Team Number: **sdmay18-34**
Client: **Optical Operations**
Adviser: **Dr. Qiao**
Project Manager: **Chandler Chockalingam**
Report Manager: **Chris Stapler**
Software Architect: **Jason Ramirez**
Chief Engineer (Tracking): **Josua Gonzalez-Neal**
QA Lead: **Logan Highland**
Chief Engineer (Hololens): **Victor Da Silva**
sdmay18-34@iastate.edu
http://sdmay18-34.sd.ece.iastate.edu/

Integration of Personnel Tracking in an Augmented Reality Environment

Project Plan

Revised: 12/1/17 | V0.3

Table of Contents

List of Figures

Include these sections only as needed.

List of Tables

List of Definitions

CSI/Channel State Information: Properties of a communication link, including information that describes how a signal propagates from the transmitter to the receiver and represents the combined effect of, for example, scattering, fading, and power decay with distance (Wikipedia)

RSSI/Received Signal Strength Indicator: a measurement of the power present in a received radio signal (Wikipedia)

Megaproject: large-scale, complex ventures that typically cost $1 billion or more, take many years to develop and build, involve multiple public and private stakeholders, are transformational, and impact millions of people (Wikipedia)

1 Introductory Material

1.1 Acknowledgement

We would like to thank Dr. Daji Qiao for pointing us in the right direction when it comes to wireless communications technologies and coming up with viable tracking solution.

We would also like to acknowledge our client Andrew, CEO of Optical Operations. He always believes in us and gives us hope whenever we would meet. He is the ideal client, giving the team concise requirements and being understanding of our lives outside of senior design.

1.2 Problem Statement

Problem Statement:
There are inherently a lot of problems with not knowing where people are located at. Whether they are in the location they say they are, or if they are missing and others are trying to find them. When workers cannot be located, there are safety concerns. If you are working with something dangerous that could harm somebody such as demolition on a building. It can also mean people can get hurt doing something they shouldn't be, and lie because you have no way of seeing where they were and what they were doing. Specifically for this project, Optical Operations LLC wants to solve the problem of general contractors for construction megaprojects (projects costing upwards of $1 billion). Not having accountability for workers leads to loss of money and time on these projects and can make a huge difference in budget and schedule.

Solution Approach:
The goal of the project is to create a tracking system that interfaces with a Hololens application to show a live map of where personnel are at any given time. The personnel are tracked through a small token, which is attached to issued Personal Protective Equipment (PPE), that communicates with a distributed tracking system that relays data to the Hololens that a general contractor will utilize for monitoring purposes. This will allow a supervisor to check the environment before doing something that could cause harm to someone in the vicinity. It will also allow them to make sure their workers are held responsible for where they are and what they are supposed to be doing.

1.3 Operating Environment

Our end product will have to work in an outside environment. This means it will need to endure almost all types of weather conditions. With this in mind, it will have to be water resistant, or have a case that is water resistant. It will need to be able to work in dusty and dirty environments and be able to withstand a reasonable amount of force applied to the token. It will also have to endure very cold temperatures, as well as hot summer temperatures. Wi-Fi will be provided and available throughout the work site at 60 megabits per second.

1.4 Intended Users and Intended Uses

This project's outcome will be marketed towards construction companies and those who want to ensure that outdoor worksites are running efficiently and safely. The players in our proposed solution will be all personnel who enter the active construction site and the supervisors who will be monitoring the location of the personnel using Hololens either on-site or the company's headquarters.

The areas that this product will prove useful is any outdoor environment where keeping track of personnel location will ensure their productivity and well being. The solution will be very versatile and will cater to the needs the clients we outfit it for. In the case of emergencies, it will be vital for responders to know the location of personnel on the worksite to facilitate the rescue process. Another intended use case is the improvement of low-efficiency worksites. Using our system worksites will be able to improve their effectiveness by ensuring that workers are in their correct positions accomplishing their jobs in a timely manner.

1.5 Expected End Product and Other Deliverables

491 Deliverables:

- A proposed solution that includes limitations, software and hardware choices, and a work plan (sprint backlog items) to complete by the 20th of December.
- Documentation of experiments and research done on various localization solutions and one conclusive idea.
- Access to the team website that contains all the documents from the semester and code written for above systems, which is currently being delivered to the client on a regular basis, whenever something new is uploaded.

492 Deliverables:

- Hardware with embedded software that acts as tokens to send positioning data back to the server, which we will have to present to our client.
- A backend service that allows for the collection of data from tokens, and handles the information as well as sending it forward for the next piece of our project.
- Simple web interface to display accuracy of the tracking system, which will be up and running when we get the initial hardware component down.
- A work plan for the rest of the project that includes the exact schedule of all the tasks left to complete, as well as documenting who's responsible for each part of the product, deliverable by February 15th.
- A modular case for hardware that can fit on the belt of a construction worker, deliverable by March 15th.
- An application for the Hololens that gets information from the backend service and displays a 3D map with personnel tracking, deliverable by May 1st.

2 Proposed Approach and Statement of Work

2.1 Functional Requirements

- Must track at least 6 people in a playground-sized environment (20 x 20 m): the end goal is to be able to track our group successfully in a small, coned-off simulated outside work environment.
- Must be accurate within 5 meters: the tracking must show the avatar as accurately as possible to track people in real time.
- Token relays information in a readable format to Hololens.
- If the active sensor, battery life = 1 work day (10 hours): needs to be able to last an entire workday without being charged.
- Sensor communication range: 10 m: must have a minimum range of 10 m to limit the number of sensors needed.
- Real-time tracking: acceptable delay of 1 second: if there is too long of a delay, the positioning will not be accurate on a moving target.
- Store 1 day's worth of data: this will help to keep a heat map to show where the worker has been for the past day, allowing general contractors to keep workers honest about where they spend their time.
- Track people moving at a maximum of 5 mph: this will allow the positioning to still be accurate on someone moving at a reasonable speed.

2.2 Non-Functional Requirements

- Realistically-sized token: wearable device (preferably attached to PPE)
- The token must be water resistant, withstand external forces (durability): main use case is a construction site for our phase, so it must be durable and be able to withstand outside weather conditions.
- System secured so it is inaccessible to unauthorized users: must be secure so others cannot gain access and view positioning of workers, very negative consequences in future phases.
- Create a system that is scalable to megaprojects (projects greater than 1 billion dollars): must be able to scale for projects that have a lot more than six workers.
- Maintainable for the length of the project: for a construction site must be able to be easily maintained for the length of construction project several months at a time.

2.3 Standards

IEEE 802.11 Standard
Our project will rely on the hardware and software that utilize this standard [1]. Its relevance comes into play in our project because we are working with wireless networks. Our practices will not be considered unethical by this IEEE standard.

Microsoft C# Coding Conventions:
There is not a standard created for the C# language according to Microsoft. However, there is a guide that includes naming conventions, layout conventions, commenting conventions, and language guidelines [2]. These guidelines are not technically standards and they are not approved by standard organizations like IEEE or ABET. Since this is a coding standard, we will not be doing any unethical practices by standards. These conventions are important for our project and we will use them when we program in C# for the Microsoft Hololens application.

Python Style Guide:
Python provides a style guide for code layout, comments, naming conventions, and use of whitespace. Again, this is not a standard administered by IEEE or ABET [3]. These conventions are important for our project and we will use them when we program in Python for the Raspberry Pi we are planning to use for our hardware and software components.

2.4 Technology Considerations

Our original plan for the localization solution for this project was to use CSI, Channel State Information, due to it having accuracy within 1 meter. We have decided to change this plan to a different technology.

After collecting data using Intel's 5300 CSI tool, we came to the realization that this technology will only work to track one person and not a large group of personnel, which is the intended goal of this tracking system. This prompted us to start pursuing an alternative solution, Received Signal Strength Indicator or RSSI. We also changed our plan of using CSI based on the need for CSI data to be collected over an open Wi-Fi network, which is a major security concern for our client.

2.5 Safety Considerations

Safety is the utmost concern for our project. In regards to the tracking devices we will outfit each worksite personnel with, we have discussed it being small enough to not interfere with their work. This factor has a lot to do with safety for the fact that if it was too heavy it could cause strain on the wearer. Another consideration we have made for our project is that we will be limited the number of sensors and additional infrastructure that we will be adding to the construction site.

2.6 Previous Work and Literature

There have been many attempts at tracking personnel and localizing objects in familiar and unfamiliar environments. For the initial phases of the project, we looked into solutions that used GPS before switching focus to an entirely Wi-Fi based approach, as it has the capability to support indoor localization, while GPS does not. The Wi-Fi-based approach that we had decided to try and implement is one that relies on channel state information. We previously planned to implement a localization algorithm detailed in *SpotFi: Decimeter Level Localization Using Wi-Fi* [4]. This paper has been published fairly recently, and it is one of the leading papers in localization based on CSI and has been cited in many other papers already. One such paper we draw additional inspiration from is *Decimeter-Level Localization with a Single Wi-Fi Access Point* [5]. These papers would have been the guidelines for implementing our own personnel tracking system. We have since changed our plan to move from CSI to RSSI in order to combat challenges that are mentioned in the Technical Considerations section.

2.7 Possible Risks and Risk Management

One risk we may face is exceeding our allotted budget. While our budget is significant ($3000), we could potentially be purchasing another Hololens device, which would cause us to exceed our budget. However, we can mitigate this risk by using the Hololens device that our client currently owns since we will not need to use it extensively until 492. This is when the other senior design team will be done using it. We can also mitigate the budget risk by selecting alternate hardware that costs less (for example, we used the Raspberry Pi Zero as oppose to the Adafruit Flora for the hardware token).

Another risk with this project is that we are working with technologies that our team has little to no experience with. For example, we are using the Microsoft Hololens, and in order to develop for it, we need to use Unity and C#. While one of our team members has used Unity and some others have used C#, most of us have a lot of knowledge of both. Additionally, in order to do tracking, we are meshing two technologies together, using Wi-Fi triangulation. This will be a big risk, as there are no implementations of this that the team has found and it is not a proven technology. However, the prospect of achieving our goal of creating a scalable is worth taking on the risk.

2.8 Project Proposed Milestones and Evaluation Criteria

Key Milestones in the project:

- Choose which hardware we are going to use for the tracking device
- Have an initial working prototype for tracking location
- Develop initial Hololens application to display location information
- Create and test an integrated system with the tracking hardware and Hololens application
- Design the experiments and prepare for final demo

2.9 Project Tracking Procedures

To track project progress through the course, we will be using Git's issue tracking system for development work. For work that is not development and deals with some of the hardware, research, and documentation aspects of our project, we will be using Trello, a virtual Scrum board. This will allow us to keep track of both our technical and non-technical aspects of our project and be sure we complete all of our tasks. This will also allow us to hold each team member accountable.

2.10 Objective of the Task

The objective of our project is to have a tracking and monitoring solution to deliver to our client that we will design and implement using the Microsoft Hololens, a Raspberry Pi, worksite base stations, and the Google Cloud Platform. The solution will be scalable and be able to be used on worksites of various layouts.

2.11 Task Approach

The figure below is our current system's architecture. It shows how the first user, a construction project's general contractor, will wear a Microsoft Hololens device that is connected to the internet. It will have data transferred and be displayed over the internet from the second user, the construction worker. They will wear a belt clip with a device attached that will interact with the Wi-Fi signal. This device will get location data by measuring signal strength of the Wi-Fi and will communicate this data to a server. This server will store the day's data in a database.

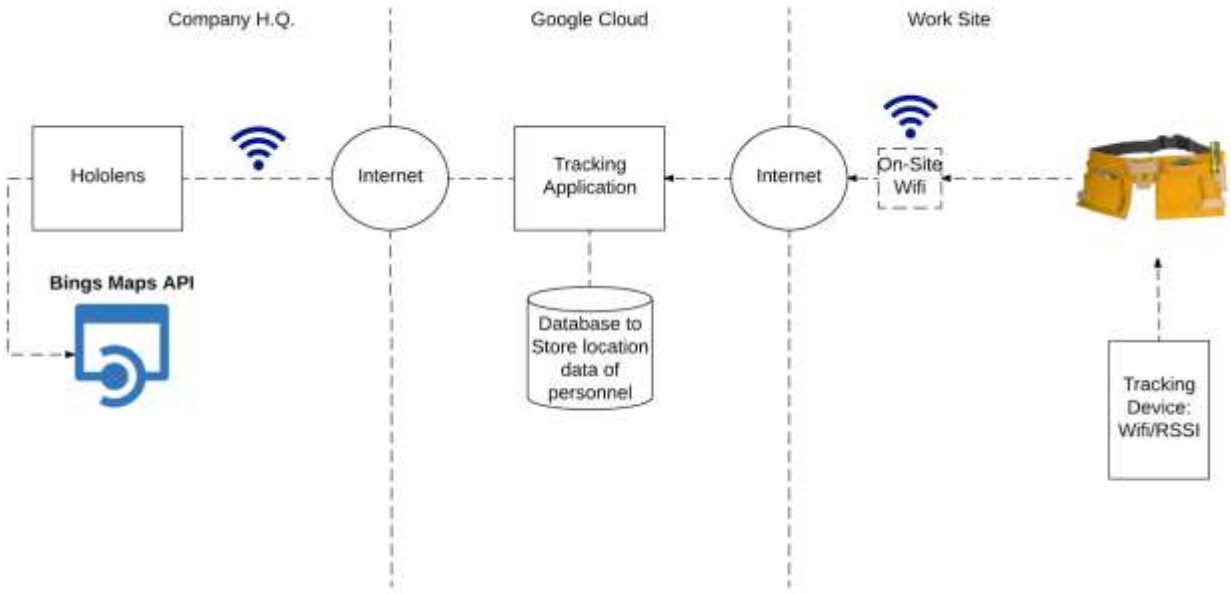

Figure 1: Architecture diagram

2.12 Expected Results and Validation

The desired outcome is a Microsoft Hololens application that works as intended to track individual employees on a construction site. The desired outcome for tracking accuracy is within 5 meters. Additionally, it is the desired outcome that we create a product that will not interfere with our end user's PPE and required equipment and have a Hololens application that will be easy for a general contractor to use.

We will confirm that our solutions work by testing the accuracy of our test plan. We will confirm that our software works as intended through unit testing and user testing.

2.13 Assessment of Proposed Solution

The newly proposed solution of RSSI for localization is a complex subject. While it will not be as accurate as CSI, our original proposed solution, it will actually work to track more than one person at a given time. This is a crucial feature that our project needs to have and in order to meet the requirements so we have to use the alternative to CSI.

We will continue to do more research and investigation into this once we start to implement the solution. With the Wi-Fi triangulation localization solution, we may choose to use a machine learning fingerprinting along with RSSI in order to gain a more accurate location tracking service. This continued research will allow us to further gauge whether RSSI will actually work for us for a final solution.

2.14 Technical Approach

Our technical approach was to find research, existing projects, and approaches to using CSI and RSSI wireless tracking technologies. The data used from these technologies will be given to our service to track locations of the nodes (Personnel) in a location/site. The location database on our service will then be pushed to our location tracking data service that will be in communication with our Hololens application.

We are going to split up our project into six separate parts:

1. Tracking Device Software
    a. Obtain RSSI values for all access points for a particular personnel device
2. Triangulation Service
    a. Processes devices' fingerprints (compilation of mac addresses and RSSI of APs)
    b. Runs triangulation algorithm
    c. Schedules data exchange between the service and tracking devices

3. LocationTrackingData Service
    a. Sends updates of user locations to the general contractor's view of the work site (via Web Application or Hololens) in real time
4. SaveUserLocation Service
    a. Sends user's latitude, longitude, work site, and time
5. Management User Interface to set up a work site
6. Hololens Application
    a. Views a worksite through an augmented environment, allows bird eye view

2.15 Test Plan

Software/Hardware Under Test:

- Software: RSSI localization software, software on Raspbian OS for Raspberry Pi, C# code for Microsoft Hololens application
- Hardware: Raspberry Pi Zero, Microsoft Hololens

Tester Staffing Requirements:

We will need at least one-third of our team or 2 members working on testing

Testing Tasks:

1. Unit tests for functional requirements of software
2. Unit tests for non-functional requirements of software
3. Perform software usability tests
4. Make any necessary software changes
5. Perform regression tests on software
6. Test hardware requirements
7. Perform hardware usability tests
8. Make any necessary hardware changes
9. Make necessary hardware changes
10. Perform integration tests
11. Perform more software unit tests on system with hardware integrated
12. Perform usability tests on entire system
13. Make any changes to whole system as necessary
14. Perform regression tests on entire system

Plan to obtain test data:

We plan to obtain the data by collecting it ourselves using people walking around a test area. We will track them at different points to stimulate a worker walking around a site. We will use this test data to test our hololens application, making sure that all parts of the projects are working.

Pass/Fail Criteria:
For the software tests, we will determine failure/passing criteria on a case to case basis for tests. For hardware tests, we will primarily be testing for usability and if the intended result is met.

Sample Test Case:
One requirement that we will need to test for our Hololens application (written in C#) is that the user of the application, the construction general contractor, has the ability to select a particular worker they want to track and the application will show them where that person has been:

- Input: worker they want to see
- Expected Output: visualization of worker they want to see in real time

3 Estimated Resources and Project Timeline

3.1 Personnel Effort Requirements

Task	Project Effort Required to Perform Task Correctly
Set up laptop/server for our system	This task involves setting up a laptop as our server for the system.
Configure Raspberry Pi Zero hardware token	This task involves programming the Raspberry Pi. We have a decent amount of knowledge in the programming language we will likely be using, Python, so we estimate it will take approximately 2 weeks for 10 hours per week for two people.
Implement Wi-Fi Triangulation System	This involves writing code based on open-source implementations for RSSI and creating and researching existing GPS RTK Systems and implementing it for Wi-Fi.
Put together prototype of our product	We will need to design an experiment to show our system works and act as a proof of concept. It will take about 5 days to a week if all preparatory work is complete for 10-20 hours for two people.
Brainstorm improvements to our prototype	This involves thinking of ways to improve our prototype for first semester based on how our presentation/demo goes at the end of fall semester. This should take the duration of winter break, or 3 weeks for 6 hours per week for 6 people.
Implement improvements to our prototype	This involves making changes to our code and hardware based on the improvements we

	brainstormed. It should take 1.5-2 weeks to complete for 10 hours per week for two people.
Develop basic Hololens application	This involves working on the Unity and C# aspects of the Hololens application and should take approximately 2 weeks to 10 hours per week.
Test Hololens application	This involves doing unit tests on the code and user testing with the Hololens device. It should take about 1 week at 10 hours per week for two people.
Configure app with server and hardware	This will involve integrating the hardware (Raspberry Pi token and localization setup), the server, and the Hololens device/application and should take approximately 2 weeks to 10 hours per week for one person.
Integration testing on Hololens/Server/Hardware system	We will be testing how the software we wrote for the Hololens works with the Hardware/Software for the token, the RSSI RTK configuration, and the server by using it and performing more unit tests. This should take 2.5 weeks at 5 hours per week for two people.
Make improvements to the system	We will do bug fixes and make changes based on what we found in our integration tests. It will take 1.5 weeks at 10 hours per week for two people.
Perform more integration tests	After making improvements based on the first round of tests, we will do another one to make sure the new code did not affect the old code/system parts that were working and ensure bugs have been fixed. It will take 1 week at 10 hours per week for two people.
Put together final demo	Design experiment to demo in our final presentation for Senior Design. It will take 2 weeks at 10 hours per week for 6 people.

Table 1: Tasks and personnel effort requirements

3.2 Other Resource Requirements

We have a variety of resources available to ensure that the project will run successfully. As we have experimented with the prospect of using a CSI-based localization solution, we have four Intel 5300 Wi-Fi chips. We will have tokens for the personnel to carry around that communicate with the access points, which we first develop prototypes for that can later be improved. We will use Raspberry Pis as the prototype token boards, as they provide many different customization options. We also have several laptops to work to act as local server nodes for on-site processing. In addition, we will need our site to have Wi-Fi access across the entirety of the area. The final thing we will need for our system is a Microsoft Hololens to show our data in, which has already been provided by our client.

3.3 Financial Requirements

Our team has been allotted a budget for our client, Optical Operations LLC, to use for this project. Our budget for hardware and supplies is $3000. Optical Operations LLC has also allowed us to use a Microsoft Hololens device for our development that was purchased in a previous semester. This will prevent us from having to make the large investment of our budget in buying a Hololens device for our project.

3.4 Project Timeline

Our steps for this project for Fall and Spring semesters, as well as our Gantt charts, are listed below.

First Semester

1. Research many solutions to solve the problem of tracking personnel in an outdoor environment
2. Work with 492 team to better understand how to design mixed-reality application
3. Review tracking solutions with advisor and client
4. Determine top solutions listing pros and cons of each
5. Order parts for best solution while writing corresponding software
6. Implement tracking solution prototype

Second Semester

1. Finish implementation of tracking solution, along with testing
2. Begin work on Hololens application
3. Work on connectivity between tracking tokens, server, and Hololens
4. Integration testing between software and hardware
5. Discover errors and make changes after collaborating with the client
6. Make finalized product
7. Demonstrate final product

Figure 2: Fall Gantt chart

Figure 3: Spring Gantt chart

4 Closure Materials

4.1 Conclusion

Our goals for this project are to enable a general contractor to visualize where their employees are at a given time for productivity, efficiency, and safety purposes. We will accomplish these goals using various cutting-edge technologies. Our proposed solution is to use a Raspberry Pi Zero for the hardware token, use Wi-Fi Triangulation to achieve tracking of personnel, and the Microsoft Hololens for visualization. We will track progress using Git Issues and Trello, and work in accordance with our project schedule as much as possible. Overall, we believe we have a strong start on our project and will continue adhering to our project plan and working diligently with the oversight of our client and the guidance of our advisor to solve this problem and accomplish our goals.

4.2 References

[1] Z. Scholl. “Open-source indoor positioning” *The Framework for Internal Navigation and Discovery*, April 2015. [Online]. Available: www.internalpositioning.com/post/open-source-announcement.

[2] B. Wagner, M. Hoffman, and M. Wenzel. “C# Coding Conventions (C# Programming Guide)” *Microsoft Docs,* July 2015. [Online]. Available: docs.microsoft.com/en-us/dotnet/csharp/programming-guide/inside-a-program/coding-conventions

[3] G. van Rossum, B. Warsaw, N. Coghlan. “Style Guide for Python Code”. *PEP 8*, July 2001. [Online]. Available: www.python.org/dev/peps/pep-0008

[4] M. Kotaru, K. Joshi, D. Bharadia, and S. Katti. "SpotFi: Decimeter Level Localization Using Wi-Fi." *Proceedings of the 2015 ACM Conference on Special Interest Group on Data Communication - SIGCOMM '15*.

[5] D. Vasisht, K. Swarun, and D. Katabi. "Decimeter-Level Localization with a Single Wi-Fi Access Point." *Proceedings of the 13th USENIX Symposium on Networked Systems Design and Implementation (NSDI '16)*. CA, USA, Santa Clara.