Wireless Location Determination

ECE 498 Capstone Project

PANDUIT®

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BRADLEY University

Presentation Outline

- **Introduction**
- Engineering Effort to Date
- Review Literature/Prior Work
- Criteria/Specification
- Brainstormed Solutions
  - Cisco Hyperlocation
  - Subpos(Subterranean Positioning System)
  - USB WiFi Dongle with Linux Computer
  - Linksys AC1900 Dual Band Open Source WiFi Wireless Router
- Chosen Technology
  - Initial Testing
- Next Semester
- Schedule
- Parts List
- References

Introduction

- Locate wireless sensors
  - GPS
    - Excellent for locating outdoors
    - Unmanageable attenuation indoors
- Need new location system indoors
  - Need plug and play infrastructure
  - Need accuracy for many sensors
    - Preferably do not want to modify the sensor firmware
  - Need to measure and triangulate in 3 dimensional space
    - Preferably in sub 1 meter accuracy

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Engineering Effort to Date

- Review prior work (10/10-10/21)
- Look into possible solutions (10/24-11/11)
- Pick the most promising solution and order parts (11/14-11/22)
- Initial testing (11/28-12/2)

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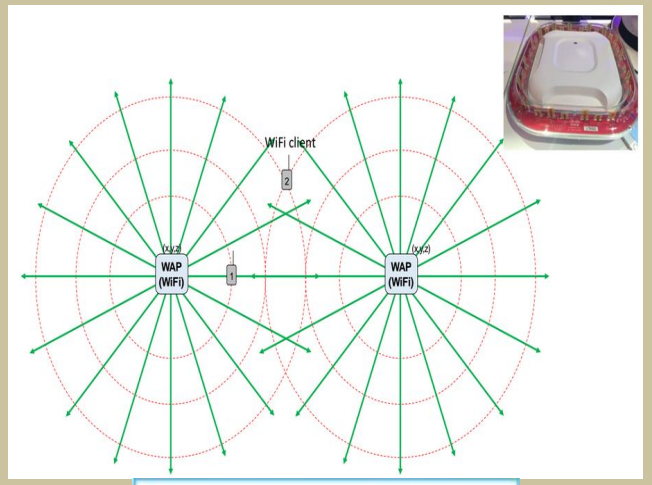
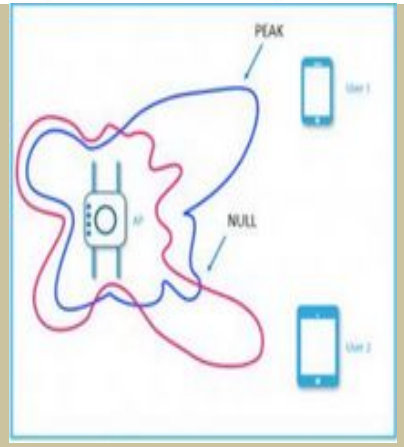
Review Literature/Prior Work

- Gained Criteria & Specifications
  - Must be plug-and-play
  - Infrastructure handles everything
  - Regulation conforming
  - Continuous monitoring
  - Accurate
- Approaches from Dr. Nordin
  - Cisco Hyperlocation
    - complete solution but only for 2D space
    - accuracy somewhat lower than desired
  - Beamforming (802.11ac)





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Criteria & Specifications

1. **Accuracy** The primary goal for this system is within $1m^3$
2. **Precision** The system aims to give reliable results on a consistent basis
3. **Coverage** Multiple beacons of the system most cover a reasonable volume
4. **Offline Computing**
   The offline expense for updating and maintaining the infrastructure
5. **Infrastructure**
   The system must be easy to deploy, improve, and maintain
6. **Computational Cost**
   The system aims to be low-power to improve battery life and decrease cost
7. **Update Interval**
   The system aims to provide as close to real-time data as possible
8. **Localization Time** - The time it takes to determine location
9. **Scalability** Possible dense sensor environment in the future

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Brainstormed Solutions

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Cisco Hyperlocation

- Accuracy 1-3 meters
- Complete product with extra features
- Expensive and proprietary
- Requires CISCO infrastructure

Image Source:
http://www.cisco.com/c/dam/en/us/products/collateral/interfaces-modules/aironet-hyperlocation-module-advanced-security/datasheet-c78-734901.doc/_jcr_content/renditions/datasheet-c78-734901_0.jpg

SubPos (Subterranean Positioning System)

- Open source (GPL)
- Accuracy within 1 meter
- Use ESP8266 - inexpensive
- Currently client-side

Image Source:
http://img.banggood.com/images/2014/xiemeijuan/12/SKU188843/SKU188843-4.jpg

Linksys AC1900 Dual Band Open Source WiFi Wireless Router

- 4 Antennas
- Open source
- $200 / router
- Must develop custom algorithm
- Accuracy and efficiency dependent on algorithm

Image Source:
https://www.amazon.com/Linksys-AC1900-Source-Wireless-WRT1900ACS/dp/B014MIBLSA

USB WiFi Dongle with Linux Computer

- Configurable hardware and software
- Custom algorithm, hardware, software required
- Not easily deployable
- Complex communication

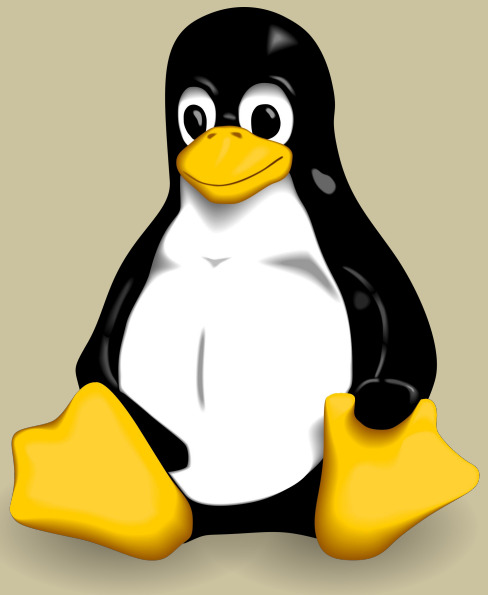

Image Source:
http://vignette1.wikia.nocookie.net/logopedia/images/0/04/Linux_logo.png/revision/latest?cb=20120814052336

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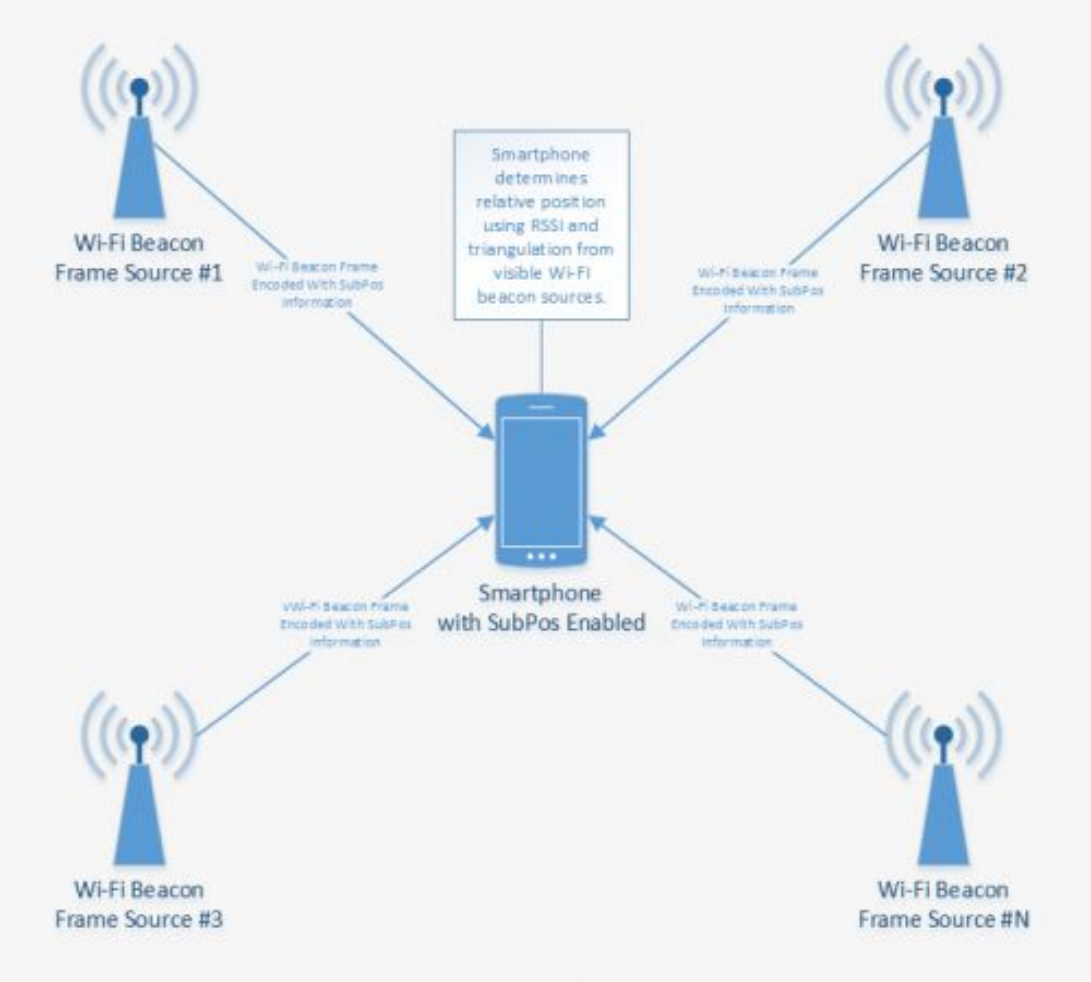
Chosen Technology

- Subpos
  - **Accuracy**: Claims <1 meter
  - **Precision:** The system aims for reliable results on a consistent basis
  - **Coverage:** How much area is covered by a single beacon
  - **Computational Cost**: Inexpensive hardware
  - **Infrastructure**: Quick and easy to install, and test
  - **Offline Computing**: Open Sourced (easy to develop, initially inexpensive)

Subpos Details

- RSSI
- Triangulation
- Trilateration

$$s = 10^{\frac{\frac{tx}{10} - rx - 10\log_{10}\frac{4\pi}{c/f}}{20*\mu}}$$



0 161

24bit	24bit	32bit	32bit	24bit	26bit
Human Readable Tag ("SPS")	Unique Device ID*	Latitude (decimal degrees, 7dp)	Longitude (decimal degrees, 7dp)	Application ID	Altitude (cm relative to sea-level)~

162 247

1bit	1bit	1bit	11bit	3bit	13bit	56bit
Below Sea Level (Altitude sign bit)	Offset Mapping Enable	3D Location Enable	TX Power (EIRP dBm, 1dp)^	Path Loss Coefficient Selection	Application Reserved	Coding Masks (0x7F and invalid chars)

* Unique to an area, not necessarily the entire world. Generally unique for an Application ID.

~ Should be height of floor relative to sea-level, not where the AP is mounted, unless 3D location enabled.

^ Decimal value is offset by +100.0 to make unsigned (dBm; -100dBm is the min 802.11 receive strength, 23dBm is max).

Values with decimal points are fixed point representations.

Initial Testing - Choosing Test Points

Initial Testing - Calculating Data Packets

Node 1, Nearest Alumni Center, Nearest Jobst:

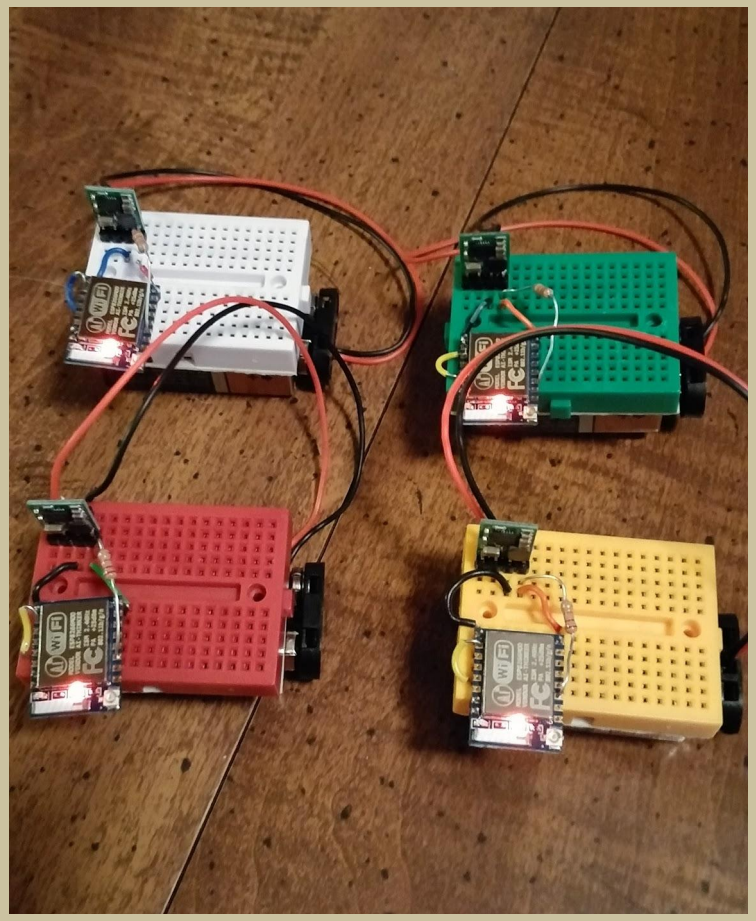
40.698356450 LAT
-89.617858976 LON
ASCII: SPSBJfc,`
HEX:
\x53\x50\x53\x00\x00\x01\x18\x42\x13\x0c\x4a\x15\x66\x63\x00\x00\x01\x00\x00\x00\x04\x2c\x00\x00\x01\x60\x04\x00\x00\x04\x00

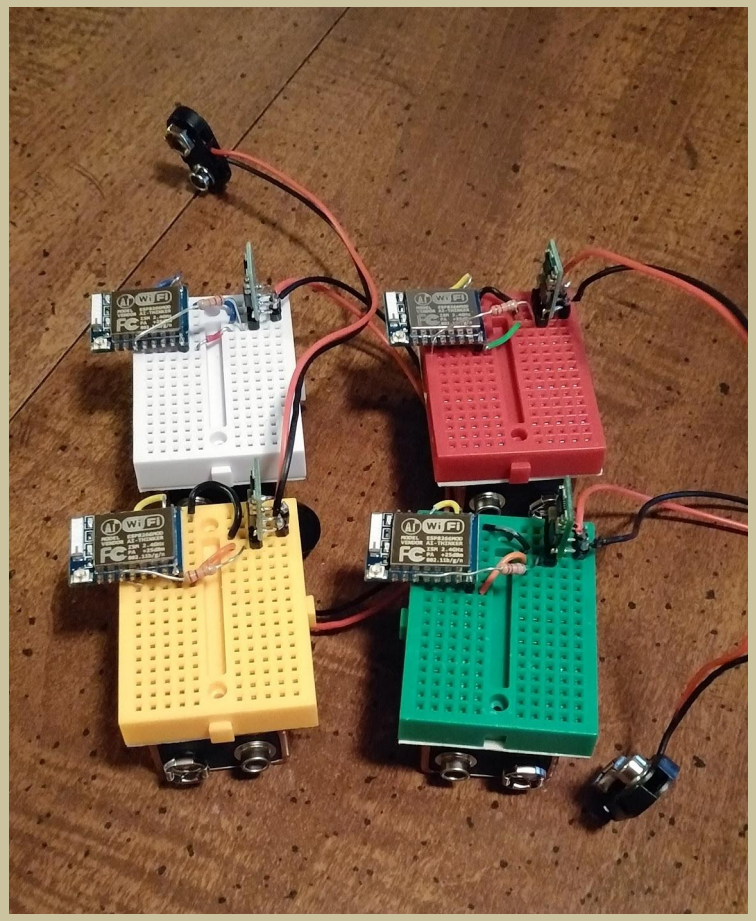
Initial Testing - Data Packet Deconstructed

\x53\x50\x53 - Tag “SPS”
\x00\x00\x01 - Device ID
\x18\x42\x13\x0c - Latitude
\x4a\x15\x66\x63 - Longitude
\x00\x00\x01 - Application ID

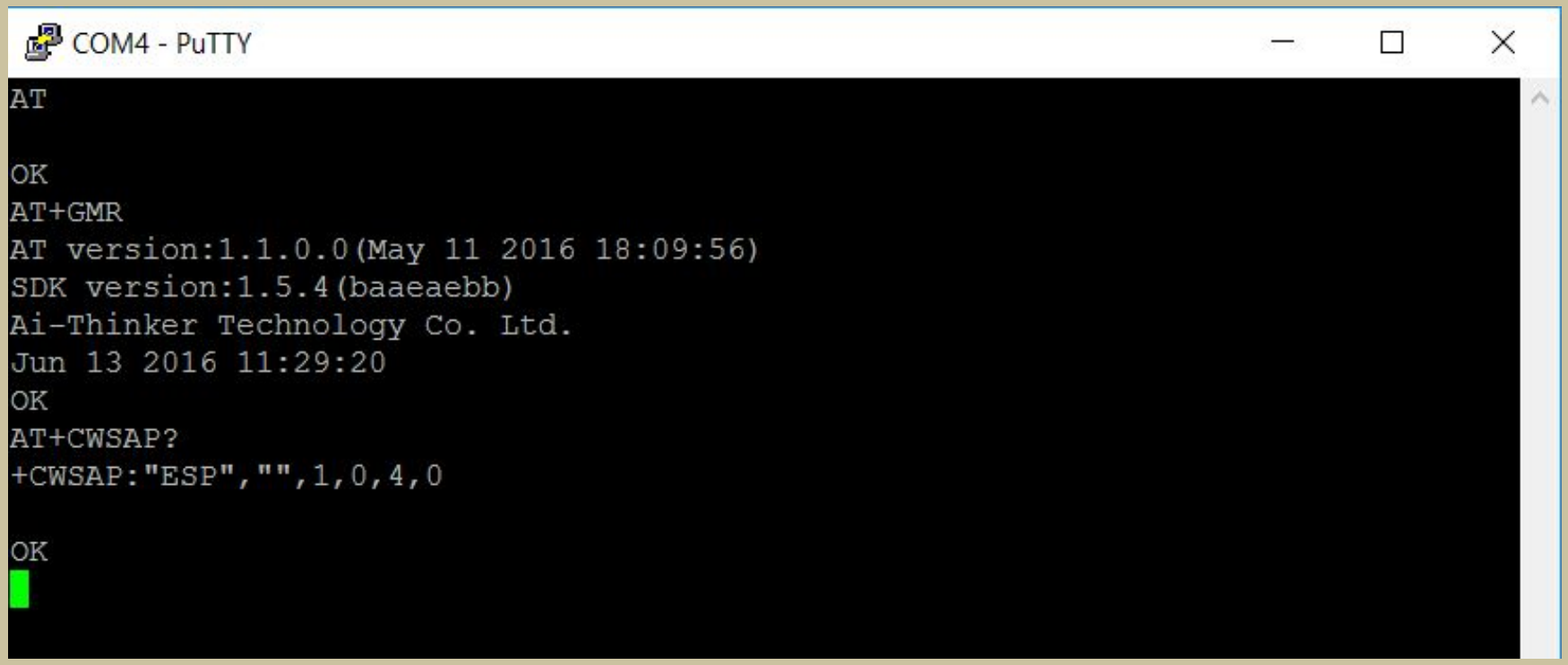
\x00\x00\x00\x0… - Altitude (cm Sea-level), Altitude Sign Bit, Offset Mapping En.
...4\x2c - 3D Location Enable, Tx Power (dBm)
\x00\x00 - Path Loss Coefficient, Reserved Bits
\x01\x60\x04\x00\x00\x04\x00 - Coding Masks

Initial Testing - Building Hardware

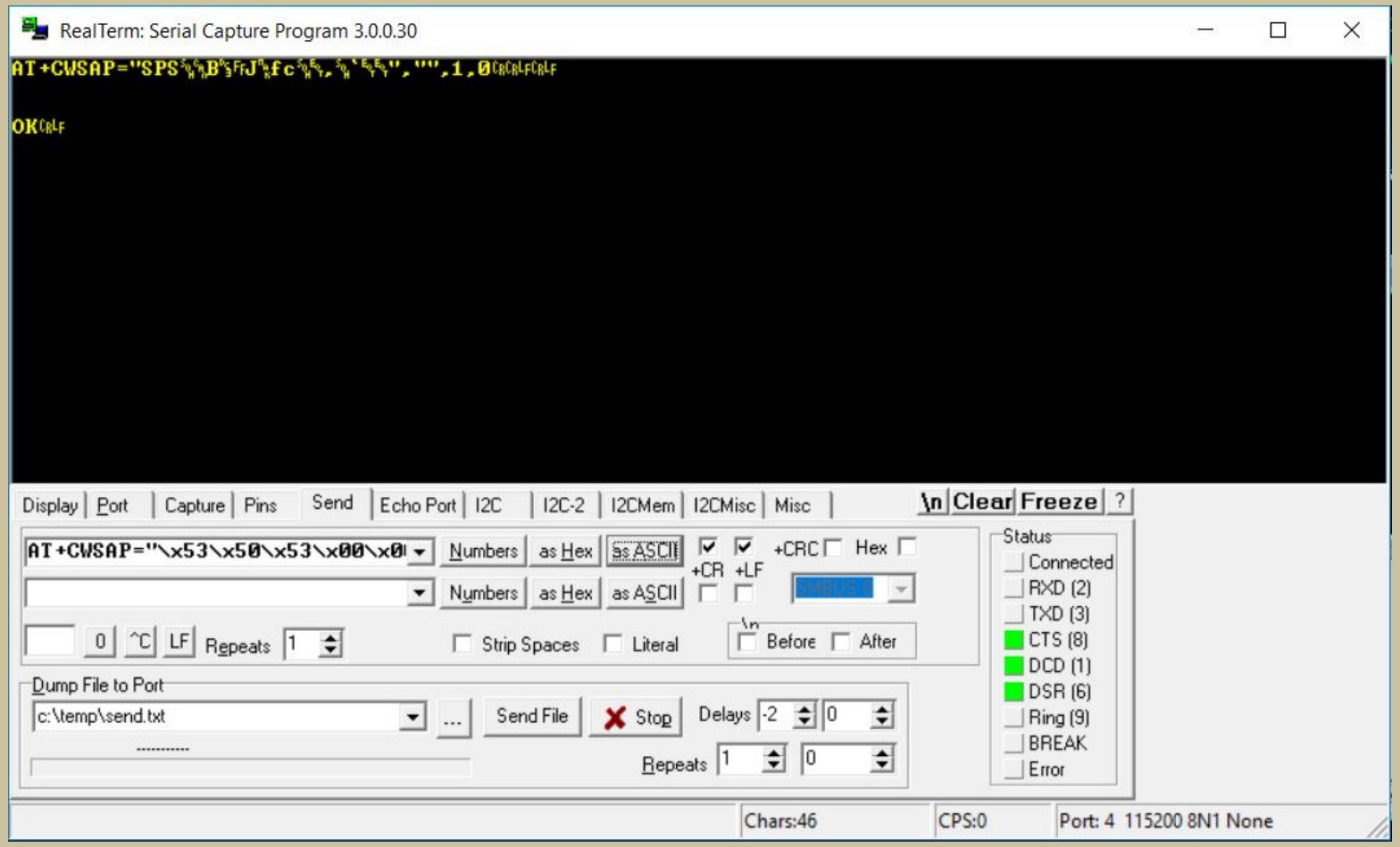




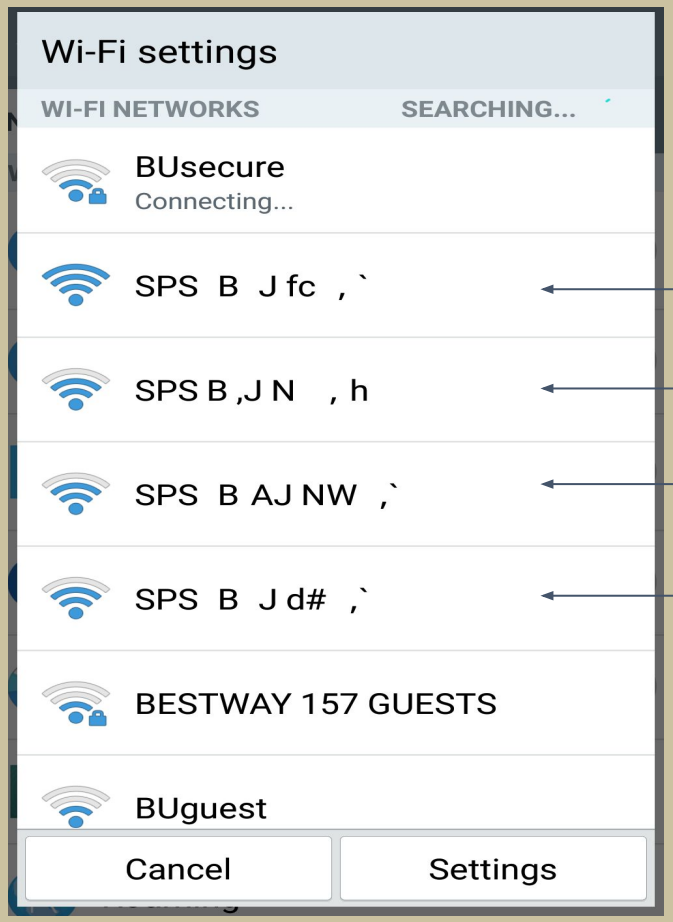
Initial Testing - AT Testing



Initial Testing - Setting New SSID



Initial Testing Results - Seeing ESP Nodes



SSIDs match the calculated SSIDs given by previously determined hex codes. This information encodes position, ID, altitude, etc.

Initial Testing - Placing Nodes

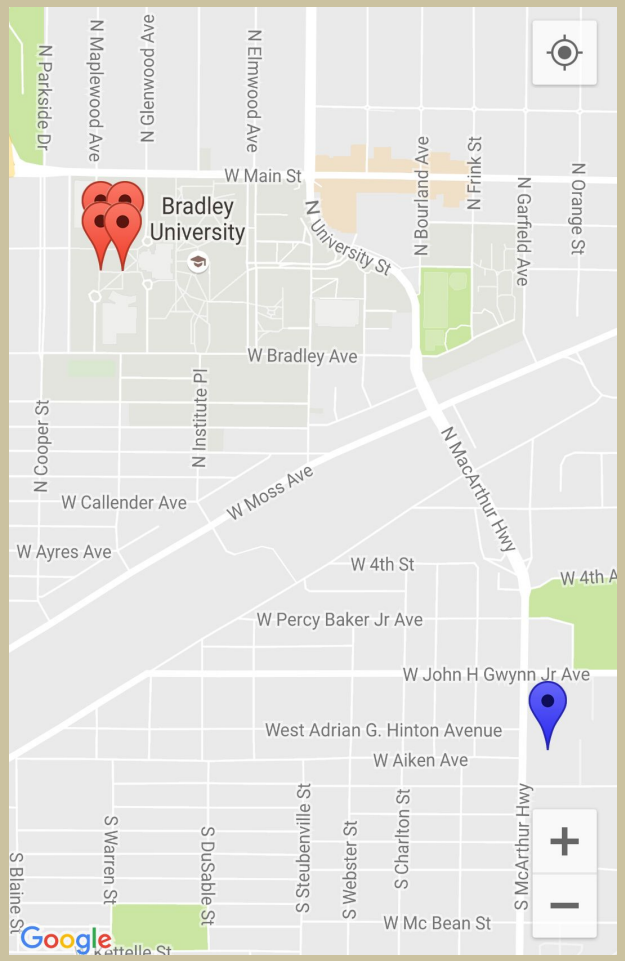
Initial Testing Results - Node Locations

Planned Locations

MATCH

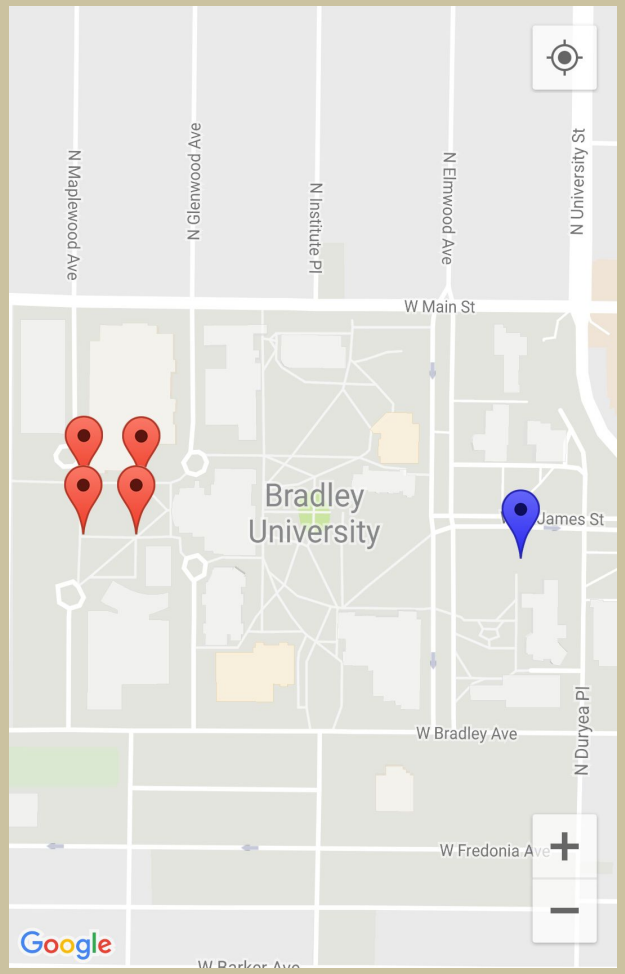
Initial Testing Results - First Test

Nodes spread very far apart. Nodes/unit area very small.



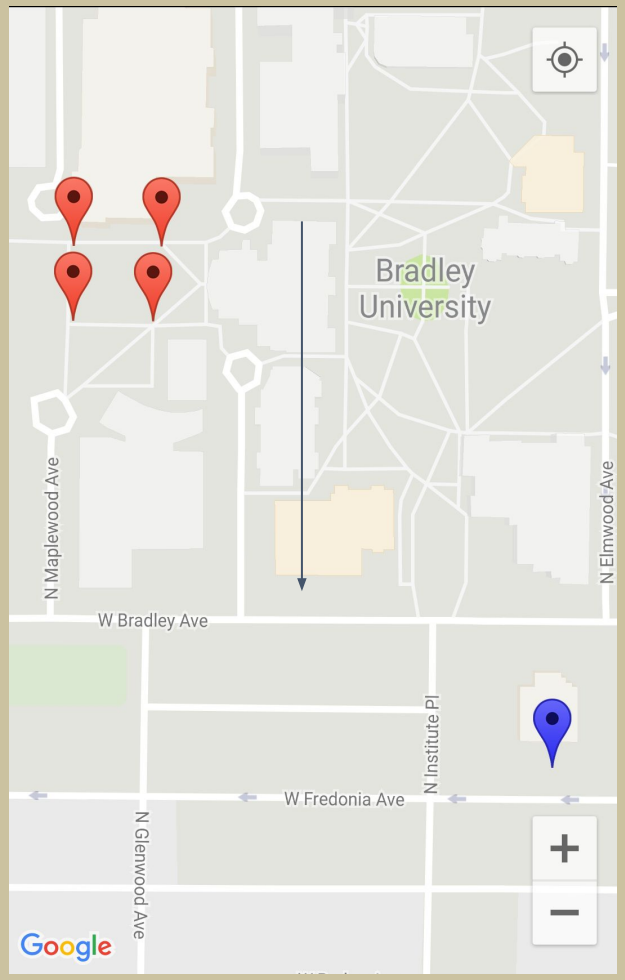
Initial Testing Results - Second Test

Nodes moved closer together.
≅1 node / 20 sq ft



Initial Testing Results - Moved Location

Physically moved closer to Node #4



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Next Semester

- More accurate client-side test
  - Not sure 4 nodes is enough to judge accuracy at that size
  - Path-loss coefficient
  - Change WiFi channels
- Change from client-side to server-side
  - Using ESP8266 modules as wireless nodes
  - Using 6dBi antennas
  - Keep accuracy as a new server-side system

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Schedule

- No Gantt Chart
  - Schedule is fluctuating until client-side tests are completed
  - Client-side tests should be completed by February 1, 2017
- Division of work
  - Nick
    - Reprogram ESP modules for second round of client-side tests
  - Michael
    - Analyze open-source code to determine method of switching to server-side
  - Nathan
    - Analyze open-source code to determine method of switching to server-side

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Parts List for the first solution attempted

Quantity	Description	Price	Ext. Price
6	HiLetgo ESP8266 Serial WIFI Wireless Module ESP-07 Wireless Module	$6.99	$41.94
3	Highfine 2 x 6dBi 2.4GHz 5GHz Dual Band WiFi RP-SMA Antenna	$9.69	$29.07
2	3.3 V Regulator (5)	$5.71	$11.42
2	9 volt battery clip (5)	$5.19	$10.38
1	USB to UART cable	$5.99	$5.99
1	Header pins (40pinsx25pc), *Note: 2mm, not 2.54mm*	$8.08	$8.08
1	Elegoo 6PCS 170 tie-points Mini Breadboard kit	$6.49	$6.49
1	8 Count - Duracell MN1604 9V Volt 6LR61 Duralock Coppertop Alkaline Batteries	$12.99	$12.99
6	3.3V, 500mA Step-Down Voltage Regulator D24V5F3	$4.25	$25.50
		Total	$151.86

References

"Cisco Hyperlocation Module with Advanced Security Data Sheet." Cisco. Cisco Systems, Inc., 12 Sept. 2016. Web. 17 Nov. 2016.

Liu, Junjie. “Survey of Wireless Based Indoor Localization Technologies.” Washington University in Saint Louis., 30 April 2014. Web. 17 Nov. 2016.

Questions?