IoT Sensor Integration and Back-end Development for Sequoia

Project Plan

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Revised: 2018-10-26 / Version 1.1

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1 Introductory Material

1.1 Acknowledgement:

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1.2 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.

Our group's specific goal of this project is threefold. 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 smartwatch to provide fall detection for the senior and use the sensors already on the smart watch such as heart rate monitor and step counter to provide other health information about the senior. Third we will use subgighertz tracking to track the location of guests when they are in the senior’s apartment.

1.3 Operating Environment

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 User(s) and Intended Use(s)

The overall system has 3 intended users the senior that is being monitored, guests of the senior, and the seniors doctors. However for the three parts of the system that our team is focusing on (the smart outlets, the wearable tracking device, and the guest tracking system) the users will only be the senior, and their guests.

The smart outlet will be used to track which appliances are being used at which times, and when this information is combined with information for other sensors to know what times the senior is eating, and what they are eating. All the senior will have to do is not unplug the appliance from the smart outlet as the appliances will be plugged in correctly when the system is installed. The only thing the senior will have to do to use the wearable tracking device is make sure that it gets changed, and to wear it. The guest tracking system will be used to track the location of the guest in the apartment so the guest actions don't get added to the behavioral profile. The only thing the guest will have to do is wear a tag when they are in the senior's residence.

2 Proposed Approach and Statement of Work

2.1 Statement of Work and Deliverables

The expected end product of this project is code to run on the system hub (developed by the previous group) that is notified when power goes through one of the smart plugs, and transmits that data to server, two programs for the smartwatch one that will provide fall detection and another that will track the heart rate and step count of the senior and send that data to the server, and code that will send the location of the guests to the server.

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.

2.2 Functional requirements

FR.1: The smart sensor hub will be notified when power goes through the smart outlet

FR.2: The data from the smart outlet shall be sent to the existing AWS server

FR.3: The smartwatch will provide an alert when a fall is detected.

FR.4: The guest tracking system will track guests with one meter accuracy.

2.3 Constraints and Technology Considerations

The tracking system will be limited in accuracy depending on the solution chosen. Using systems involving wifi or bluetooth can get an accuracy between one and three meters, whereas systems involving rfid or ultra wideband can get an accuracy under one meter. Another constraint consideration is the amount of wiring required for these tracking solutions. Ideally, the less wiring required for the solution, the better. Systems involving RFID would involve extensive wiring, while systems using bluetooth or ultra wideband would only need wires for 4 to 5 beacons. For the smart outlet, its size cannot be too large to make use of the outlet inconvenient.

2.4 Assumptions and Limitations

2.4.1 Assumptions:

- The senior will not take off the smart watch
- The senior will not plug appliances to non-smart outlets
- The senior will charge the wearable device when necessary
- The senior will not rearrange their apartment
- Guest will always wear the tracking badge when in the senior's apartment

2.4.2 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 watch
- The smart watch may need to connect to a phone

2.5 Related work and Market Survey

This solution for our client's problem revolves around combining existing technologies and combining them to create a solution that has value than any of the one components. Research was conducted in the following categories: active tracking, passive tracking, and smart outlets.

As research was conducted about active tracking, it was determined that the two best high-level options would be to either have the senior use a wearable device or use ultra-wideband radio. When considering wearable devices, we needed to look at the features of each device available on the market, as well as consider if the senior would enjoy the device. If the wearable had all of the correct features, but the seniors did not like wearing it, useful data would not be able to be collected. On the other hand, if the most liked wearable option didn't have the necessary sensors, useful data would also not be able to be collected. To determine the interest of the seniors, the client conducted a market survey at Green Hills Community. The result showed that most seniors would be open to using an Apple Watch or a Fitbit device.

At the same time as our client conducted the market survey, we did research to see what kind of availability there was for the different wearables as well as what capabilities each one had, and how easily we could utilize those capabilities. We determined that the APIs for WearOS [1] and the Apple Watch [2] were the easiest to interact with since developers have the ability to get direct sensor data on the device, whereas the Fitbit API [3] only allowed developers to access data from the Fitbit servers rather than locally on the devices. This narrowed our search down to the Apple Watch and WearOS. The sensors available on the Apple Watch, combined with the market interest, makes it the most promising option as a wearable device for our application. Another benefit of using a wearable device for tracking is that it could be used to detect fall detection, which is a feature that our client wants. There is no first or third party fall detection applications that exist for Fitbit devices, but there is a first-party solution for Apple Watch [4] and an open source third party solution for WearOS [5].

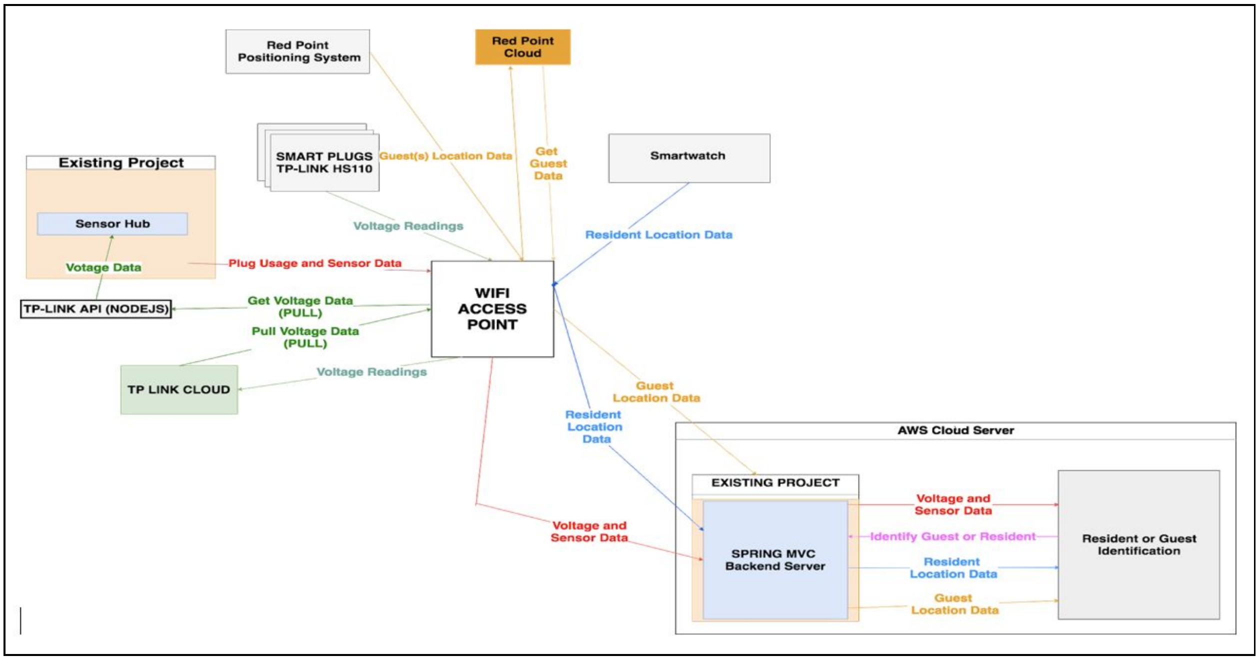
Our client has an existing relationship with a company who develops ultra-wideband tracking solutions called Red Point Positioning. The client requested that we conduct research on Red Point Positioning's tracking solution to see if it could be a viable option for active tracking instead of a more intrusive wearable device. At this point in research, we are still waiting on a development kit to evaluate the effectiveness of the tracking as it relates to the constraints of the environment of the Green Hills Community apartments.

The current devices on the market solve only part of the problem that our project will address. The wearable devices are only able to collect local sensor data like accelerometer and gyroscope to deliver features like fall detection for the senior, but not precise location data within the home. Ultra-wideband tracking would provide precise location data, which is necessary for identifying what kind of user triggered an event, but does not provide data necessary for fall detection. Our solution will combine the benefits of each of these systems to create a more holistic solution that will incorporate event identification, location tracking and fall detection using the strengths of the individual systems.

2.6 Proposed Design

This project consists of technical components involving resident and guest tracking, and collection of health data using a wearable device and electronic appliance usage using a smart outlet. This will be used to verify event identification for tasks such as opening drawers, using appliances, laying in bed, etc. For tracking, it was decided to use a ultra wideband RTLS smart badge from Redpoint Positioning. Guests will wear this smart badge when visiting to identify events made in their vicinity. A LG Sport smartwatch will be used to collect health data from the resident through the use of sensors such as: a heart rate monitor, step counter, and an accelerometer (for fall detection). Finally, a TP-Link HS-110 smart outlet to track electronic appliance usage in the residence.

The selection of a method of resident and guest tracking was the first major design factor to consider. Guest location tracking will be done using a smart badge that uses ultra-wideband from Redpoint Positioning. The smart badge was chosen for its sub-meter accuracy and for its convenience for guests to wear The smart badge will be worn by guests when they are visiting the resident. The guest's position can then be tracked to link guests to sensor event triggers when they are present. For sensor events triggered not at the guests location or events triggered when the guest is not present, we initially plan to assume they were triggered by the resident. Tracking the location of the resident is therefore a stretch goal, as it is not needed for a base functionality of this project. In order to track the residents' location, we could use Redpoint's smart badge or asset tag, or use a bluetooth and wifi location application for the smartwatch. Location data will be collected from the Redpoint servers (and the smartwatch, in the bluetooth and wifi tracking stretch goal if done) and sent to our AWS server. To see how these components will work with the rest of the project components, the diagram in Figure 2.6.1 shows the smart badge (listed as Redpoint Positioning System) with gold lines representing data transfer, and the smartwatch with blue lines representing data transfer.



[Figure 2.6.1: Component Interaction Architecture]

Using the smart badge (and possibly smart watch or asset tag), the tracking data needs to be sent to the web server for event identification. The established part of the overall system this project is a part of already has sensors for event identification, but it lacks a way to identify whether a guest or the patient triggered the event. By tracking location, we can identify which user triggered the event based on their proximity to the sensors sending the data. This is why accuracy is important, as events triggered by different users at the same time can happen in the same room. With the accuracy under a meter, the system could correctly differentiate the resident opening the fridge and a guest sitting at a table in the same room.

The LG Sport smartwatch will be used to collect basic health data from the resident. This will include measuring heart rate, recording step count, and sending alerts if the resident falls over. This will either be done by obtaining licenses for existing code repositories for smartwatch applications or by writing custom smartwatch applications ourselves. The LG Sport was chosen over the Apple Watch series 4 due to its ability to work without pairing to a smartphone, something the Apple Watch is not capable of. As mentioned before the smartwatch's interaction with the other system components can be seen in Figure 2.6.1 with blue lines representing data transfer.

The TP-Link smart outlet will be part of the numerous sensors in the residence. This sensor needs to track electrical usage in order to identify between usage of electrical appliances such as a stove, a toaster, or a microwave. Data from this outlet then needs to be sent to the web server for event identification. The outlet was chosen due to its availability at many retailers and due to its ability to poll for voltage, current, and power consumption. The outlet's interaction with the other project components can be seen in Figure 2.6.1 with red and grey lines representing its data transfer.

2.7 Security Considerations

As personal data involving the patient's health will be stored in a central database, security needs to be taken into consideration. For the scope of this project, the data only needs to send and store the data securely.

2.8 Safety Considerations

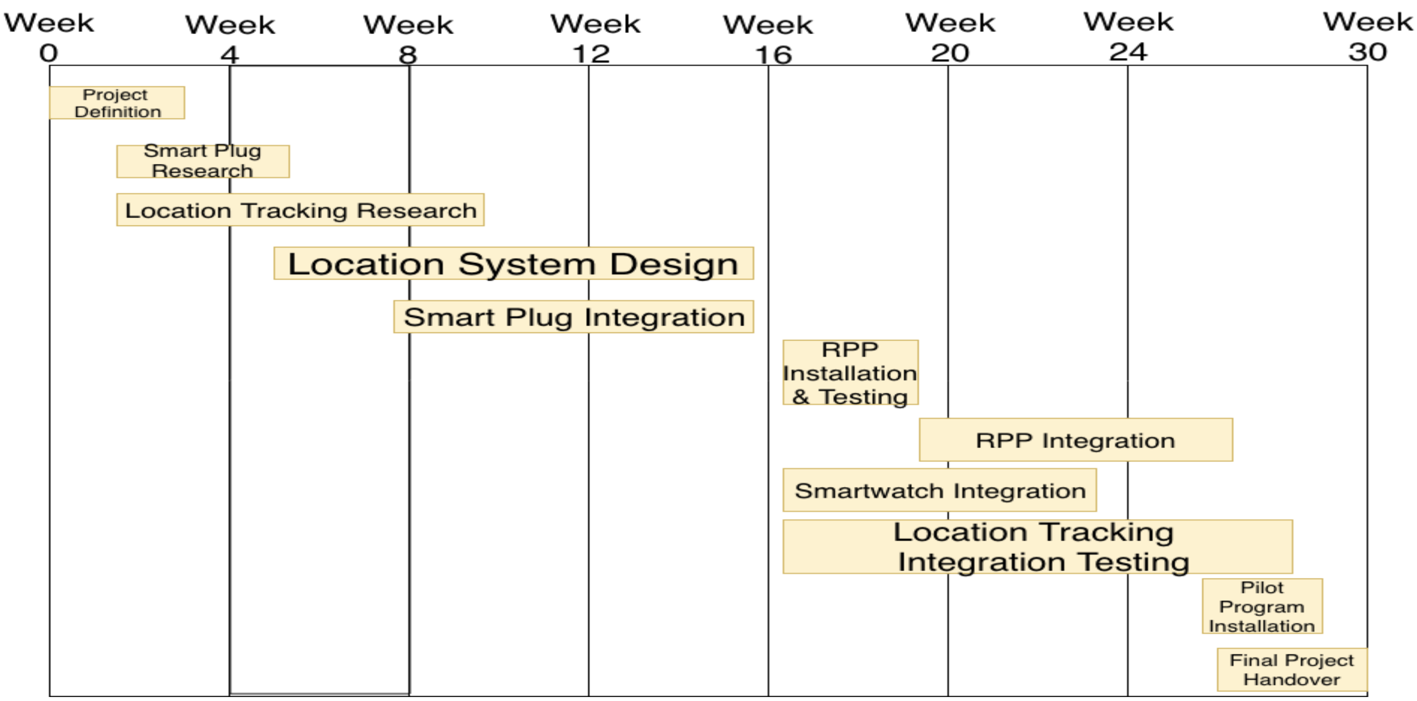
As we will be working with electrical outlets in this project, precaution will have to be taken with using the smart outlet to avoid a shock from the outlet.

2.9 Possible Risks and Risk Management

Title: Health Data Security
Risk: Mitigate
Information: As data will be sent for collection on a web server, we need to verify that the data is securely sent to the web server and is then therefore kept secure when on that web server. This can be challenging when using simpler devices such as rfid or

ultrawide band that would not have established security protocols that things like smart devices could have.
Mitigation: We should verify data is only sent to the web server without the possibility of outsiders receiving the data. In addition, we should verify that the web server has specific control over which devices can send and receive data.

3 Project Timeline, Estimated Resources and Challenges



[Figure 3.1: Project Timeline]

Task	Description	Work Estimate
Project Definition	Understanding project problem. Coming up with requirements.	10 hrs
Smart Plug Research	Research what smart plug should be used in our system. Do market survey and cost analysis. Buying best available smart plug.	10 hrs
Location Tracking Research	Research for how we are going to track the senior. Figuring out what hardware is necessary.	20 hrs
Smart Plug Integration	Finding a way to integrate off the shelf smart plug into current sensor system.	20 hrs
Location Systems Design	Designing a system that can accurately track a senior.	40 hrs
Red Point Positioning (RPP) Installation and Testing	Our client would like to use RPP as a tracking solution for guests. Our client has let us know we should have access to a devkit by the end of the current semester. Our team will then install anchor points in a test environment and see how guests can be tracked using RPP.	20 hrs
Red Point Positioning (RPP) Integration	Once RPP has been found to be a feasible solution, our team will work on integrating the RPP solution into the existing project solution.	150 hrs
Smart Watch Integration	Our client would like us to	150 hrs

	use a smartwatch to track heart rate info and for fall detection of the senior citizen. Our team is tasked with finding a fall detection app for a LG Sport smartwatch and figure out a way to get data from the smartwatch to the server.	
Location Tracking Integration Testing	Testing to make sure integration of developed solutions does not break system.	40 hrs
Pilot Program Installation	Installation of finished system into pilot program user's apartment.	20 hrs.
Final Project Handover	Final documentation and handing over project back to client.	10 hrs

[Table 3.1: Estimated Time Resources]

3.1 Standards

The data that we are collecting from out smart watch is sensitive health information because of this we need to make sure that the data is secured so unauthorized people cannot gain access to the data.in order to do this we must. The standard that we plan on using to make sure the data stays secure are the HIPAA data security standards. Along with this standard for for securing data we will also hold ourselves to the IEEE code of ethics when determining how the system should be used. We will raise any ethical concerns that arise to our client and advisor.

3.1.1 Testing and Test Plan

FR.1: The smart sensor hub will be notified when power goes through the smart outlet.

Test case:

As the first functional requirement we must first determine when the smart outlet is actually collecting data. We will need an appliance to be plugged into the outlet and see if the sensor hub is alerted. When the appliance is turned on it should notify the hub that the appliance is now on and data should now be collected.

Test steps:

1. Plug an appliance into the smart outlet and plug it into the wall outlet.
2. Turn on the appliance and see if the smart sensor hub receives an alert.

Expected result:

When the appliance is turned on it will send a notification to the smart sensor hub saying the appliance is now on.

FR.2: The data from the smart outlet shall be sent to the existing AWS server.

Test case:

For this requirement we want to be able to test the appliances with the outlets to see if we can see how much and when the power is being drawn. Also, we must see if the data is being sent to the AWS server when the plug is taking data.

Test steps:

3. Make sure the smart outlet API is integrated in the program.
4. Turn on an appliance with the outlet and determine if any data was recorded.
5. Ensure all recorded data is feasible for the appliance being used.

Expected result:

Data from the outlet should be sent to the AWS server, and be correlated to the appliance.

FR.3: The smartwatch will provide an alert when a fall is detected.

Test case:

Have a test user wear the device and determine all wanted data is being taken, most importantly the fall detection. We must have the wearer try and get a fall notification from the watch and see what data is being sent to the server.

Test steps:

1. Find a test user to wear the watch until data collection is completed.
2. Have the tester try to get a fall notification.
3. See that the notification was received instantaneously when fall occurs unless otherwise stated.
4. Verify all data from the fall was sent, received, and correct instantly when fall occurs.

Expected result:

The smartwatch should send a notification to an EMS responder instantaneously when the wearer has taken a tumble unless otherwise stated. Also, any other important data is sent to the server and correct.

FR.4: The guest tracking system will track guests with one meter accuracy.

Test case:

Find a test user to wear the device and walk around the apartment to test location tracking. Have the device record location of the wearer and determine if the location is within one meter of accuracy.

Test steps:

1. Have the test user wear the device and move around the apartment.
2. Track location of the tester and determine if it is correct and within a meter of actual location.

Expected result:

Be able to determine where the user is up to a meter. For example, whether the user is at the fridge or the stove.

3.2 Feasibility Assessment

The project involves numerous hardware components, such as the LG Sport smartwatch, the TP-Link HS-110 smart outlets, the Red Point Positioning ultra-wide band system, along with the company's current smart-home ecosystem. Due to the nature of each hardware component, and the different methods of sending and processing information between devices, there exists multiple risks with integrating each component into the smart home ecosystem. Currently the company is working on a backend service that all of these devices will be connected to, but the senior design team does not have control over how it is programmed or designed. As a result, it may prove to be difficult to interface with the company's' backend services without implementing another hardware interface.

Utilizing the LG Sport and the various hardware sensors in the current smart-home ecosystem to identify specific user actions is also an anticipated challenge. The objective is to successfully identify when a user may have performed certain actions - identifying the circumstances when these actions are performed may prove to be difficult, as there is potential interference from guest's visiting the user. The team will have to consider ways to determine the user from visitors.

3.3 Other Resource Requirements

With the selection to use the LG Sport watch, the team will utilize Android Studio for development. We will also utilize Amazon Web Services for the current company's backend system, along with the Java Spring backend framework.

The team will also need to utilize the company's current sensor hub to successfully integrate the smart watch tracking and smart outlets into the smart home ecosystem.

3.4 Financial Requirements

The project requires a few hardware components to be successfully. The project will utilize the LG Sport smartwatch, which will cost $300.

The project will also require funding for the TP-Link HS-110. Each outlet individually costs $16 - $30, depending on where it is purchased.

Finally, the Red Point Positioning ultra-wide band system will require funding. Currently, our client is negotiating a deal with the Red Point Positioning team, to see if our team can secure test unit. The price for the system will be determined at a later date.

4 Closure Materials

4.1 Conclusions

In conclusion, the goal of the Sequoia project is to use sensors to monitor the daily habits of senior citizens, and use that data to see when those habits change, possible indicating a heath issues before other symptoms are showing. This will allows seniors to stay in their homes longer and have a better quality of life.

In support of this goal our team will integrate a smart outlet into the already existing sensor network in order to monitor what appliances are being used. This will help monitor the seniors eating habits. We will have this implemented by mid-November to have it ready for trials. We will also implement the use of a smartwatch to provide fall detection for the senior along with heart rate monitoring, and step counting. The final thing we will provide is an implementation of sub gigahertz guest tracking to make sure that sensor data from guests does not get added to the seniors behavioral profile.

4.2 References

[1] https://developer.android.com/reference/android/support/wearable/packages
[2] https://developer.apple.com/watchos
[3] https://dev.fitbit.com
[4] https://support.apple.com/en-us/HT208944
[5] https://github.com/alessandror/AndroidFallDetectionApp