

Indoor Localization with Wi-Fi Signal Strength Fingerprints

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Motivation of Indoor Localization Research

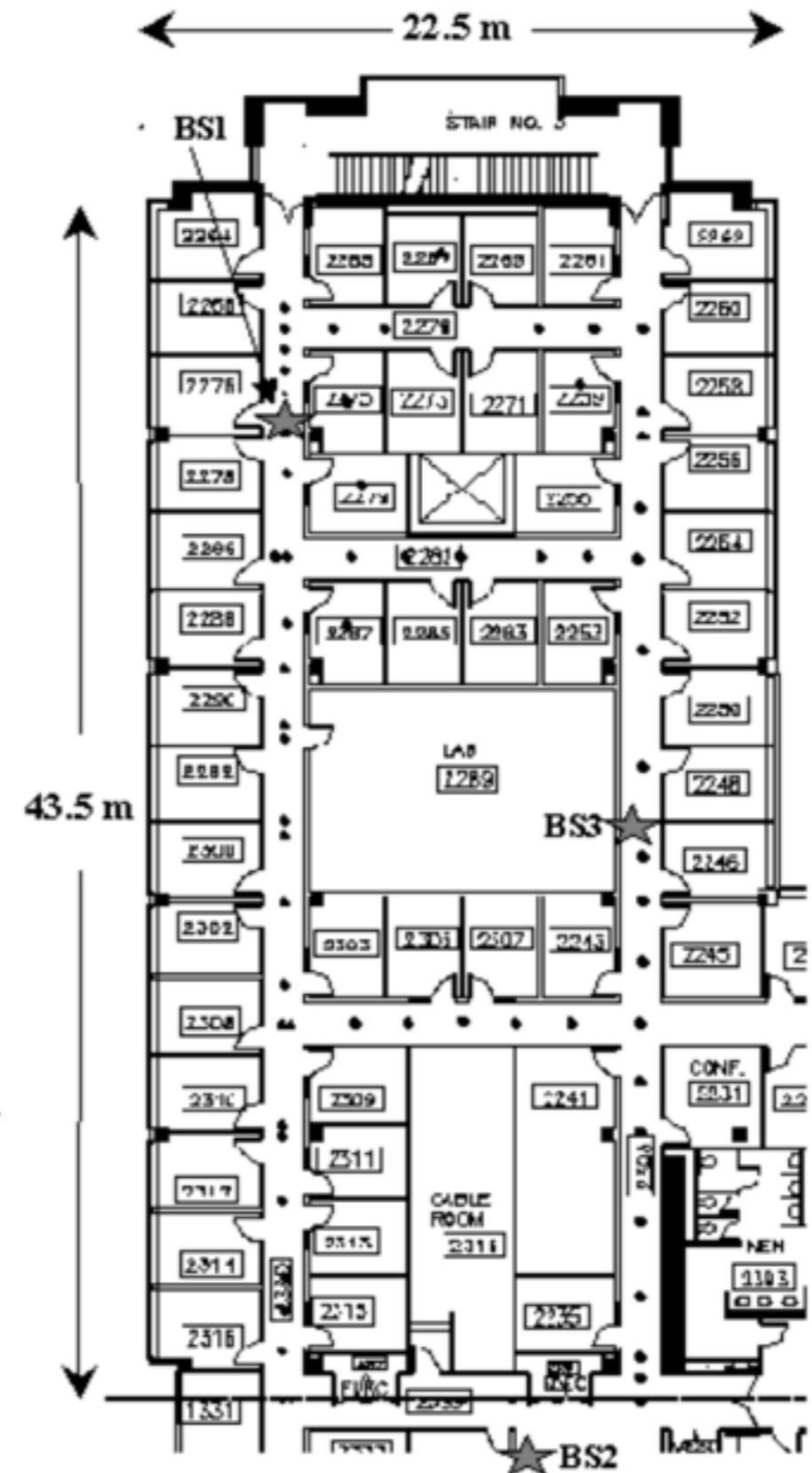
- Location based services
 - Indoor navigation
 - Occupancy-based energy saving
 - Augmented reality games
 - Item tracking
 - Targeted advertising
 - Social networking
 - Emergency response
- GPS doesn't work well in buildings
 - Buildings block or attenuate GPS satellite signals
 - Indoor localization requires more accuracy (sub-meter vs meters)

Original Work using Wi-Fi Signal Strength

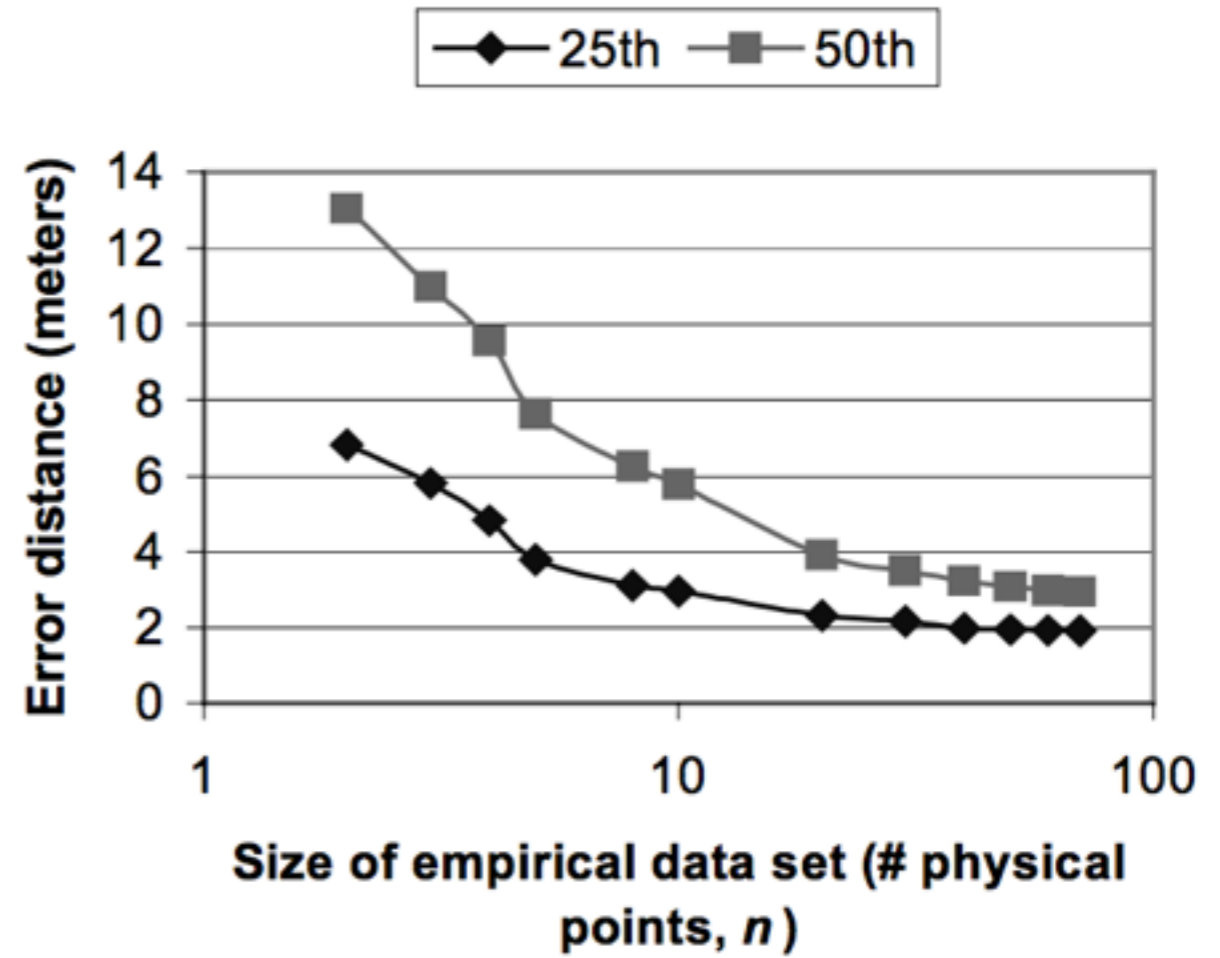
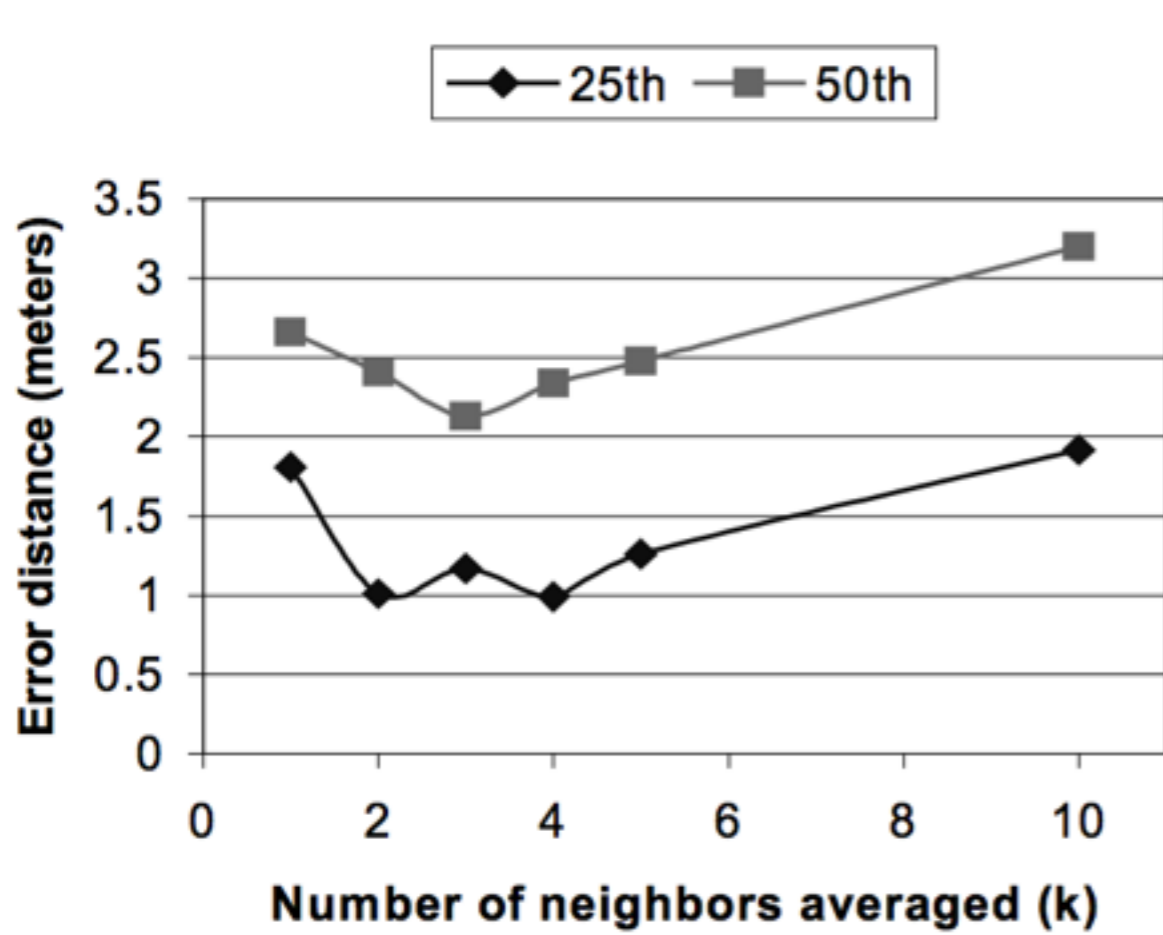
Bahl and Padmanabhan.

RADAR: An in-building RF-based user location and tracking system.
INFOCOM 2000.

- Used 3 WiFi Access Points (AP)
- Collected signal strength at 70 distinct physical locations
- Collected in each of 4 directions



Original Work using Wi-Fi Signal Strength

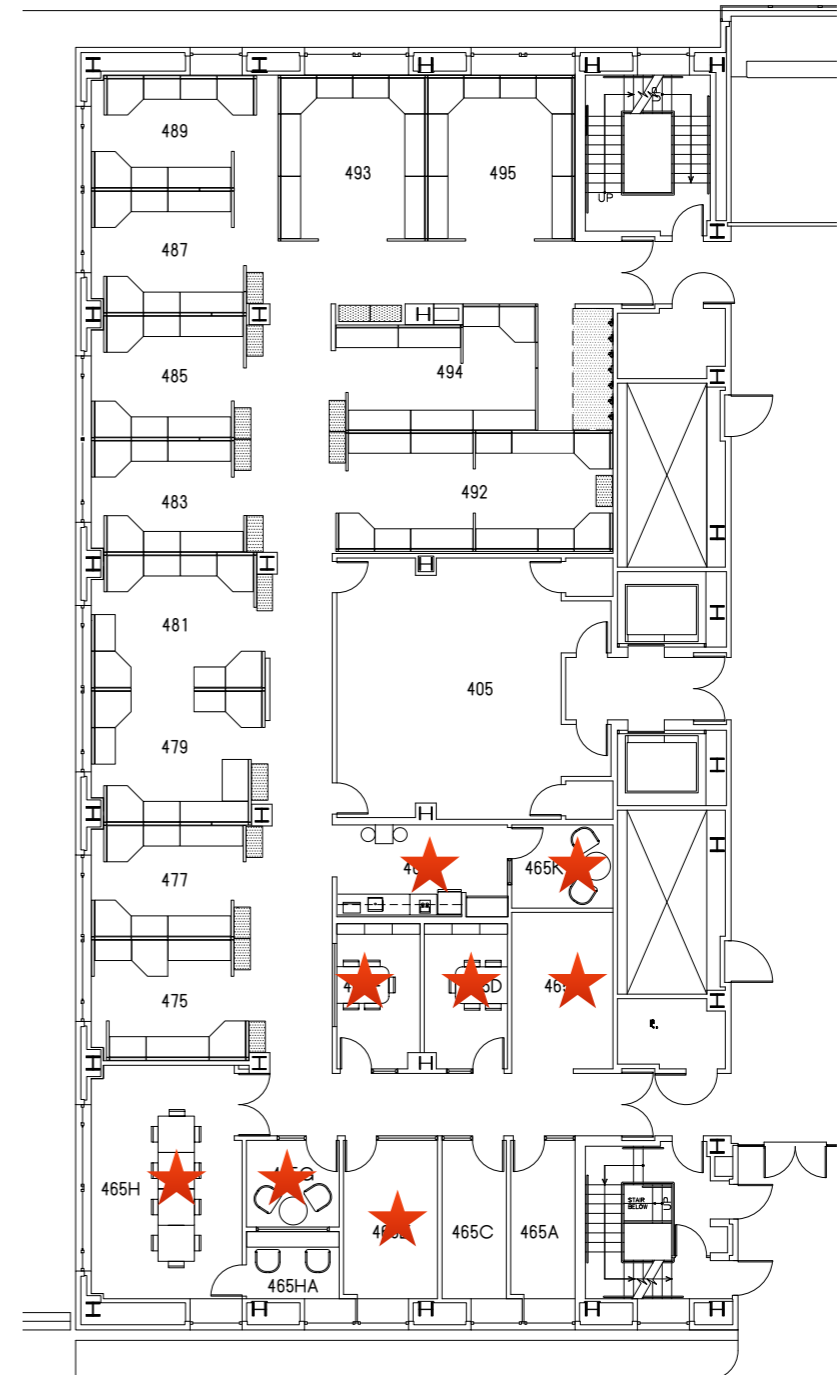


Goals of this Work

- Validate assumptions about WiFi signals strengths, after 14 years
 - Whether Signal Strengths are consistent?
 - Whether Signal Strengths are distinguishable?
 - How much data are missing in one scan?
- Explore potential improvements of localization results
 - How it is applied to room level accuracy?
 - Are there other information I can use for localization?

Data Collection

- 8 wall-separated rooms/spaces in AMPLab
- Collect WiFi Signal Strengths using Android 2.3 phones (LG Revolution VS910)
- Each room takes at least one day
- Scan continuously, Android takes 800ms for one scan
- 4 phones in 465H, 3 Android phones in other rooms



Raw Data Format

- **Data are stored as CSV files grouped by a list of directories**
- **One directory contains data that one phone collected in one room (I'm looking at only room level accuracy)**
- **Each CSV file contains these columns**
 - **epoch:** UNIX timestamp of the sample
 - **SSID:** Service Set ID, or Wi-Fi network name
 - **capability:** the authentication, key management, and encryption schemes supported by the access point.
 - **BSSID:** MAC address of the access point.
 - **frequency:** The frequency in MHz of the channel over which the client is communicating with the access point.
 - **RSSI:** The detected signal level in dBm
- **One WiFi scan generates several rows**

Raw Data Format

epoch, SSID, capability, BSSID, frequency, RSSI

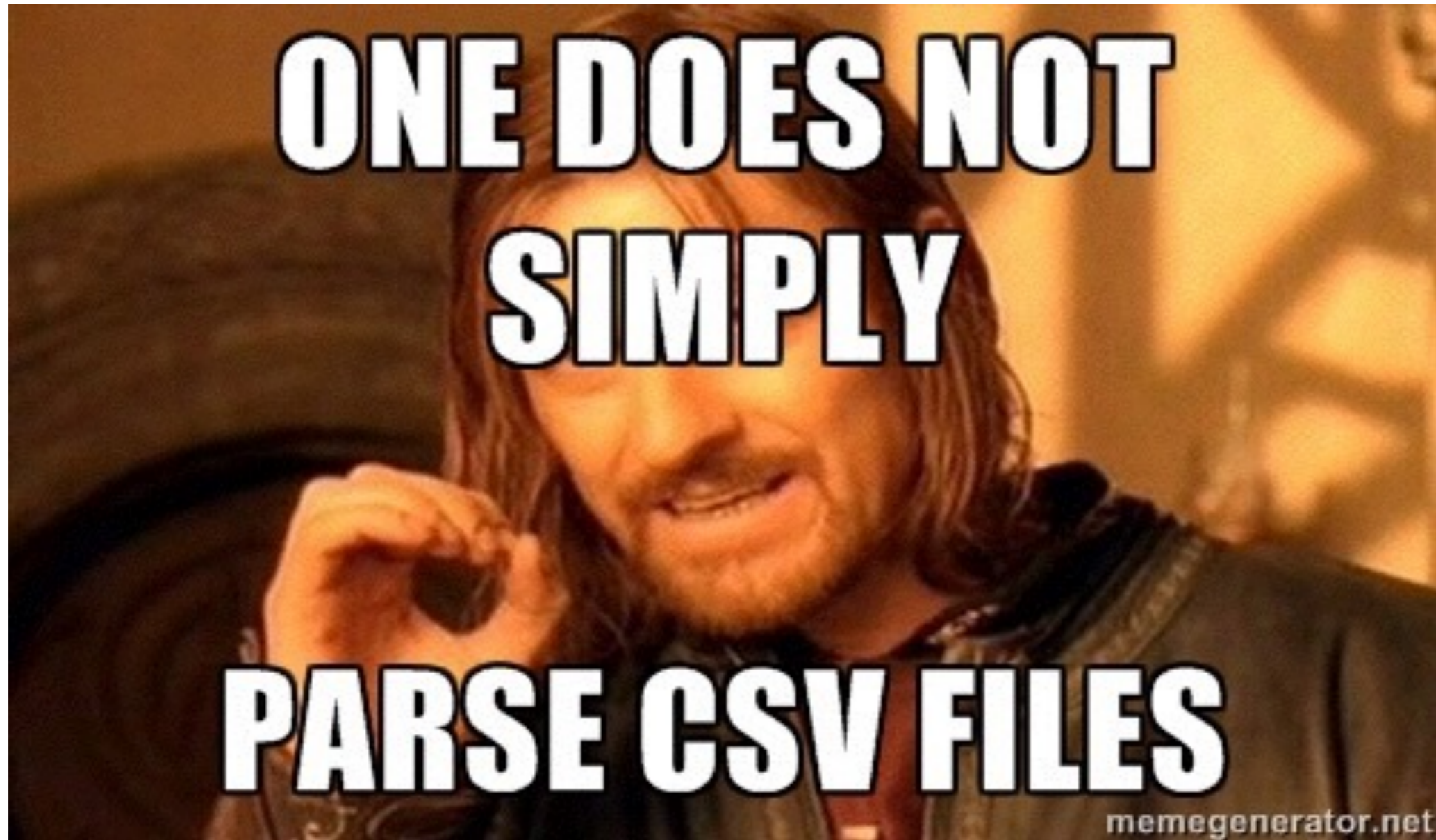
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1411334930872,attwifi,,00:17:df:a7:4c:f5,2412,-79
1411334930872,AirBears,,00:17:df:a7:4c:f3,2412,-81
1411334930872,410BOX,,00:24:a5:f5:50:bb,2437,-82
1411334930872,EECS-Guest,,00:22:90:39:07:11,2437,-86
1411334930872,attwifi,,00:22:90:39:70:a5,2437,-91
1411334930872,EECS-Guest,,00:22:90:39:70:a1,2437,-93
1411334932261,AirBears2,[WPA2-EAP-CCMP],00:17:df:a7:4c:f4,2412,-82
1411334932261,EECS-PSK,[WPA2-PSK-CCMP],00:17:df:a7:4c:f2,2412,-82
1411334932261,EECS-PSK,[WPA2-PSK-CCMP],00:22:90:39:07:12,2437,-85
1411334932261,AirBears2,[WPA2-EAP-CCMP],00:22:90:39:07:14,2437,-87
1411334932261,EECS-Secure,[WPA2-EAP-CCMP],00:22:90:39:07:10,2437,-84
1411334932261,EECS-Secure,[WPA2-EAP-CCMP],00:23:04:89:cc:80,2412,-90
```


Interesting...

epoch, SSID, capability, BSSID, frequency, RSSI

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1396946498451, Please Hackers, Just Dont Please, [WPA2-PSK-CCMP], d0:22:be:c9:d9:3e, 2462, -98
1396946499253, Please Hackers, Just Dont Please, [WPA2-PSK-CCMP], d0:22:be:c9:d9:3e, 2462, -98
1396775704009, Please Hackers, Just Dont Please, [WPA2-PSK-CCMP], d0:22:be:c9:d9:3e, 2437, -95
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1395593978380, Please Hackers, Just Dont Please, [WPA2-PSK-CCMP], d0:22:be:c9:d9:3e, 2462, -98
1395593980765, Please Hackers, Just Dont Please, [WPA2-PSK-CCMP], d0:22:be:c9:d9:3e, 2462, -97
1410797013384, Please Hackers, Just Dont Please, [WPA2-PSK-CCMP], d0:22:be:c9:d9:3e, 2437, -95
1410967812647, Please Hackers, Just Dont Please, [WPA2-PSK-CCMP], d0:22:be:c9:d9:3e, 2462, -97
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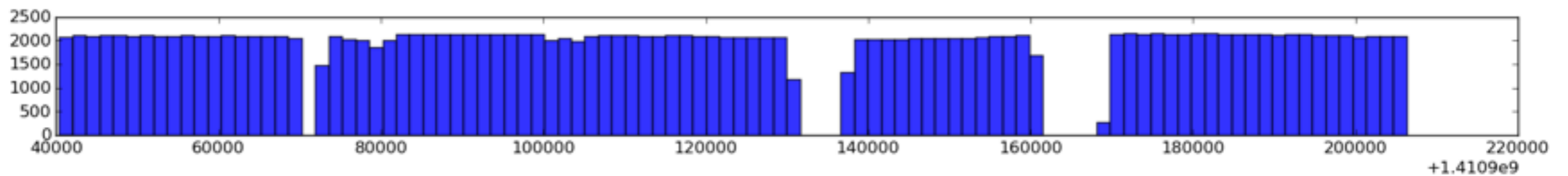
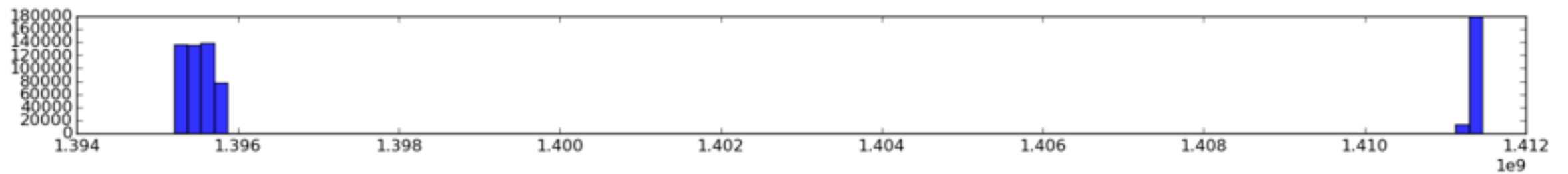
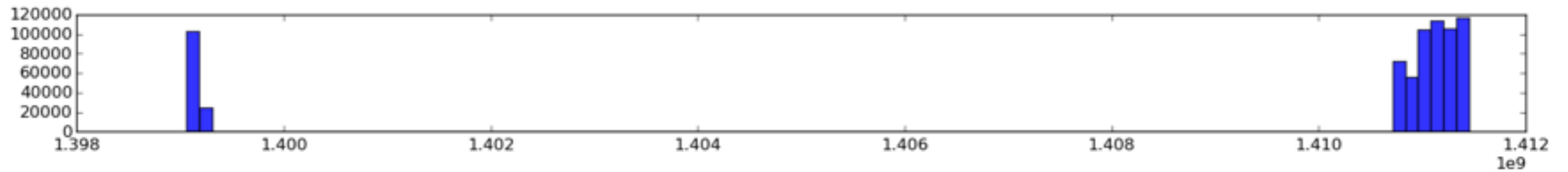
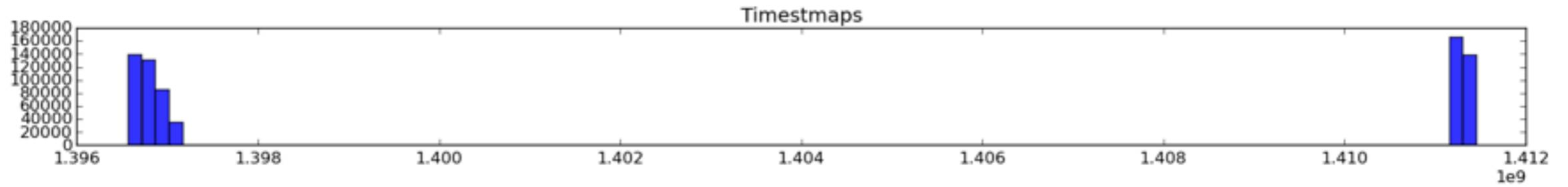
Interesting...



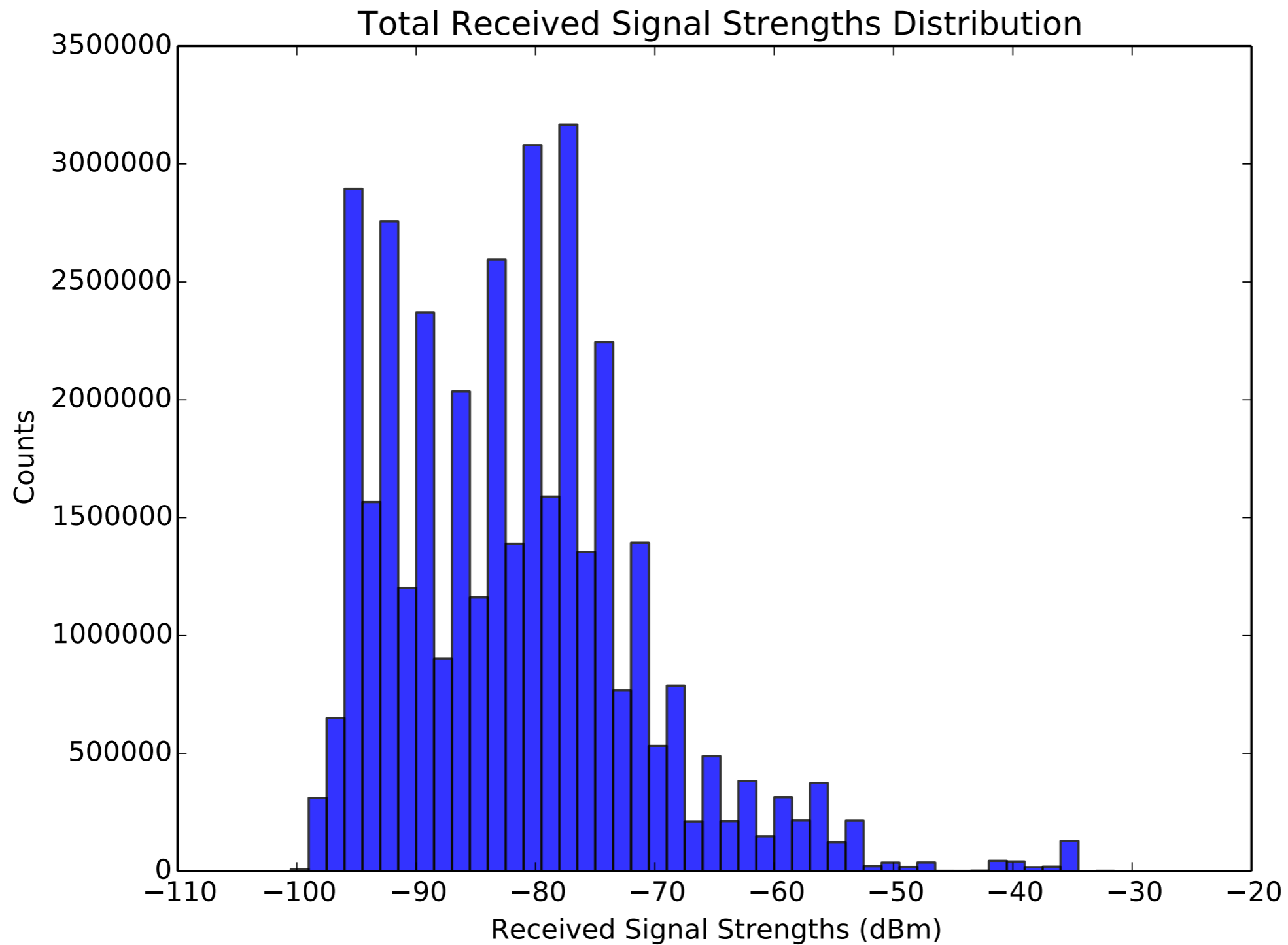
Data Features

- 2,263,496 scans
- 37,813,320 RSSI values collected
- Each scan has 16.7 RSSI values on average
- 540 individual MACs we can hear in 8 rooms
 - A N-antenna MIMO router can have N MACs
 - This includes many routers from other buildings

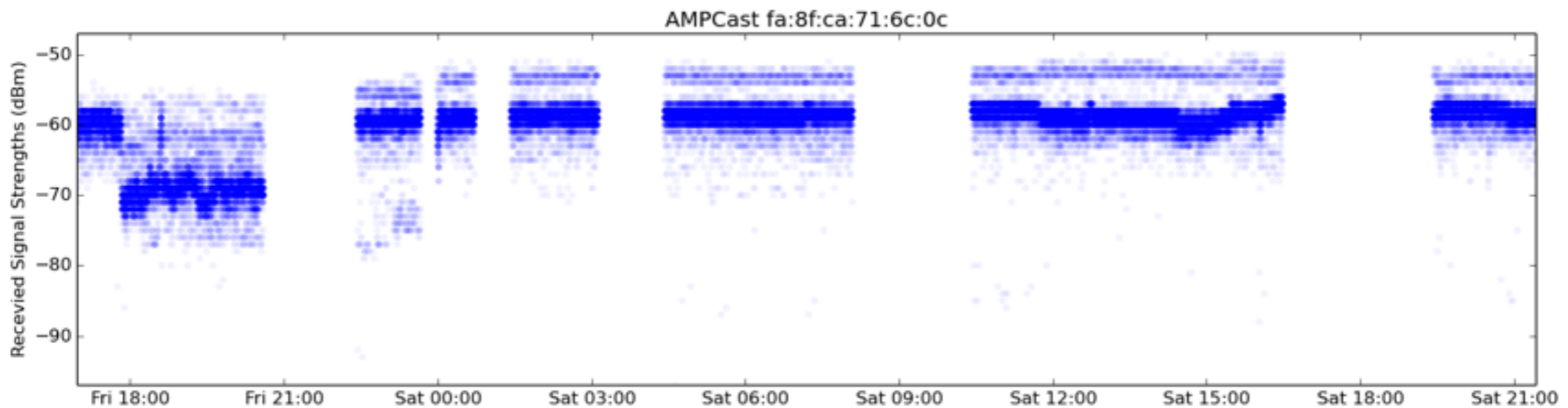
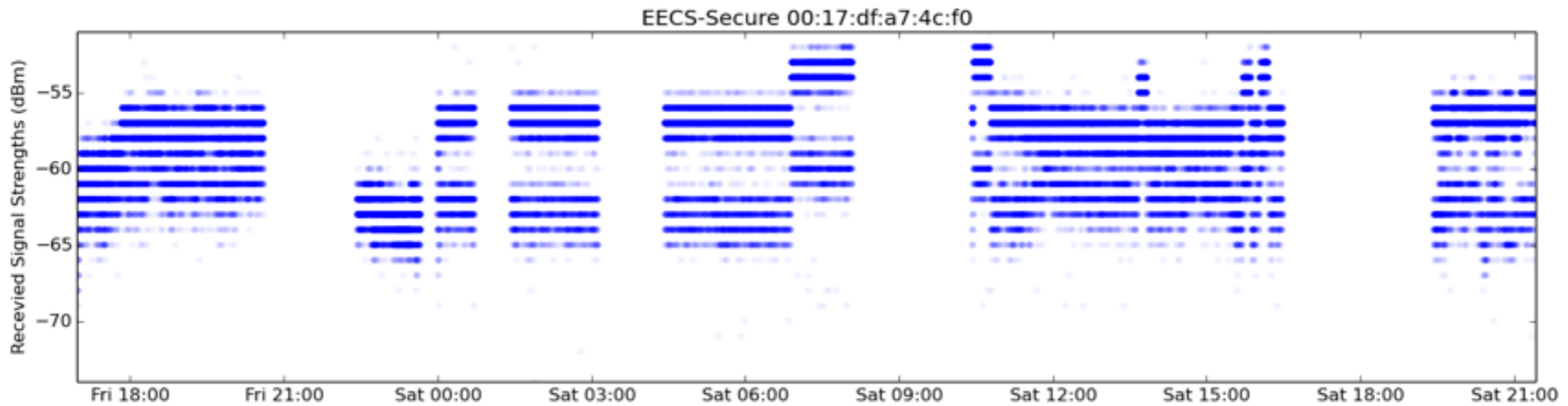
Timestamps



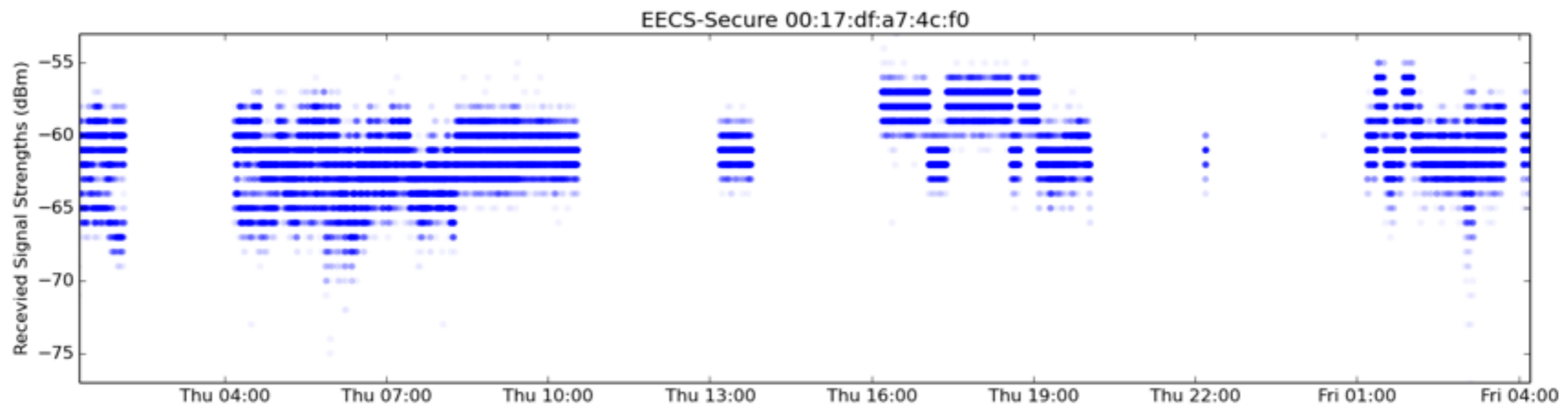
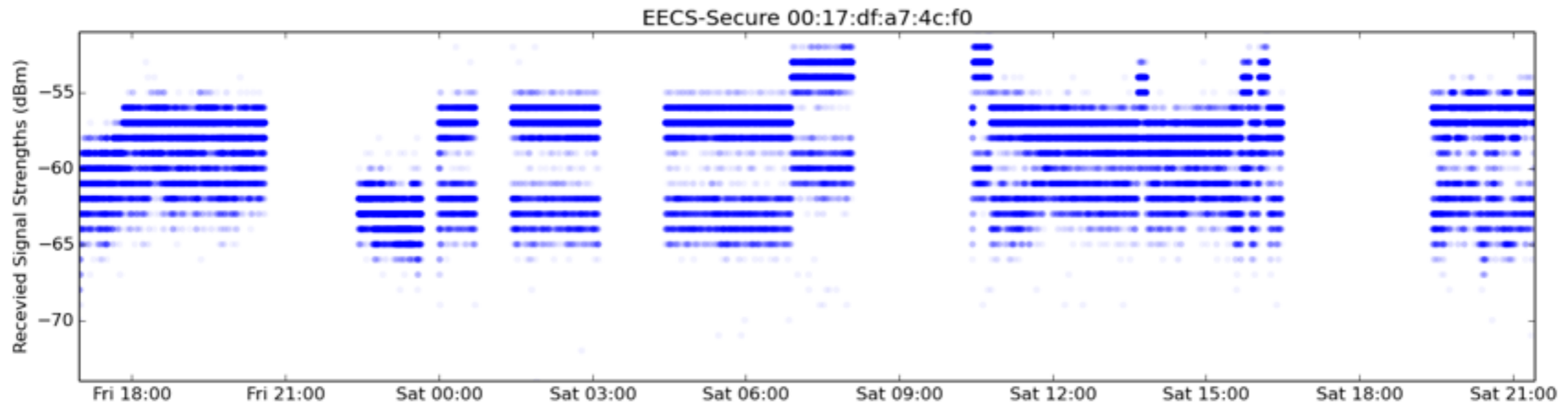
RSSI Distribution



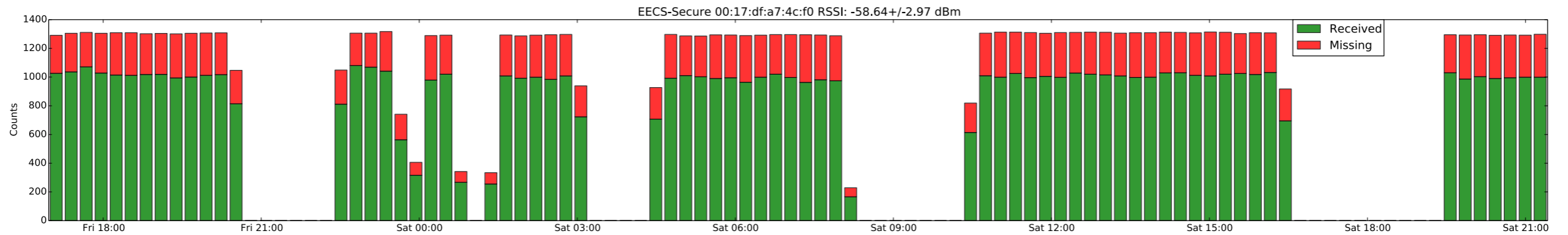
Are RSSIs Stable?



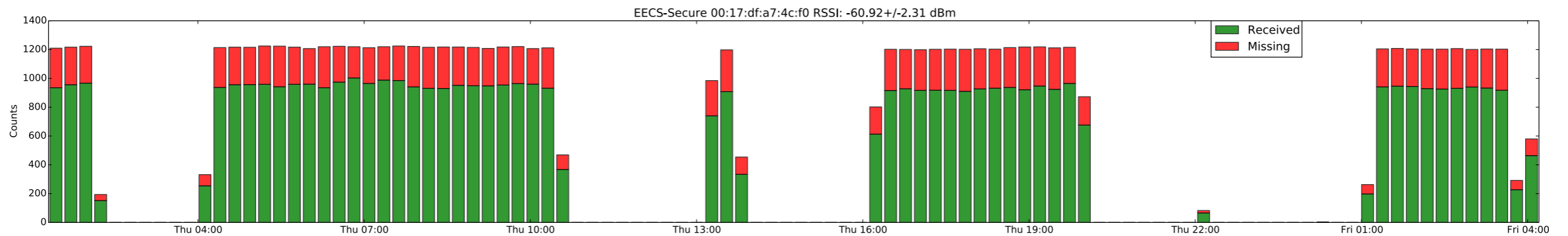
Are RSSIs Stable?



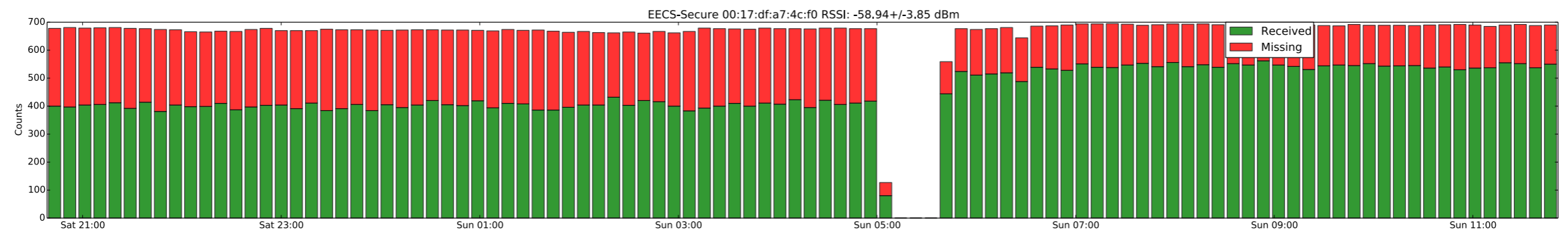
Missing values



Room 465F, Phone 1, Left Upper of the Table

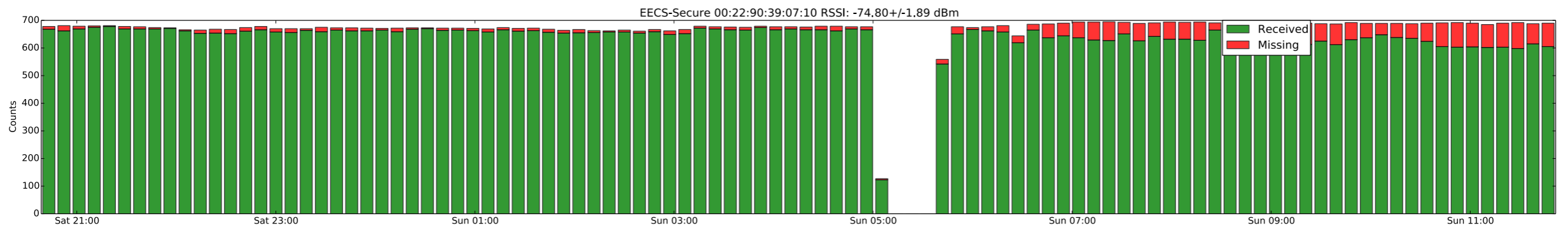


Room 465F, Phone 2, Right Upper of the Table

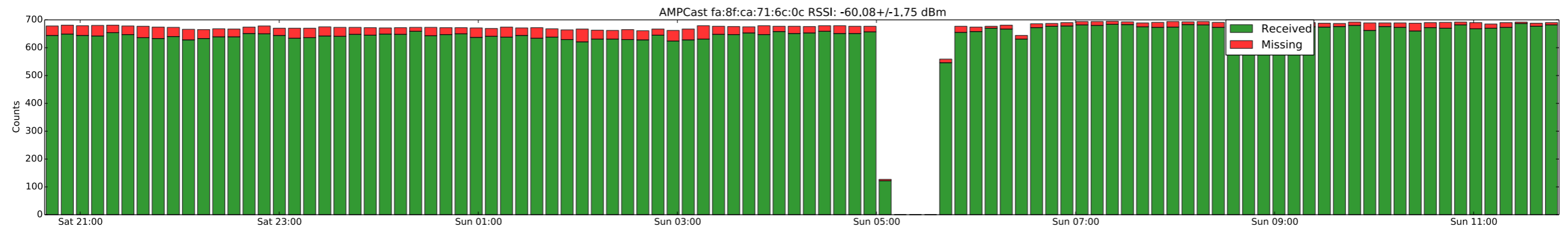


Room 465F, Phone 3, Bottom Middle of the Table

Missing values

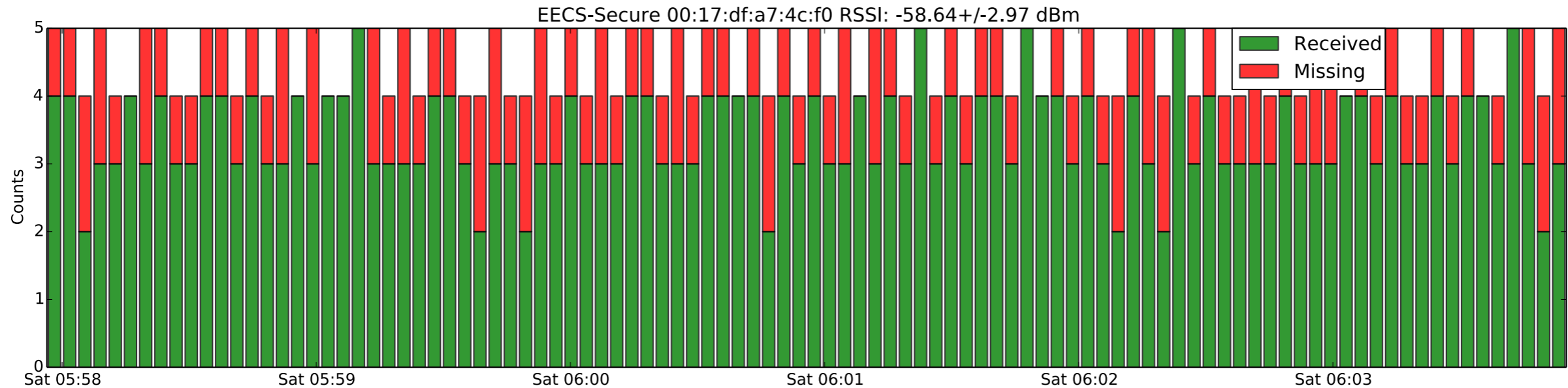


Room 465F, Phone 3, Bottom Middle of the Table, Mostly Appeared AP



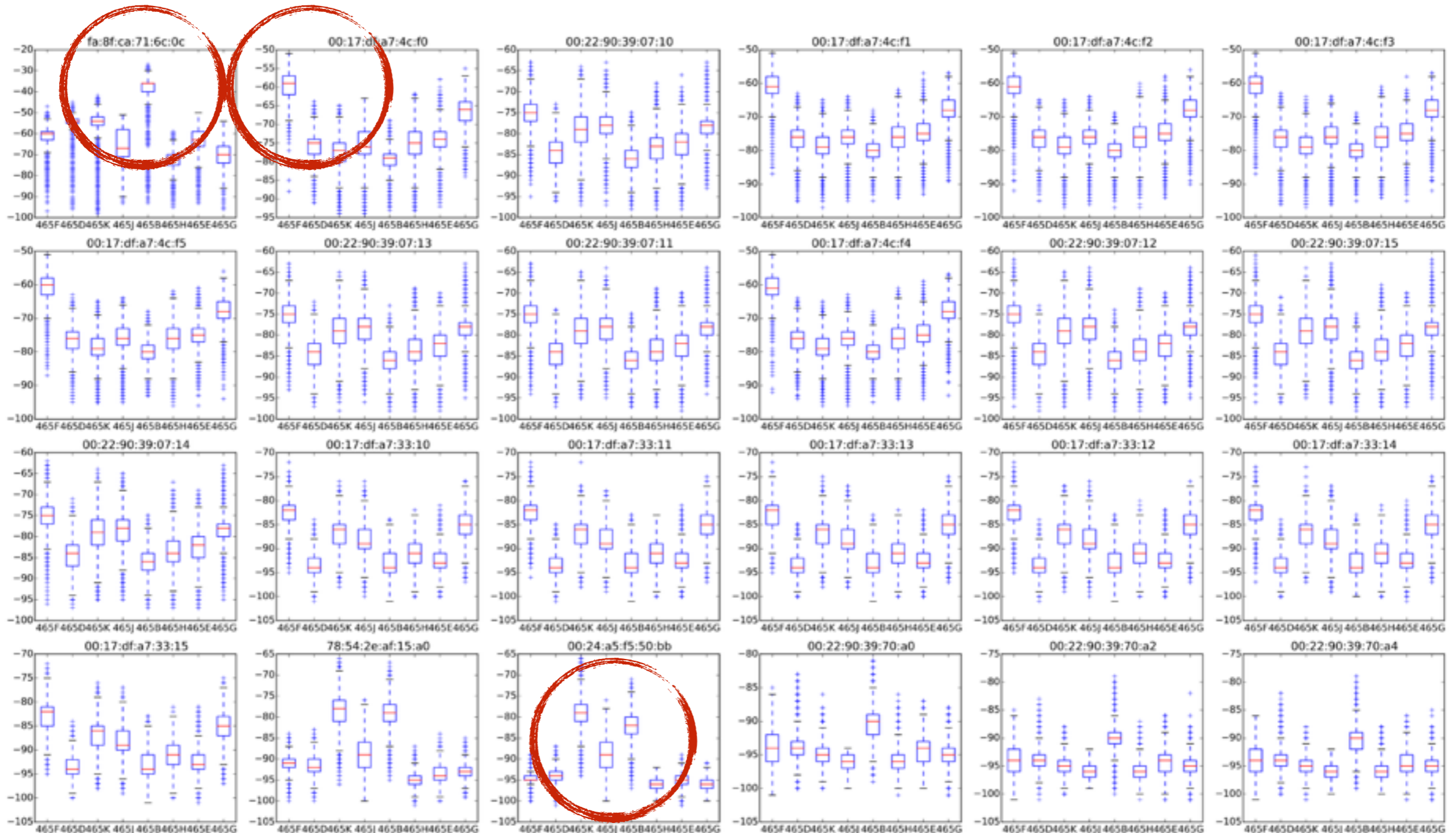
Room 465F, Phone 3, Bottom Middle of the Table, 2nd Mostly Appeared AP

Missing values

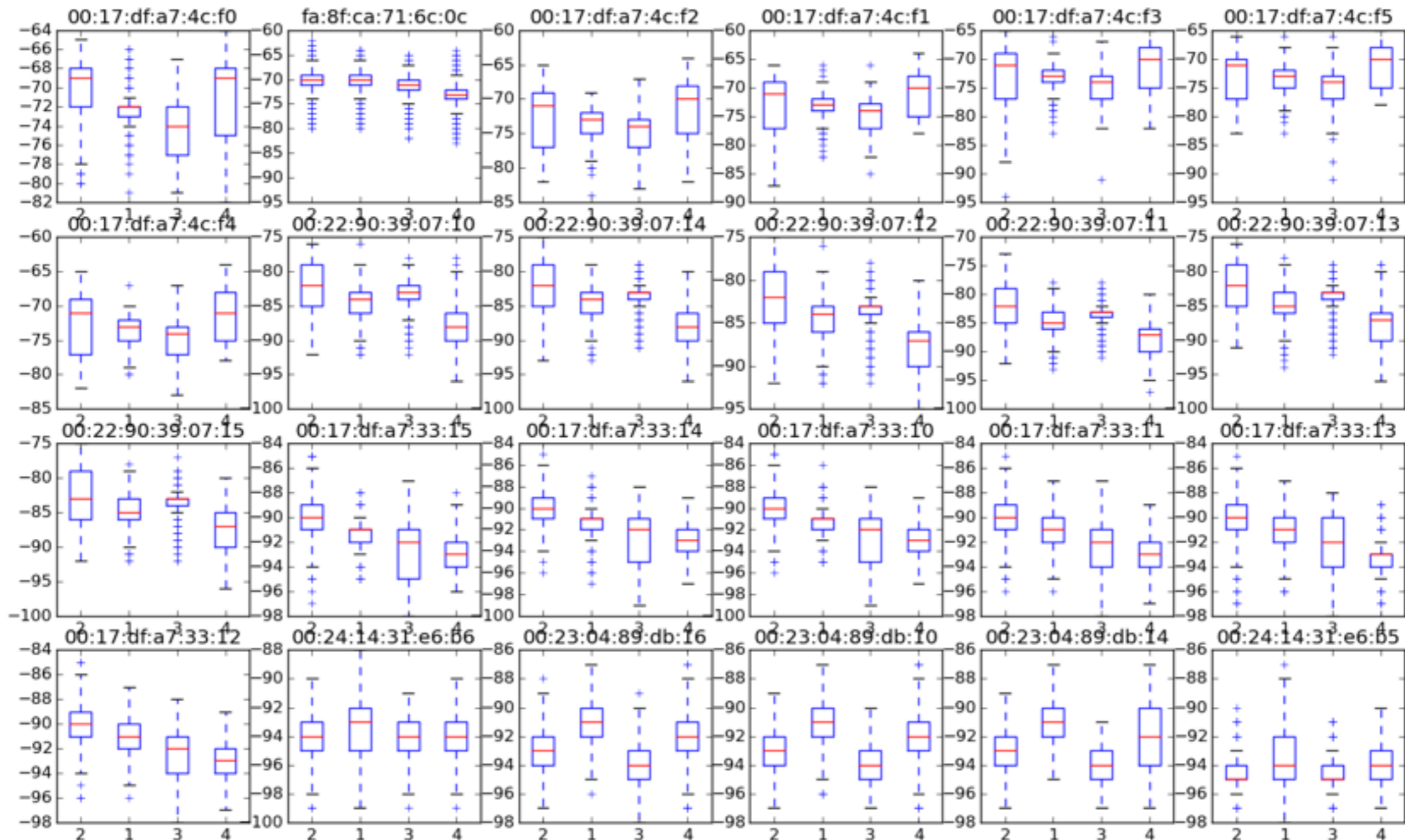


- Missing values are not bursty over time
- Missing possibilities seem consistent

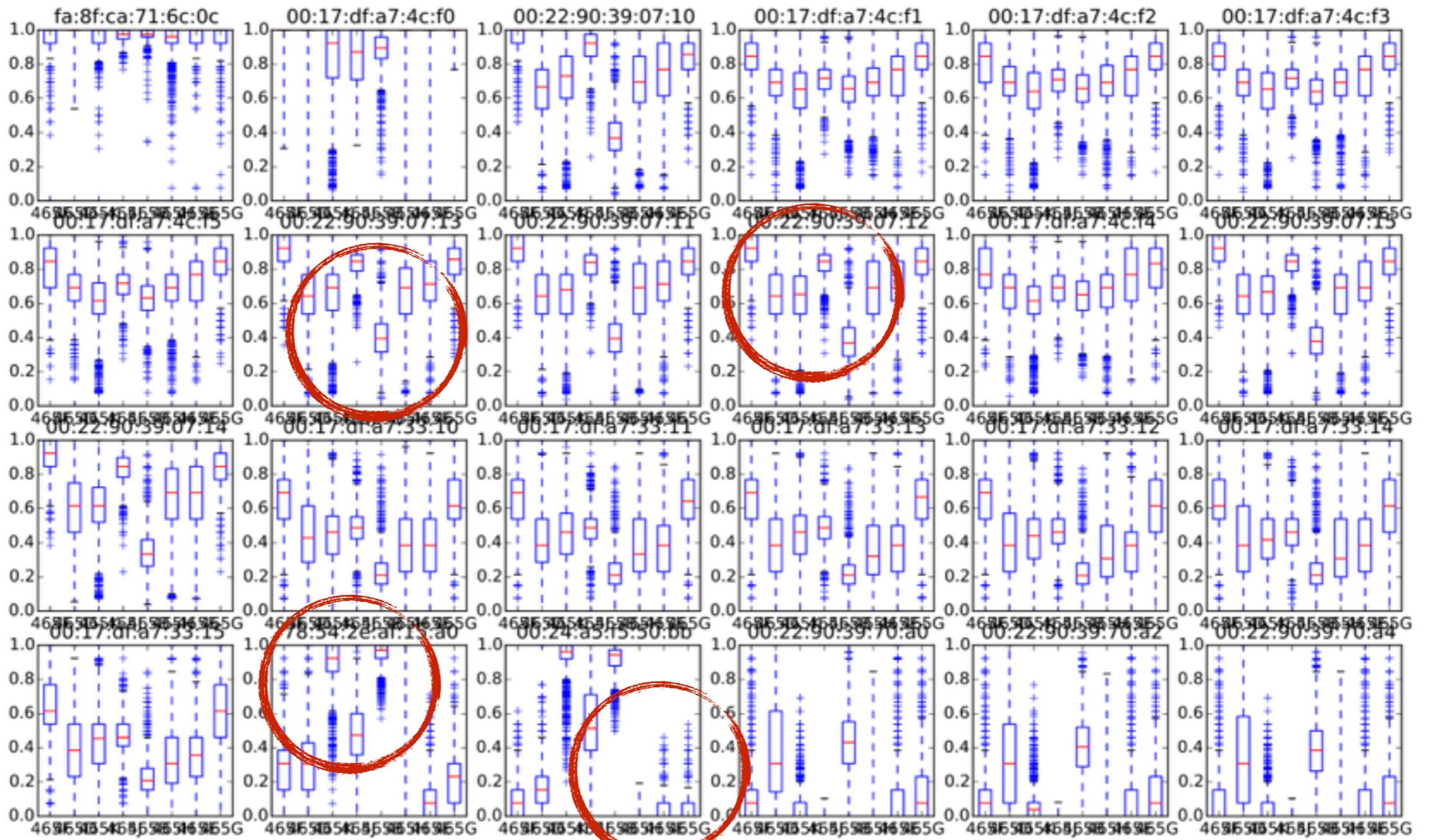
Are RSSIs Distinguishable?



Are RSSIs Distinguishable among Phones



Are Appearance Possibility Distinguishable?

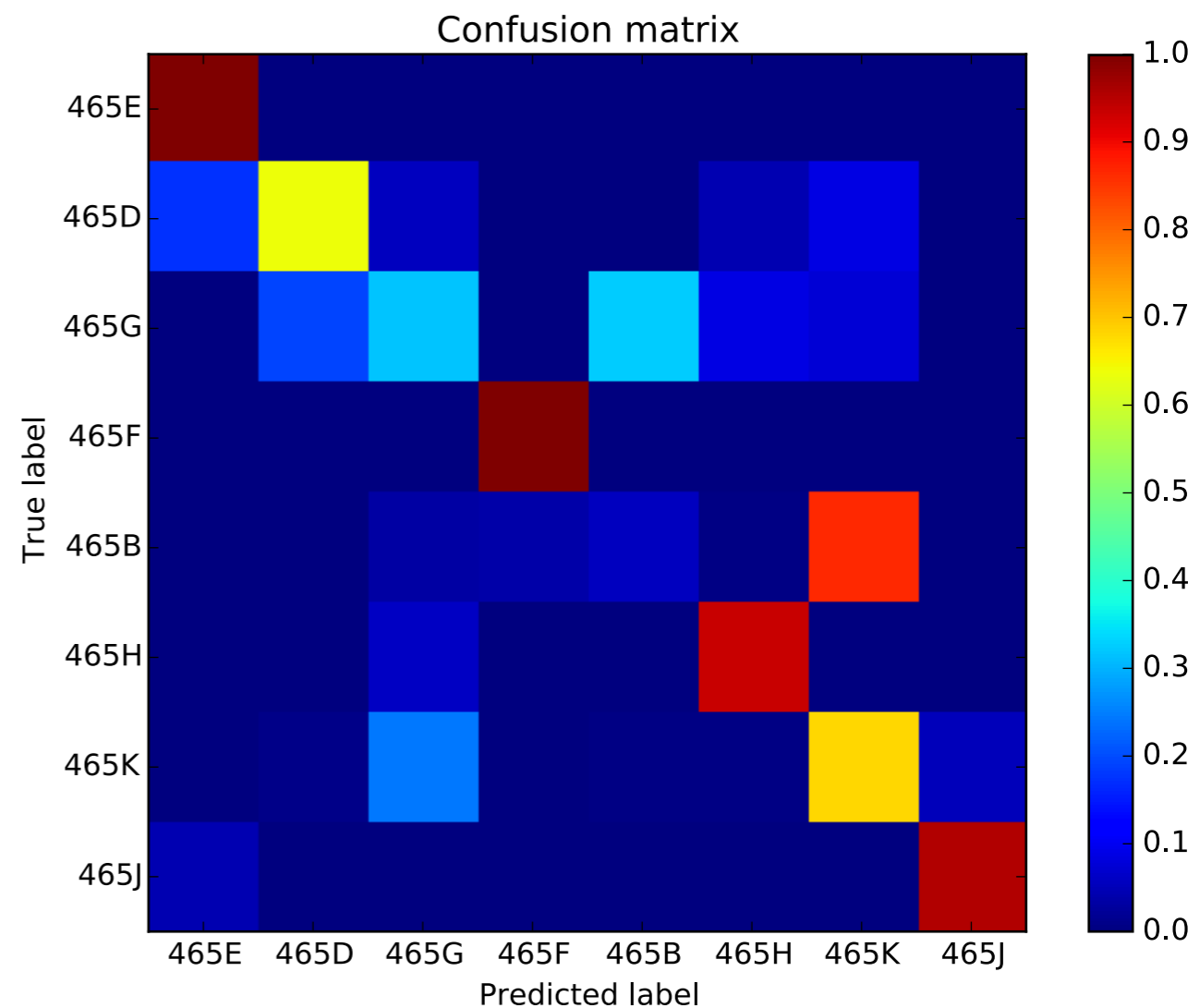


Localization Performance

- Normal RSSI Classification
- Remove Spurious APs
- Use Appear Possibility for Classification

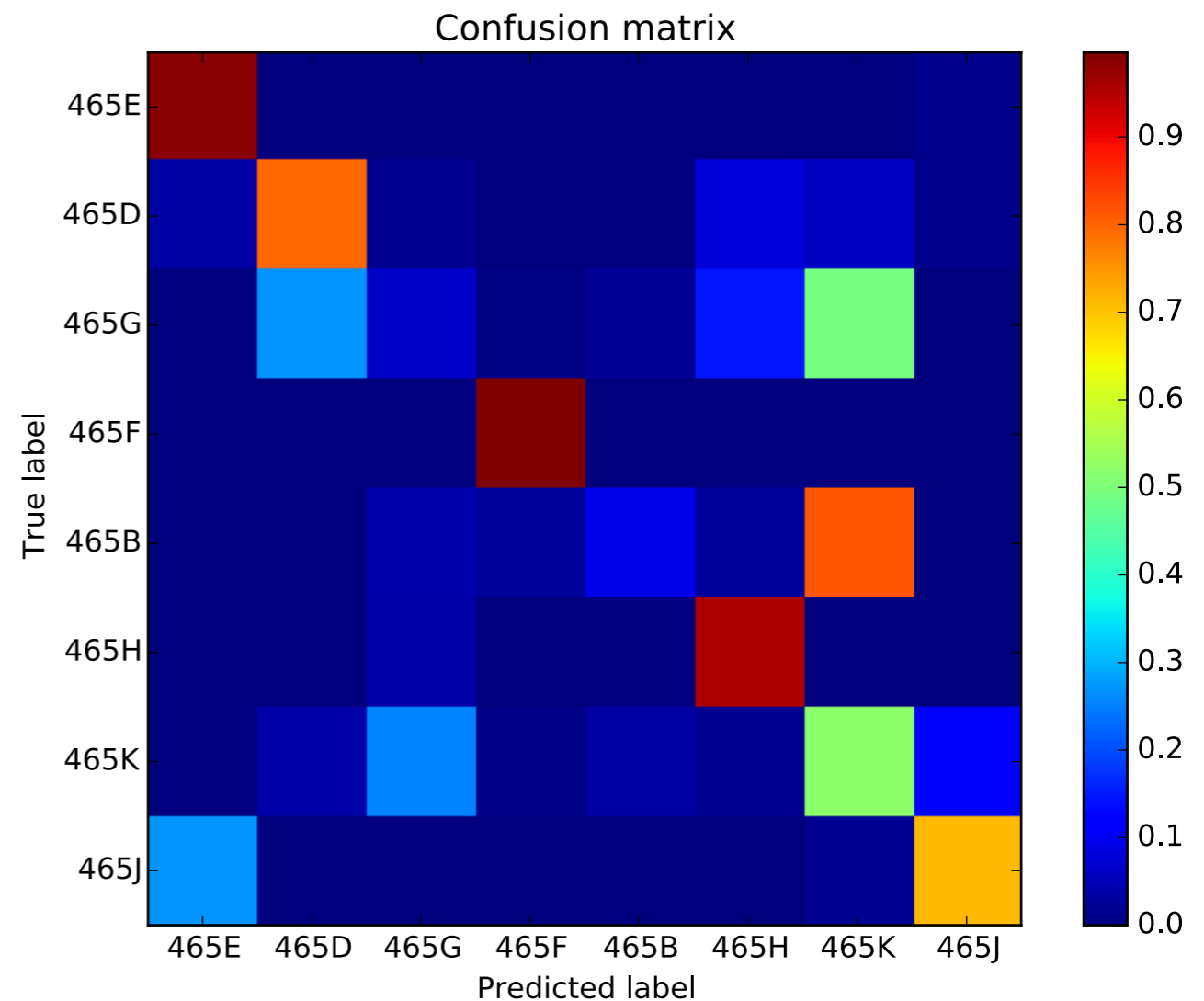
Normal RSSI Classification

- Stratified Cross Validation
- Use earliest group for training, which contains 22,639 scans
- Use latest group for testing, which contains 22,631 scans
- 76% accuracy



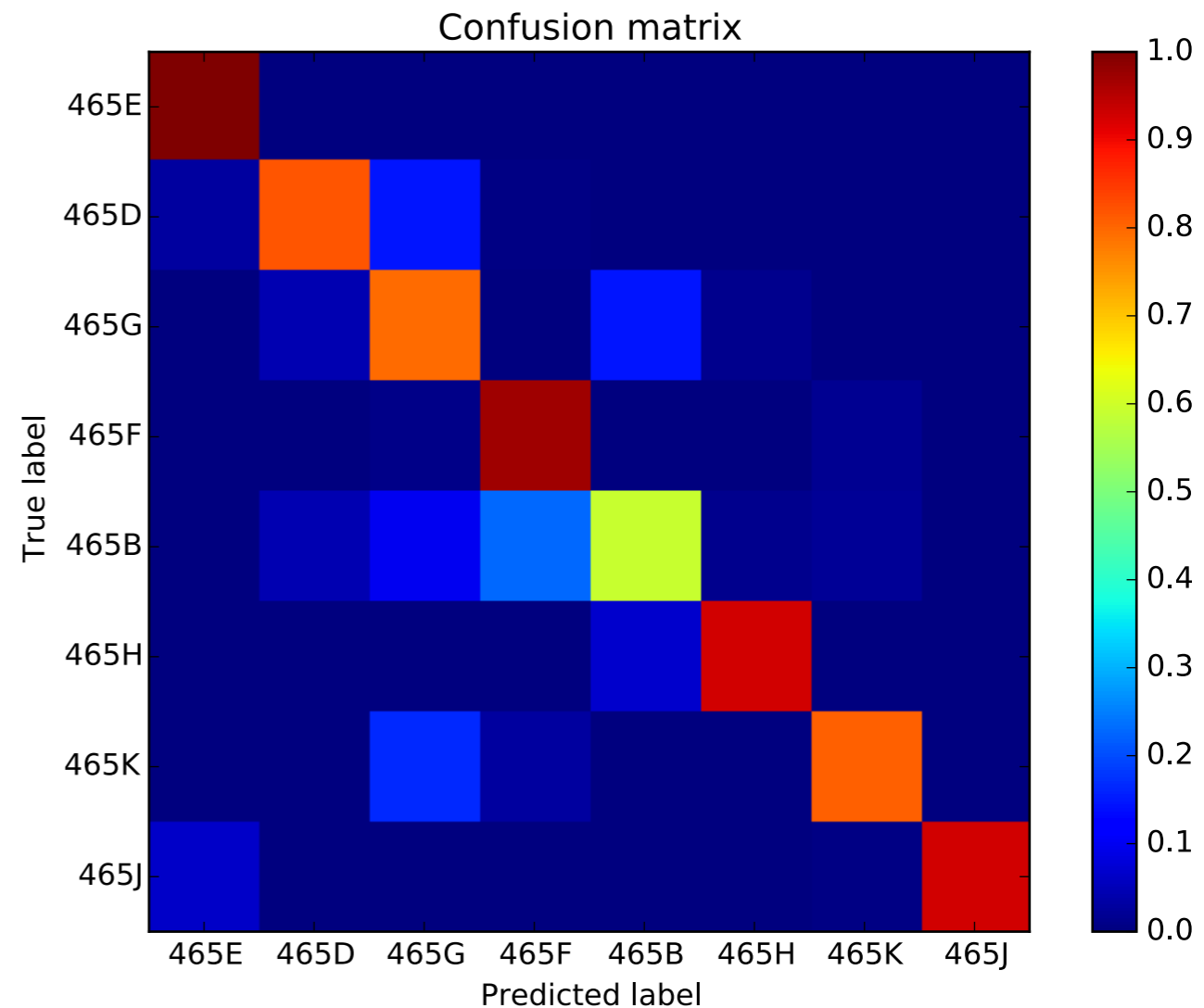
Remove Spurious APs

- Only keep the union of 3 mostly appeared MACs in each room
- 69% Accuracy

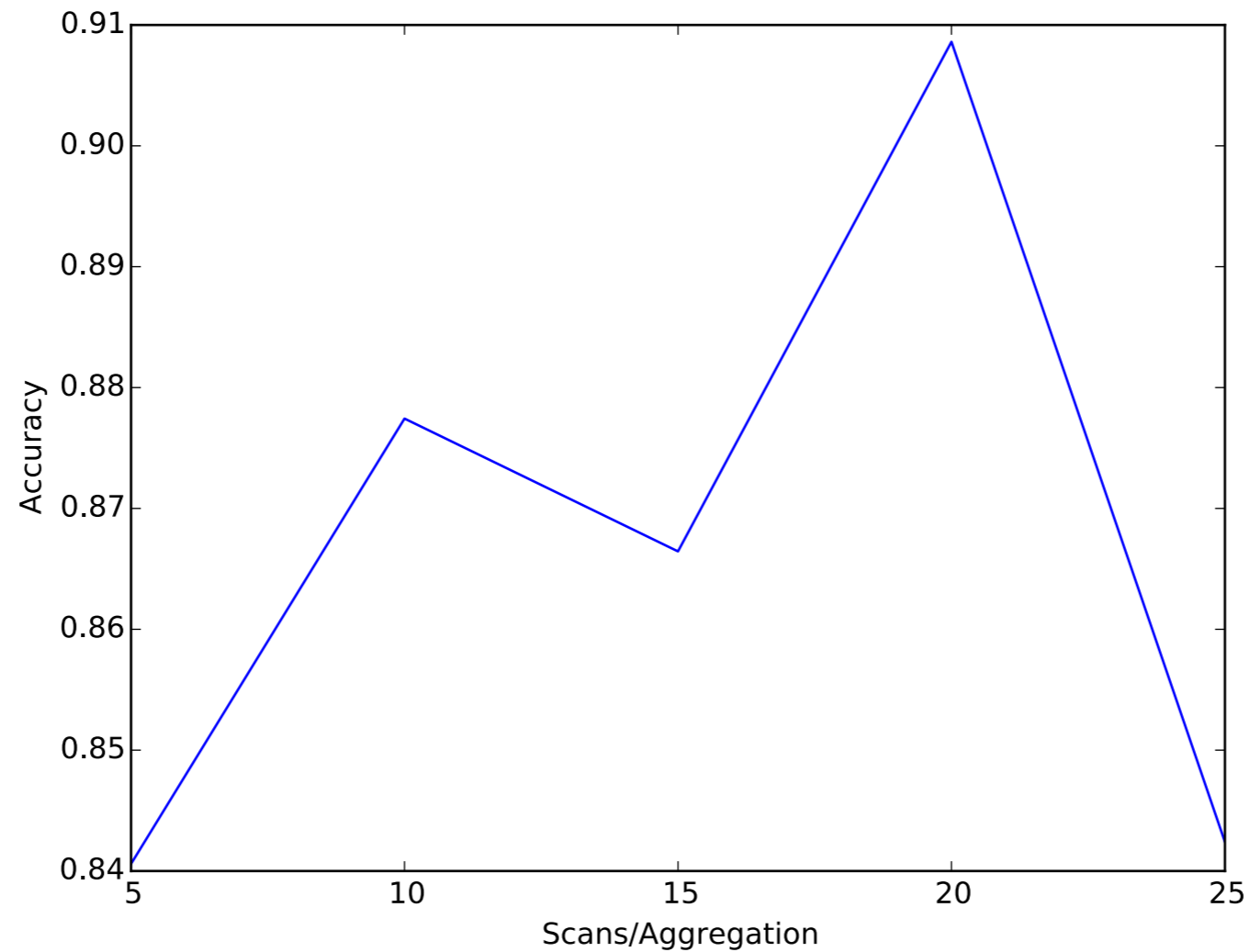


Use Appearance Possibility for Classification

- Aggregate MAC appearance possibility every 10 scans as features
- 88% Accuracy



Use Appearance Possibility for Classification



Conclusions & Future Work

- RSSIs are not consistent
- Appearance possibility can get more accurate results than using RSSI for localization
- They can potentially be combined

Thank you!
Questions?