits. Due to being placed in the home, the sensors will not be exposed to any harsh weather conditions or environments. The only physical danger for these sensors is the risk of being unplugged or removed from their power sources, this would compromise the effectiveness of the sensor network.

Another potential hazard is security. Due to the nature of the project, the data collected will need to be uploaded to the cloud to store. This information is quite personal (tracking location, habits, ect.) and therefore must be kept secure to ensure privacy.

The sensor network will be placed in a seniors apartment or home in order to collect data on their habits so they will not be subject to any harsh weather conditions. The wearable tracking device will be worn both inside and outside of the residence so it should be able to function in some unfavorable weather conditions such as rain.

1.4 Intended Users and Uses

The overall system will include three intended users: the senior that will be monitored, the senior's visitors (family and friends), and the senior's doctor's or nurses. Currently, there is a network of sensors that have been established. Our project will expand on this network by adding two additional components: the smart outlet, and the wearable tracking device. Our scope will thus be limited to these two components. Due to the limited scope, our only user will be the senior.

The smart outlet will be used to track which appliances are being used and when. It will report the time it occured, along with specific power statistics. Primarily the current (Amps), voltage (Volts), and power (Watts) will be recorded from the outlet, and then sent to the current sensor network.

The wearable tracking device will be used to track the senior inside and outside of the home. It will also provide fall detection and heart rate monitoring. For outside of the home usage, the tracking device will retrieve GPS information to establish the senior's current location. For inside the home usage, the tracking device will utilize it's built in sensors such as the pedometer, accelerometer, magnetometer to assist in identifying events that occur in the home.

1.5 Assumptions and Limitations

Assumptions:

- The senior will not take off the wearable tracking device
- The senior will not plug appliances to non-smart outlets
- The weable will be some kind of watch because the results of a survey of seniors showed they were must open to wearing that type of device.
- The senior will charge the wearable device when necessary

- The senior will not rearrange their apartment

Limitations:

- The smart outlets must not greatly restrict outlet usage
- Not all appliances run on standard 120 volt outlets so a different method is needed to monitor their power.
- The amount of data we can get is restricted by the API of the chosen wearable
- The smart watch may need to connect to a phone

1.6 Expected End Product and Deliverables

The expected end product of this project is a smart outlet that can transmit data to the hub of the already existing system, a working solution to track the senior both inside and outside their apartment, and provide fall detection with an existing wearable device, and a working solution to track guests in the apartment to filter out the the guest data from the behavioral profile.

Along with this we will provide any information and documents needed about the setup of the devices that will be needed to set up the system in more units, and scale up the use of the system.

The smart outlet will be able to send the following data to the sensor hub of the system: Plug ID, time of reading, date of reading, and power data. The plug that we have chosen to use is the TP-Link HS110. The expected delivery date for the prototype is October 21st.

The senior tracking solution will be able to get the location of the senior both when they are inside, and when they are outside, and provide fall detection for the senior. It will also be able to send that information to the existing AWS server. The expected delivery date for an idea for the solution is November 14th and the expected delivery date for the implementation is March 24th

The guest tracking system will be able to to track the location of the guest in the home. It will send the data that is collected to the existing AWS server. The expected delivery date for the idea for the solution is November 28th and the expected delivery date for the implementation is March 24th.

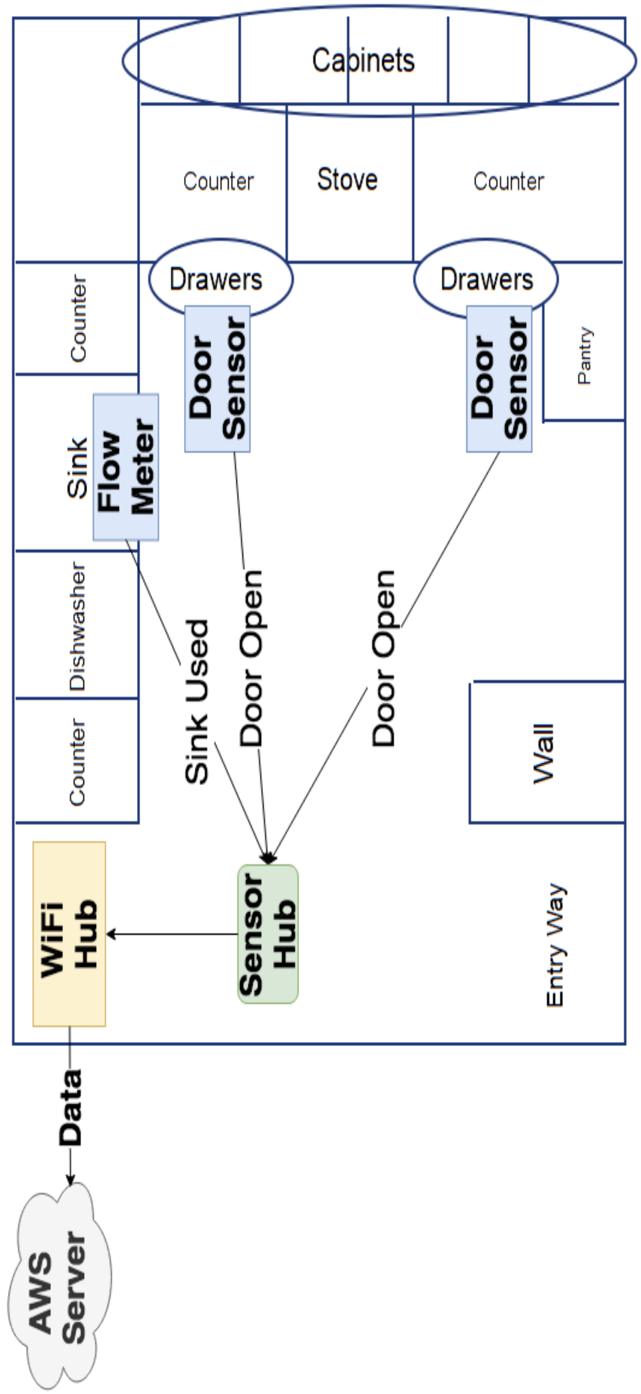
2. Specifications and Analysis

2.1 Proposed Design

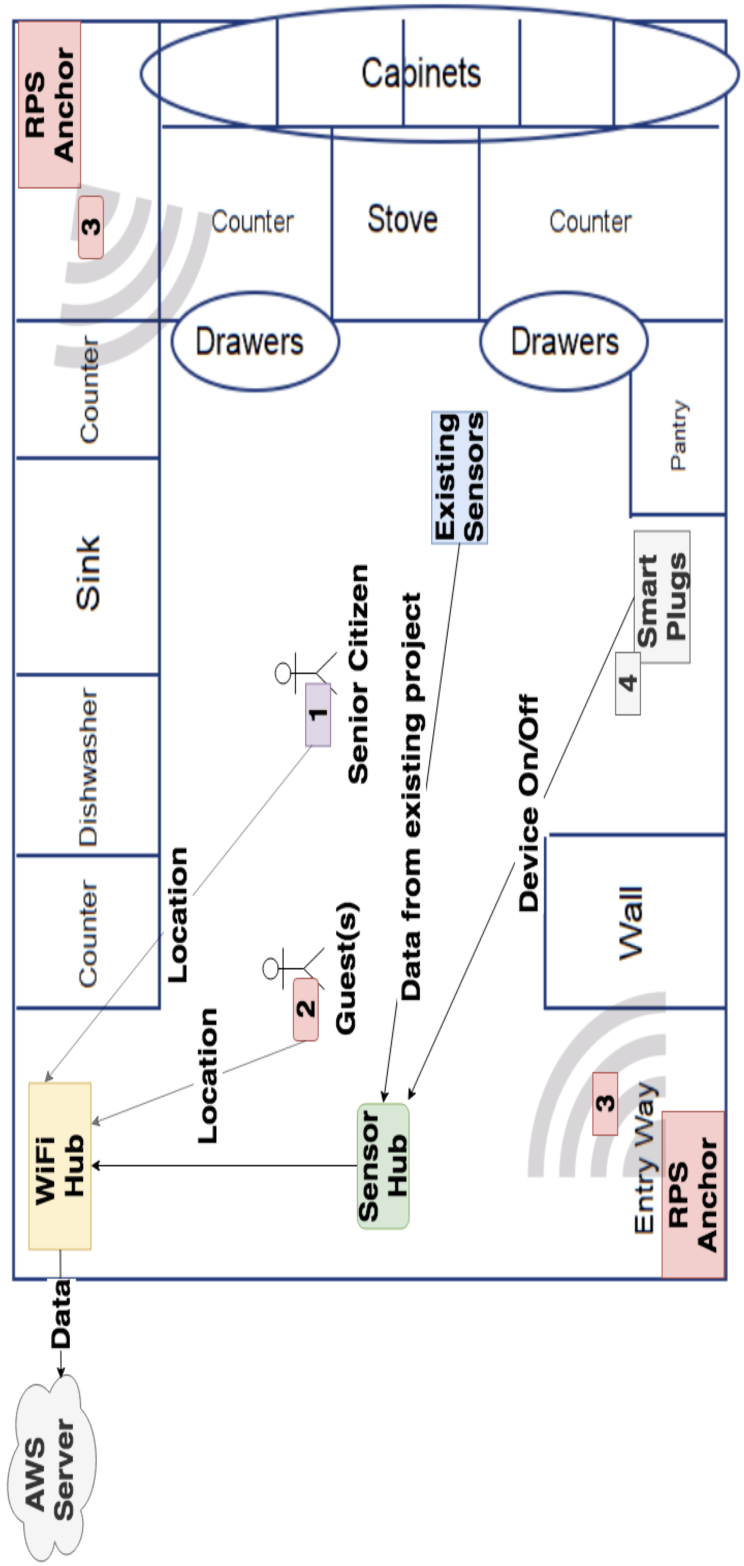
Our proposed design involves researching and implementing a smart plug to track appliance usage and a wearable device to track location and health data. The research for the smart plug resulted in picking the TP-Link smart plug. After receiving the plug, testing was started to pull data off the plug to send to a server. Research for the wearable tracking device is still ongoing, but the selection has moved to a smart watch with a specific set of requirements. Once a smartwatch is chosen, tracking with bluetooth and possibly wifi can be tested and compared to tracking using the Redpoint RLTS tracking system.

We decided on using the TCP-link smart outlet due to its availability at local retailers, whereas the other choice (PowerBlade) didn't have that availability. After receiving a TP-Link plug, our team implemented data transfer to NodeJS API to view values such as current, power, and voltage. As we've verified that we can pull data from the outlet, we're now working with the team before us that developed code for the server to get the smart outlet data on the server.

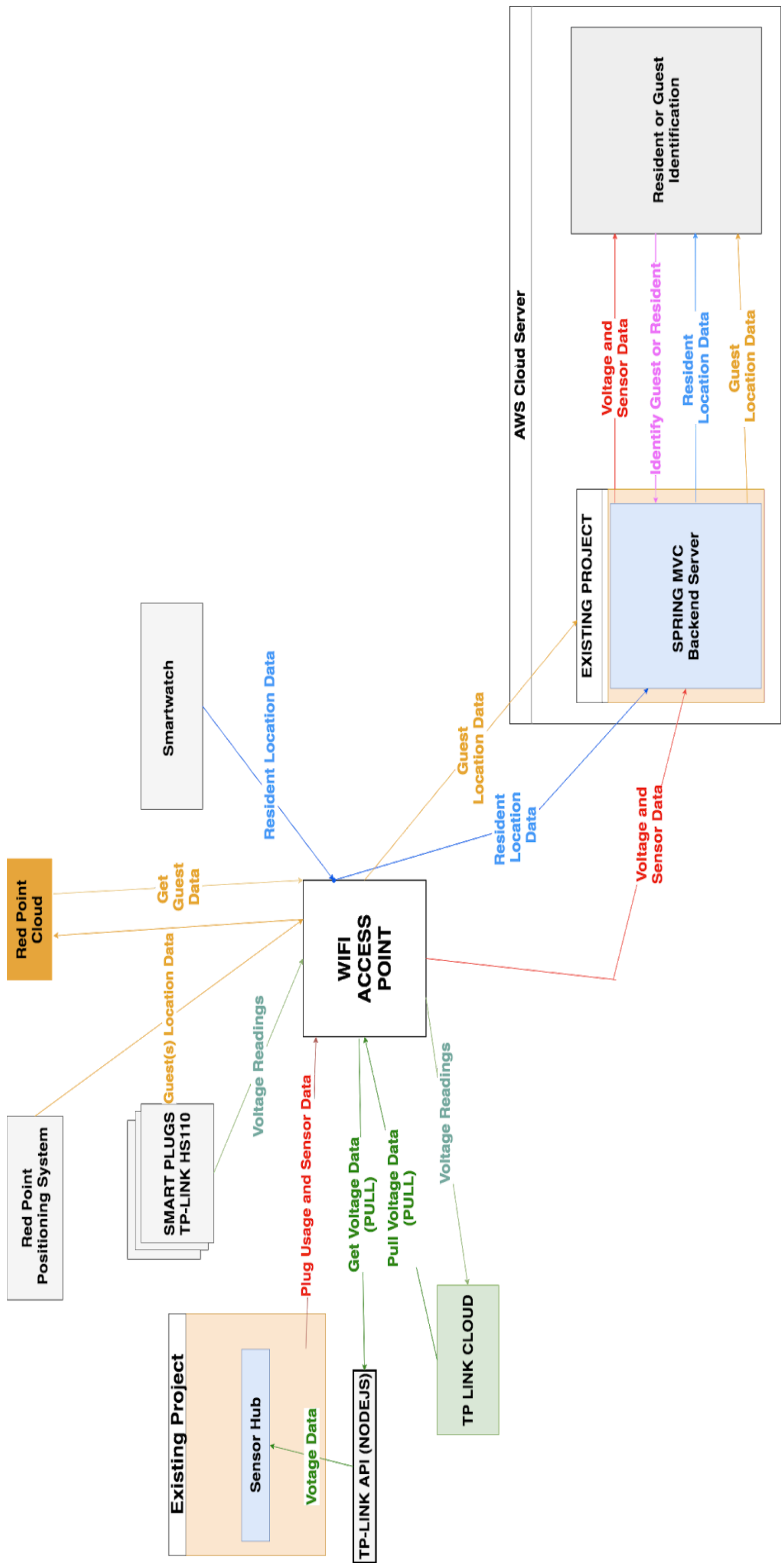
For the wearable tracking device, we started out with a wide range of possible solutions. This has now been narrowed down to using a smart watch alongside either the Redpoint tracking system or bluetooth and possibly wifi location tracking. Additionally, it was decided that the smart watch should be a standalone device with at least 3G capability and have a long battery life. This has narrowed the scope of devices significantly. The most likely candidates for this are the Apple Watch (preferably series 2 or newer) and the LG Sport.



[Figure 2.1.1] Schematic of existing plan for sensors in the kitchen



[Figure 2.1.2] Our extension to this project



AWS Cloud Server
Resident or Guest Identification
Voltage and Sensor Data
Identify Guest or Resident
Resident Location Data
Guest Location Data
EXISTING PROJECT
SPRING MVC Backend Server
Smartwatch
Resident Location Data
Guest Location Data
Resident Location Data
Voltage and Sensor Data
Red Point Cloud
Get Guest Data
Guest(s) Location Data
WIFI ACCESS POINT
Red Point Positioning System
SMART PLUGS TP-LINK HS110
Voltage Readings
Plug Usage and Sensor Data
Get Voltage Data (PULL)
Pull Voltage Data (PULL)
Voltage Readings
Existing Project
Sensor Hub
Votage Data
TP-LINK API (NODEJS)
TP LINK CLOUD

[Figure 2.1.3] Application data flow

2.2 Design Analysis

Our team has bought a TP-Link HS110 smart plug and are in the process of using the Node.JS API provided from TP-Link. Connection to the smart plug has been made and data can be viewed. Our team is currently meeting with the team who is working on the existing project in order to start getting data into the server. In addition, our team is looking into an open source TP-Link API to be able to send data based on an event driven architecture.

Strengths:
Modularity- Each component will function independently of each other
Scalability - Project should be able to scale to more rooms.

Weaknesses:
Security- This project relies on wifi communication to send data to the backend server. Our team will need to ensure data is not stolen through the wifi network.
Integration - The project will build on top of an existing project. Our team is assuming that the existing project will be done to specification.
Redundancy - There is no current plan for wifi outages within the environment of the project.

3. Testing and Implementation

3.1 Interface Specifications

There will be a significant amount of hardware/software interfacing due to the nature of the project. We will have several discrete embedded systems working together to enable features like event identification, effective data collection and safety alerts. Software will need to be developed for each of these systems in order to provide data that is usable from the sensor hub and AWS server.

The wearable device that will track the seniors and the wearables that will track the guests will have custom software running on them in order to process and communicate sensor data from the wearable devices to a server where that data can be analyzed and processed into the resultant predictive health model.

On the AWS server we will be creating software that will monitor and process data from the Wi-Fi connected smart outlet, to which home appliances will be connected. This software will interface with the TP-Link Cloud to retrieve data collected by the smart outlet.

3.2 Hardware and software

For this project we will be using a few different hardware components to test the different phases of our project. Most of the components used in development will also be the components we will use in testing. All of the hardware components will be provided by the client, and each group member will have access to the component when needed.

The first hardware component is the TP-Link Smart Plug. Even though this was used for development no additional hardware components will be needed to test the plug. For testing we will insert the plug into an outlet and plug some sort of appliance into the plug. The plug should then automatically be sending data to our server. The data that need and can be collected from the plug is the current, power, and voltage being drawn when the appliance is turned on.

The second piece of hardware that will be needed is the smart watch. This component, like the smart plug, was also used during development and will not need additional resources for testing. During testing when the watch is turned on it should automatically be collecting the patients data. The watch will contain many different sensors including, GPS, heart rate monitor, and others, to be used for the collection of data. Some of the collected data should include heart rate, patients movement, daily health statistics, fall detection, and etc.

Lastly, the final hardware component used for testing will be the Red Point Positioning (RPP) hardware. At this point we don't know specifically what the testing components will be needed. However, one component that we know will be needed is the tracking chip provided by the RPP development kit. This kit should include all of the new sensors needed and the tracking device used to track an individual. When all of this is set up we can begin reading the data being collected on whoever is wearing the tracking device inside a certain geofenced location.

3.3 Functional Testing

During the testing phase our functional requirements will be the most important due to that this is the area where we will see if everything we have implemented is working up to par with our standards. Most of these tests will be integration testing and system testing. For example, the smart plug will need integration testing in order to see how well it is working with the previous system. Then, the smartwatch will need both integration and system testing because it will be a component in the system and finally the Red Point Positioning component will need lots of system testing before it can be fully functional.

For testing the main goal is to make sure the data taken by the plug is collected and sent to our existing AWS server. To make sure this is happening we will need make sure the smart outlet API is correctly implemented into our program. Then, we will need to make sure the smart plug is plugged into an outlet with an appliance plugged into the plug and turned on all while having the server up and running waiting to see what data is showing up. When the data is collected we will need to verify it is correct and it is feasible compared to the appliance we tested.

Next, to test the smart watch we will need a volunteer to wear the watch for a certain period of time. This way the watch has enough time to collect the wearer's health data. The main goal of this test is to also make sure the data from the watch is collected and sent to the server. When the watch is fully implemented we will have the test user wear the watch until data collection is completed. Then, we will have to make sure all traditional health data is being collected and specific data, like location, is also being tracked and sent to the server. Then, like before we will have to manually verify all collected data is correct.

Finally, for the Red Point Positioning (RPP) testing the main goal is to be able to track the senior to within 1 meter of accuracy in their home. After the RPP system is fully implemented we will need a test user to wear the device and have him/her walk around the apartment to test location tracking. When the tester is moving around the apartment we need to see what locations are being sent to the server and determine if they are the correct.

3.4 Non-Functional Testing

Testing for performance, security, usability, compatibility

Some non-functional requirements in general is to see how fast the data from the devices are being sent to the server, and determine the security features are implemented correctly. We will need to make sure data is being sent in a timely fashion and also make sure all data being sent over the wifi connection is not being lost or manipulated.

The performance of the devices we are implementing is not a huge factor in our project. We would like the devices to be working correctly before we focus on how we can send data faster. However, with that being said some of the devices only send data so fast. For example, the smart watch data collection may need to be polled every so often instead of it sending data when it is collected. To test this we will need to see if both and can be implemented and which one sends data at a quicker rate.

Next up we have the security implementations. In order to test this we will need to see if someone can break into our system and manipulate so data and make sure not data is lost in the collection process. On the security side of things we just need to make sure we have a basic implementation of security features to protect our data. Next, to see how much data is lost we will need to collect a huge amount of data and see if there are any holes where data was lost. If there are any holes in the data we will know some data is either lost or not collected at all.

3.5 Process

Testing the TP-Link Smart Outlet consisted of connecting various devices to the outlet as an electrical load and polling the TP-Link Cloud for the device's data. This process showed the type and granularity of the data that could be expected from the device as well as the responsiveness of the NodeJS API and the TP-Link Cloud.

No testing has been completed for the smartwatch or Red Point Positioning hardware, which is a result of ongoing research.

3.6 Results

The results of the initial testing of the TP-Link Smart Outlet showed us what kind of data we could expect to receive from the device.

The first test was to collect data about the NodeJS API's object that represented the smart outlet. This allowed us to plan ahead to see what kind of data is possible to collect in the future.

```
myPlug: HS110 {device: Object, params: Object, genericType: "plug"}
  alias: "alpha-1"
  appServerUrl: "https://use1-wap.tplinkcloud.com"
  connected: true
  device: Object {fwVer: "1.2.5 Build 171206 Rel.085954", deviceName: "Wi-Fi Smart Plug With Energy Monitoring", status: 1, …}
  disconnected: false
  firmwareVersion: "1.2.5 Build 171206 Rel.085954"
  genericType: "plug"
  humanName: "alpha-1"
  id: "80062F4C50E9656CA54DBDA47EA8AD2B19E8D269"
  mac: "AC84C620FA37"
  model: "HS110(US)"
  name: "Wi-Fi Smart Plug With Energy Monitoring"
  params: Object {appName: "Kasa_Android", termID: "d47bf699-5830-4ef1-beeb-a7272bcab619", appVer: "1.4.4.607", …}
  role: 0
  status: 1
  type: "IOT.SMARTPLUGSWITCH"
  __proto__: HS100 {constructor: , getPowerUsage: , getDayStats: , …}
```


[Figure 3.6.1] TP-Link Cloud API smart outlet object data

After it was known what methods and data were available through the myPlug object, we conducted a test where there was no electrical load to see what the power monitoring method returned.


```
powerStats: Object {current: 0.012346, voltage: 118.77438, power: 0, …}
  current: 0.012346
  err_code: 0
  power: 0
  total: 0.004
  voltage: 118.77438
```


[Figure 3.6.2] Power monitoring method data, no load

Once we had a baseline for what electrical load and power monitoring data looked like, we tested the plug with different electrical loads. The first load was a charging iPad Pro and the second load was a toaster.


```
powerStats: Object {current: 0.216679, voltage: 118.750464, power: 13.91104, …}
  current: 0.216679
  err_code: 0
  power: 13.91104
  total: 0.004
  voltage: 118.750464
```


[Figure 3.6.3] Power monitoring method data, charging iPad Pro

```
powerStats: Object {current: 6.372684, voltage: 118.580974, power: 755.674055, …}
  current: 6.372684
  err_code: 0
  power: 755.674055
  total: 0.006
  voltage: 118.580974
```


[Figure 3.6.4] Power monitoring method data, toaster

The only challenge we faced during this testing was the experimental nature of it. These were tests of discovery rather than proving data or reliability, so we had to adjust the testing process as we moved on and learned more about the device.

4 Closing Material

4.1 Conclusion

So far our team has researched the major parts of our project: tracking with a smartwatch and getting power data with a smart plug. We have also ordered and received the smart plug that we have decided to use for the project, and have written both skeleton code and test code for getting the data from the smart plug.

Our main goal is to provide health monitoring for senior citizens by placing sensors in their home and building a behavioral profile from the data in order to diagnose medical conditions before symptoms are showing allowing seniors to stay in their homes longer. Our team specifically is working on adding a smart outlet to the sensor network to detect if an appliance is turned on, and add senior and guest tracking to the system. Our best idea for the senior tracking is to use a smartwatch that the senior would wear that can track their location because it is both a plausible solution, and based on a survey of seniors they are more open to wearing a smartwatch than any other wearable that could be used for tracking. Our best idea for guest tracking is to use sub gigahertz tracking to accurately track guests in the home to make sure the guest action does not get added to the behavioral profile of the senior.

4.2 References

This will likely be different than in project plan, since these will be technical references versus related work / market survey references. Do professional citation style(ex. IEEE).

4.3 Appendices