VIP - Indoor Positioning System

Vertically Integrated Projects

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Introduction

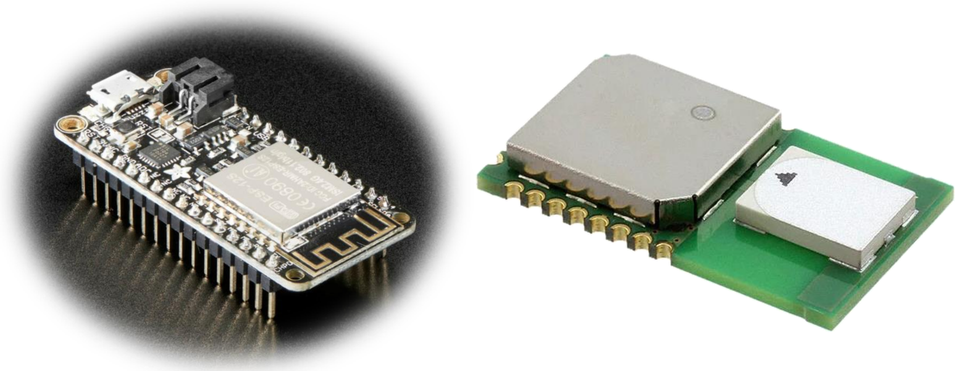
Outdoor positioning systems (e.g., the Global Positioning System -- GPS) offer real-time positioning which has enabled many novel applications in navigation, logistics, and location-aware services. Unfortunately, GPS does not work in indoor spaces without a clear view of the sky. The goal of this project is to develop a full system (including beacon anchors and locator tags) necessary to achieve high-precision (approximately 10-cm) positioning in an indoor environment. The focus of the project is predominantly on the firmware/software side with some initial Arduino-based prototyping.

Objectives

- Achieve accurate range distances between system modules
- Develop software to calculate position within a given area
- Make system easily deployable in any place
- Develop the system to be user friendly and easy to understand

Materials

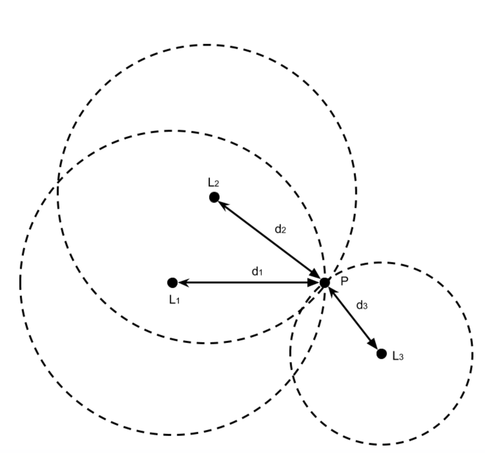
- ESP8266
- DWM1000



Methods

Finding Position in 2D (Trilateration)

The process of finding position by measurement of distances from known positions is called trilateration. For this it was necessary to have 3 anchors and 1 tag. In our system anchors are devices programmed to have fixed locations. All measurements are taken from these positions. A tag is the device taking all range measurements from the anchors.

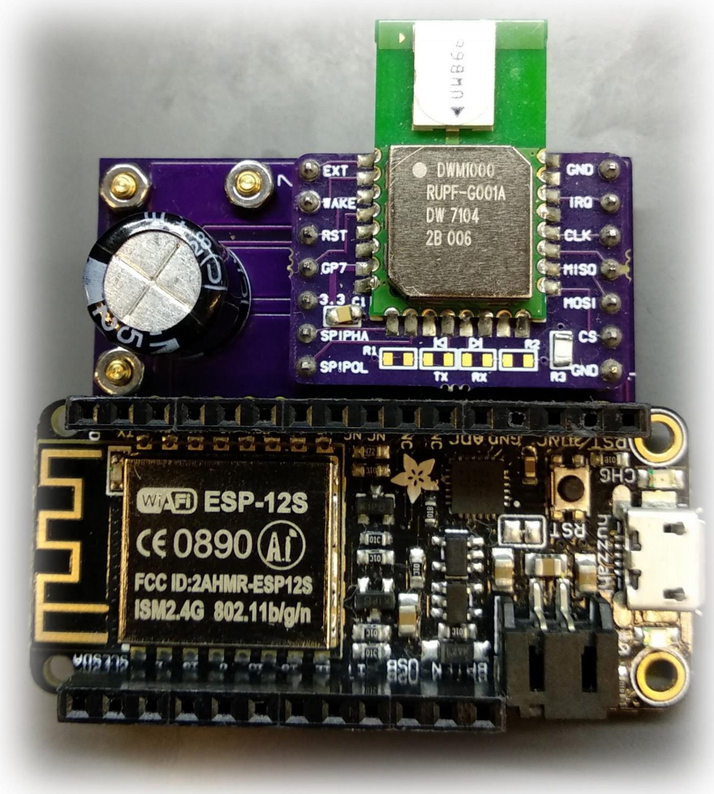


Methods

Hardware and PCB Design

The hardware being used to take range measurements is the DWM1000. The use of the ESP-8266 microcontroller allows the team to use Arduino to program the system. Arduino streamlines project development and allows for new team members to start working on the project once they have learned the basics.

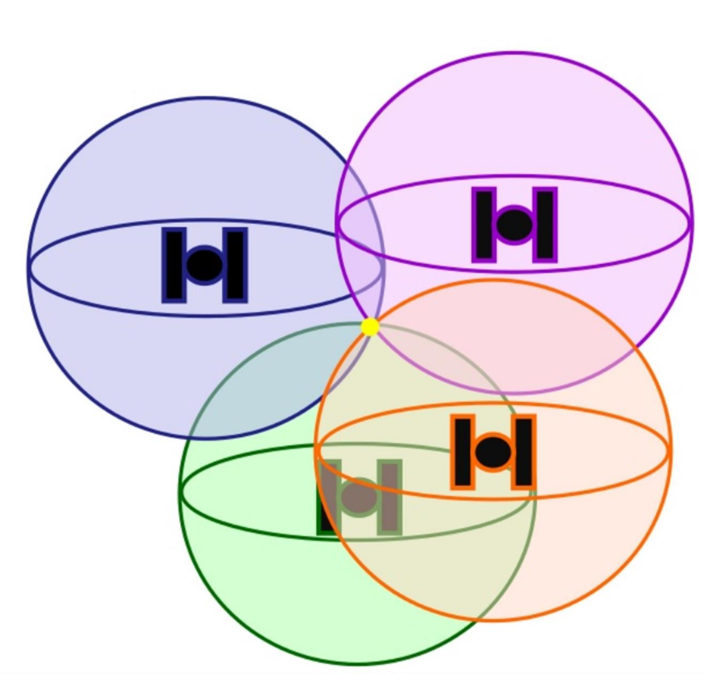
Though our initial prototypes used breadboards, we later developed PCB-based implementations because we needed reliable hardware.. PCB design started week 1 and by week 10 the team had moved all devices onto a PCB. Design



Establishing Range in 3D Space

Development on finding position in 3D yielded valuable results. While in 2D, only 3 anchors were needed to obtain 3 intercepting circles. In 3D 4 beacons are needed this forms 3 pairs of beacons and treat their ranges as the radii of 3 pairs of spheres, sharing one beacon between the pairs. Thus, altogether the 4 beacons can form 3 planes that intersect at a single point, the position of our tag.

Three Dimensional (3D) Positioning

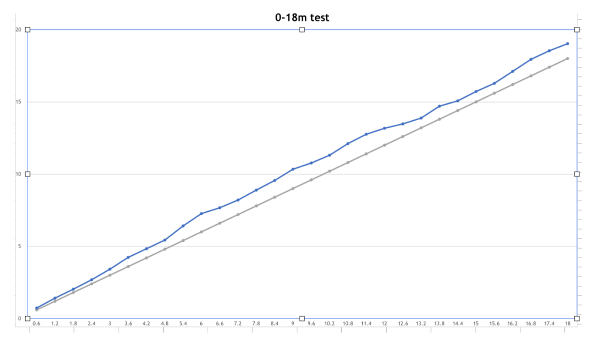


Results

Range Error Calibration

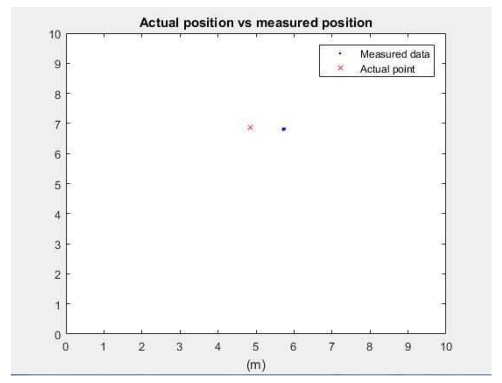
Seeing that range accuracy is essential to position calculation, one team took charge of measuring error. With this data we could calibrate the tags to take more accurate range measurements, thus giving us more accurate position calculations. The following table summarizes our findings.

Range (meters)	Error (meters)
0-5	+0.6
5-10	+0.7
10-15	+0.8
20+	+1.5



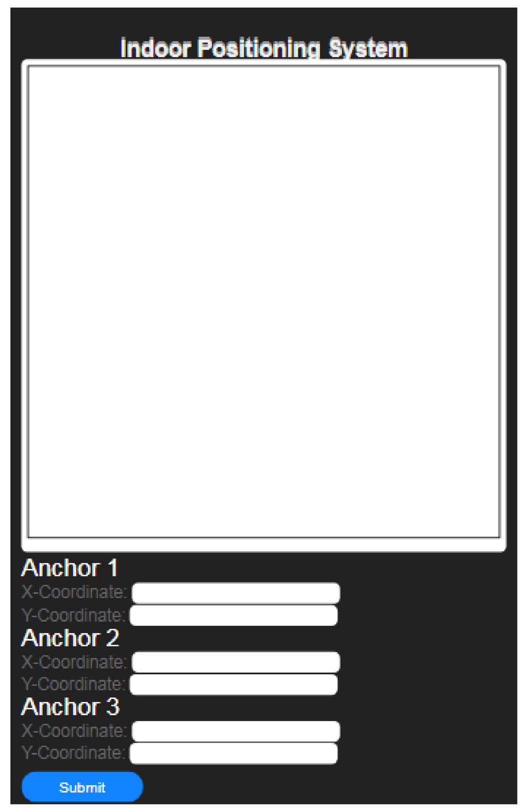
Range Error

Position Error



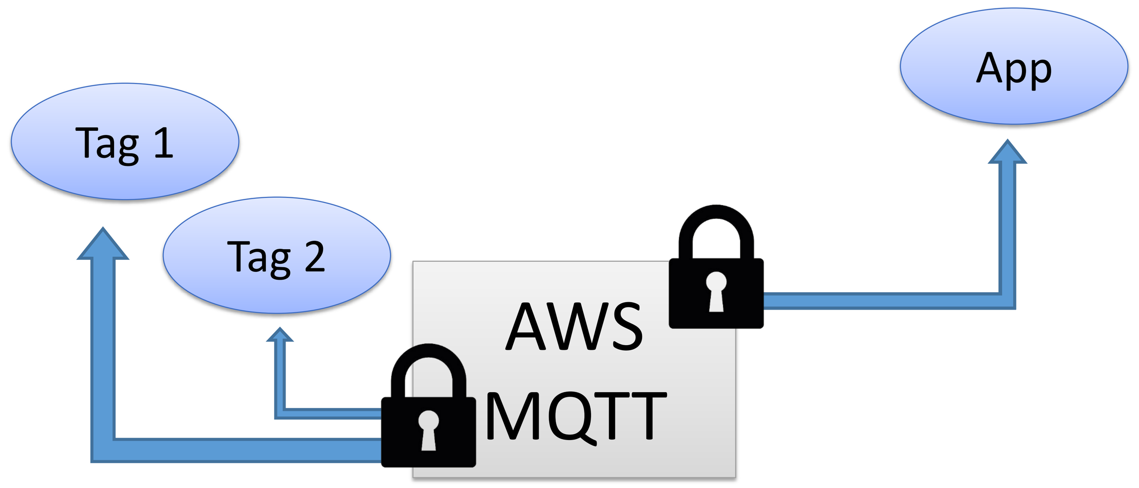
Position display on map

With position calculated the system required a way to display the position on a map. With the recent migration of many programs to the mobile space the team felt the best course of action was to develop an app where a user could configure and interact with the system. Version 1 of the app allows for simple configuration of the anchors. Additionally, it receives position data from the tag and displays the position on the map area. Further development will include the ability to upload a map.



Amazon Web Services MQTT Broker

The 'brain' of this project revolves around an implementation of AWS (Amazon Web Services). The purpose of AWS is to provide a secure and comprehensive cloud infrastructure for the use of allowing devices to 'speak' to each other in an efficient manner. For this project, AWS served as the bridge between the user's phone and the tag. Utilizing AWS IOT, an MQTT messaging protocol was used to create network for all the devices in this system to communicate. User authentication was also implemented using AWS IAM (Identity and Access Management) to ensure that all connected devices in this system are known and secure. This feature is very important as it ensures a secure connection between the devices and protects the location information of the user.



Conclusion

There are many pieces to this project and each team made fast advancements in the beginning. However, the real challenge was getting all our pieces to fit together into the system. Currently, the system is able to calculate and display 2D position. Later iterations will implement the advancements with 3D positioning and the range measurement calibration to get the most accurate position possible.

References

Trojer, Thomas. "Arduino-DWM1000." *GitHub*, 8 Oct. 2017, github.com/thotro/arduino-dw1000.

"DWM1000 Datasheet." *DecaWave*, Decawave Ltd., 2016, www.decawave.com/sites/default/files/resources/DWM1000-Datasheet-V1.6.pdf.

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