Wi-Fi Engineer's Guide to Proximity Beacons

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Agenda

- Use Cases
- Proximity Solution
- Demo
- Bluetooth 4.2
- BLE Impact on 2.4 GHz WiFi
- Crowdsourced iBeacon Interference Testing
- Basic Rate Bluetooth
- Bluetooth Low Energy (BLE)
- Proximity Beacons
- iBeacons, Eddystone
- iBeacons for Notifications and Wayfinding
- Beacon Hardware
- WLAN Vendors and Proximity Beacon Support

Why Beacons?

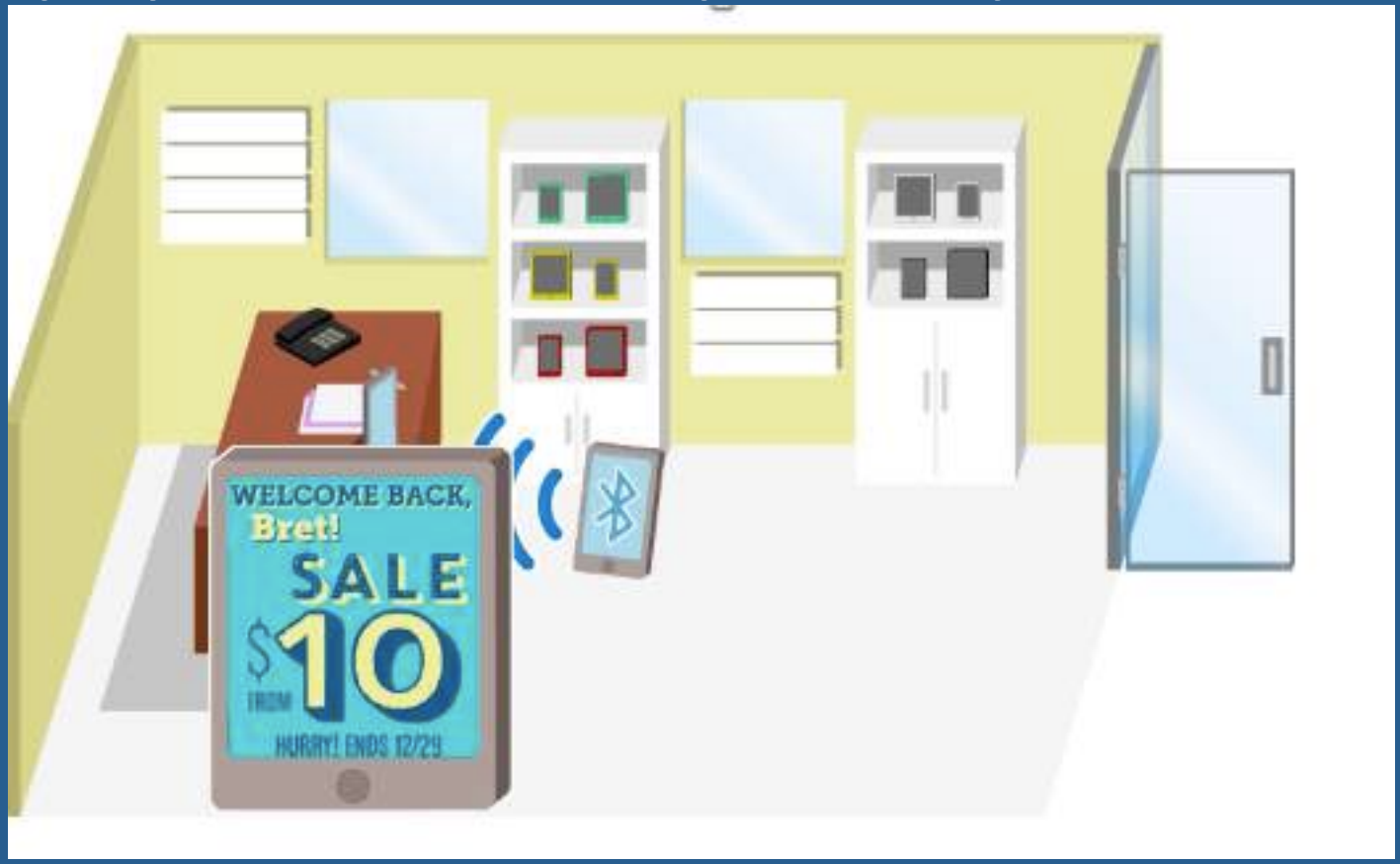
- Privacy (opt in model)
  - Turn off Bluetooth
  - Turn off location services
  - Don't install app
  - Disable notifications
- Benefits
  - Works indoors vs GPS
  - Micro-location vs WiFi
  - Leverages Bluetooth
  - Low cost components

Local & Push Notifications

- Local/Push notification prompting user to launch app.

Personalized Advertising

- Tablet used as personalized advertising display based on user proximity.



Wearables, Tags (IoT)

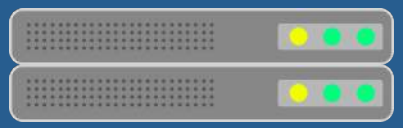
- iBeacon tag on devices located based on proximity to beacon detector/scanner. Alert messages on console and email.

Proximity Solution Parts

SSL

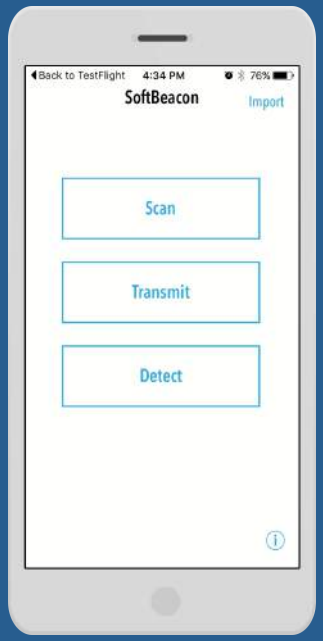
Apple Notification Service (optional)

- Push Notifications



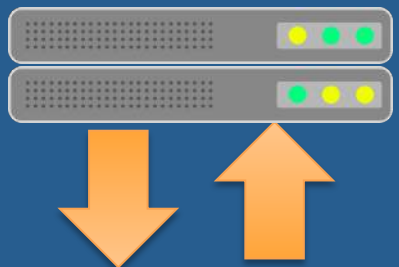
Proximity App

- BLE interface in mobile device detects beacons
- App configured to take actions based on beacon proximity
- “Master” when configuring beacons
- Local Notifications



App Server (optional)

- User/App authentication
- App configuration
- Analytics Data
- Push Notifications



Beacon

- “Advertiser” when beaconing
- or “Slave” in configuration mode

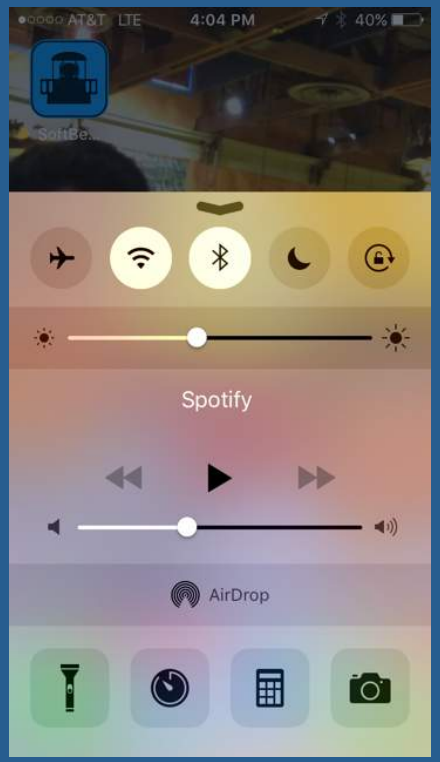
3rd Party Client (optional)

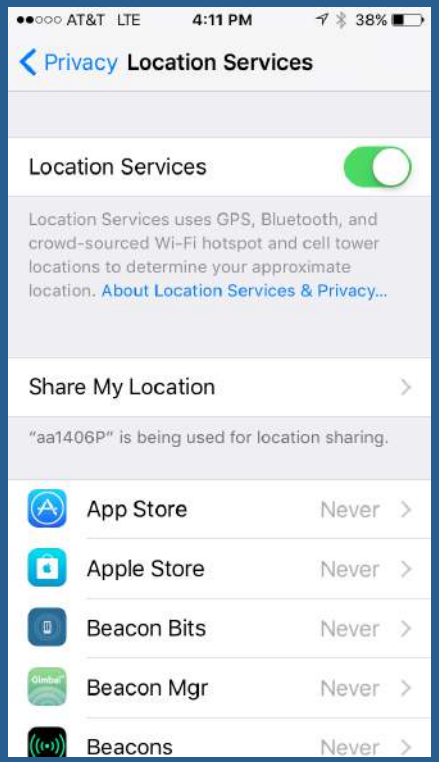
- Notifications
- Analytics
- Manage Campaigns / System

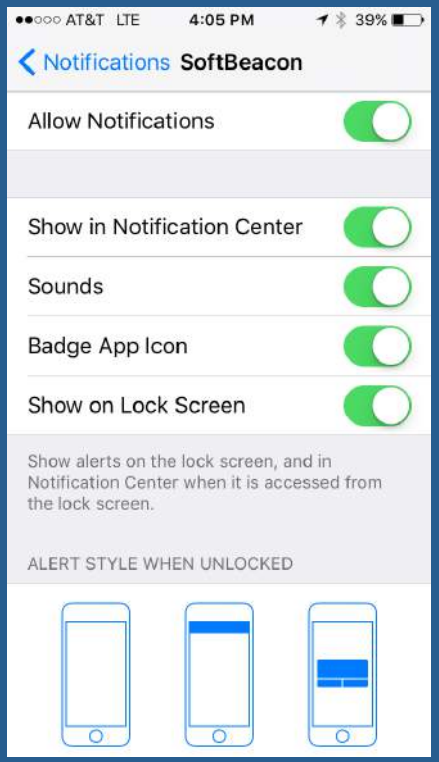
Proximity Demo

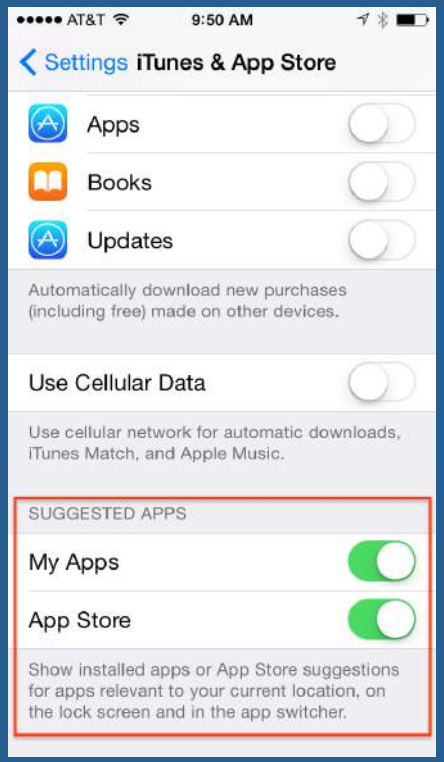
Getting iPhone Ready for Proximity App Demo

1. Enable Bluetooth
2. Enable Location Services (privacy)
3. Enable Notifications (Prompt user when screen locked, using app, not using app)
4. Enable “Suggested Apps” (Show app icon on bottom left corner)









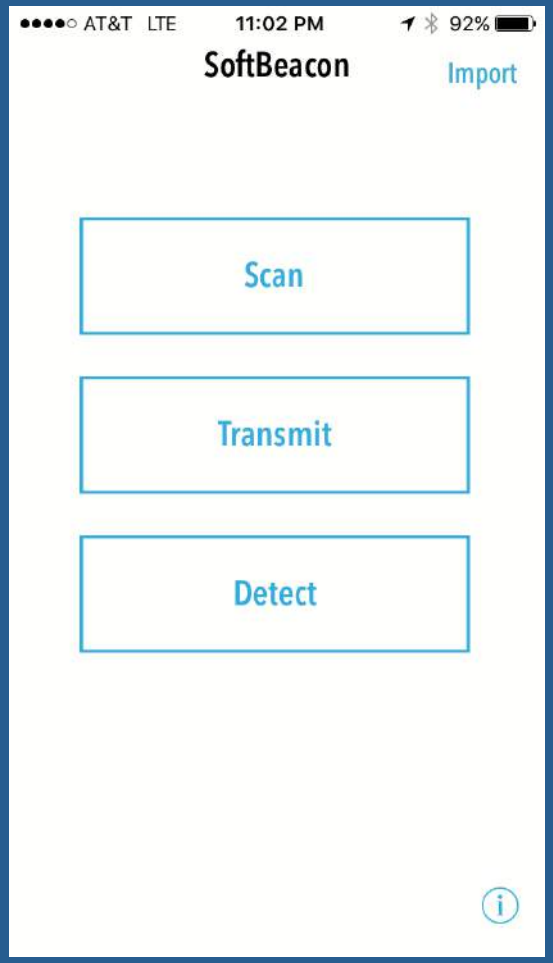
Estimote Beacons For Demo

- Low cost
- Battery replaceable (sort of…cut open casing)
- Place upside down to turn off beaconing (very handy for testing)
- iBeacon and Eddystone
- Motion sensing beaconing
- App for configuring UUID, Major, Minor

- Configuration
  - Beacon type (iBeacon)
  - UUID, Major, Minor
  - Beacon frequency
  - Beacon power

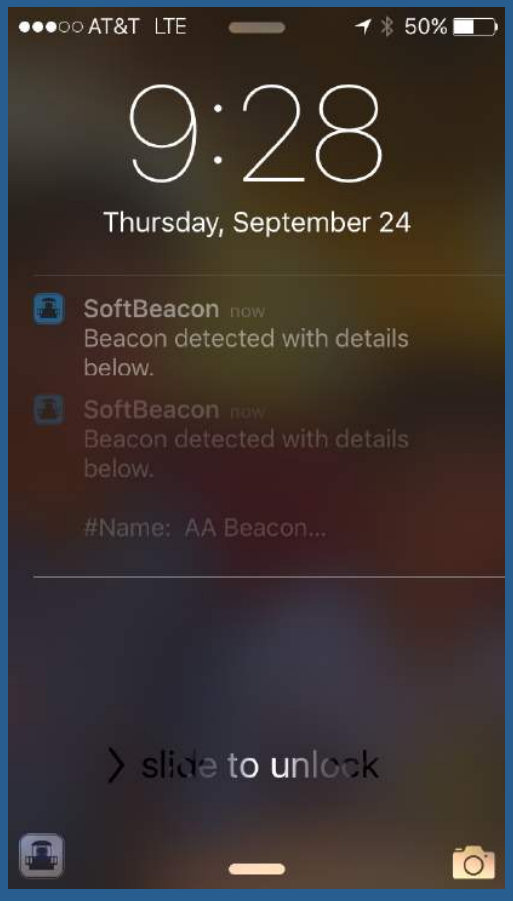
Configure App

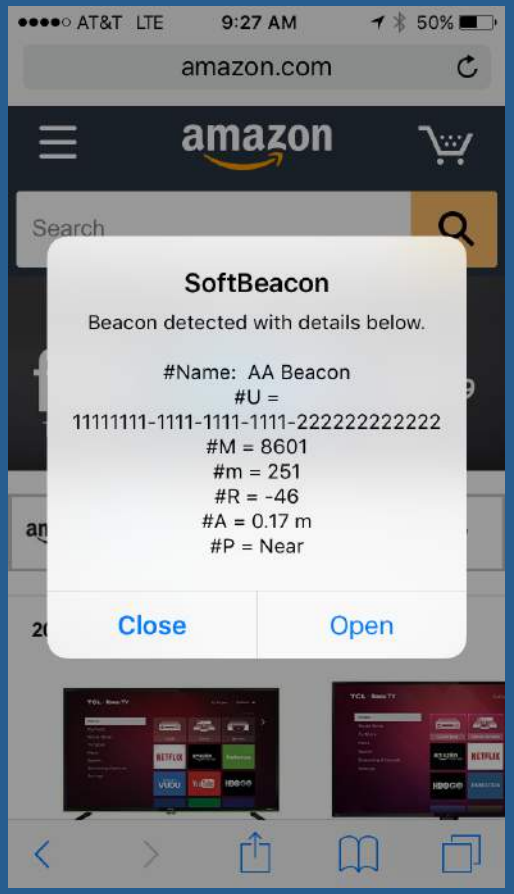
- Configure Region for Detection
  - #U = UUID
  - #M = Major
  - #m = Minor
- Proximity Notifications
- Additional Proximity Actions
  - Email
  - Open App
  - Open URL



Demo

1. Locked phone
2. Unlocked phone
3. Unlocked phone, using different app





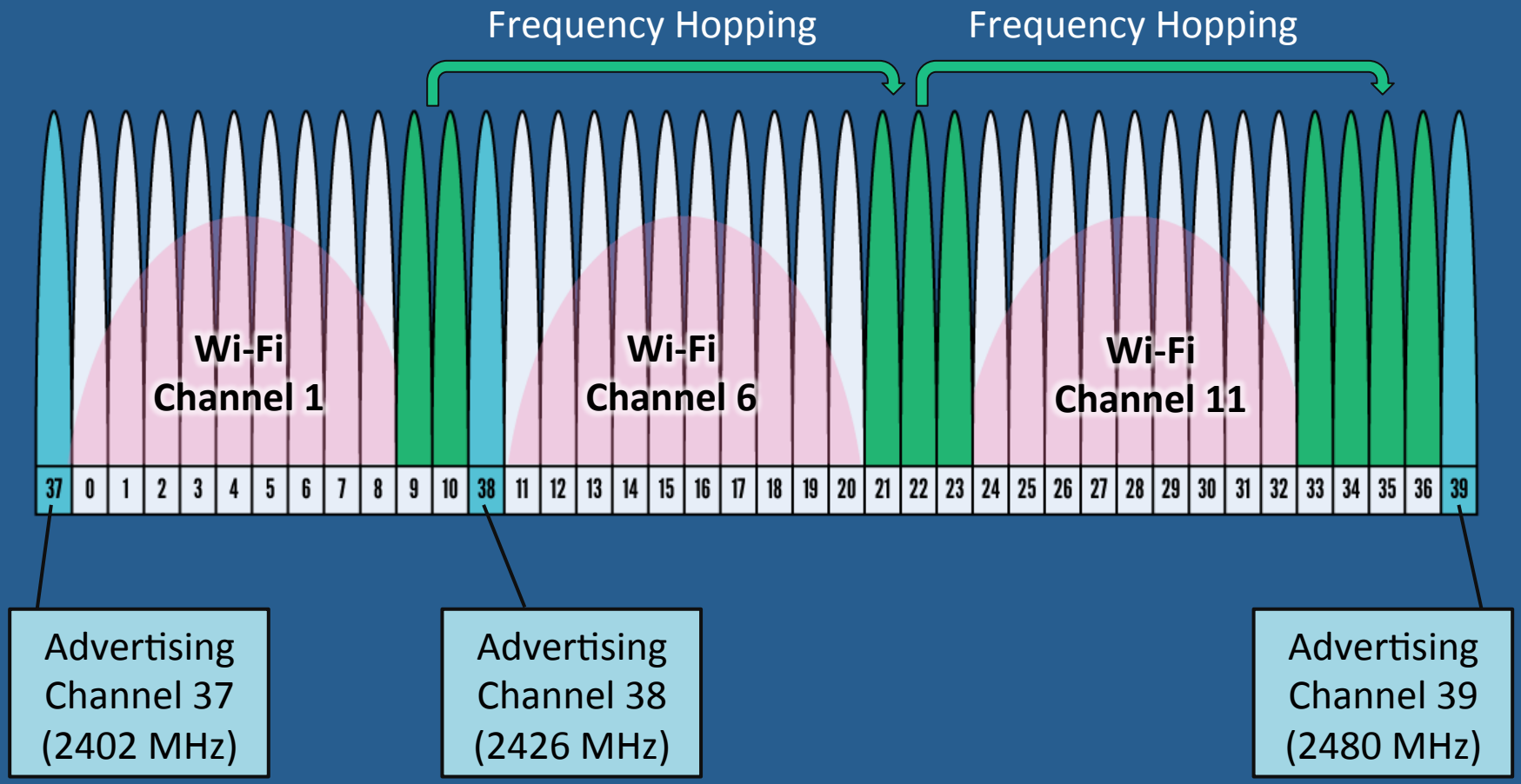
Bluetooth 4.2

- 2.4 GHz ISM band
- Adaptive Frequency-hopping spread spectrum to avoid crowded frequencies
- Device discovery, connection establishment, connection mechanisms/ control
- Basic Rate (BR)
  - 721 kbps for Basic Rate
  - 2.1 Mbps for Enhanced Data Rate (EDR)
  - 54 Mbps with the 802.11 Alternate MAC/PHY (AMP)
  - 79 Channels, 1 MHz separation
- Low Energy (BLE)
  - 1 Mbps
  - Lower current consumption (coin-cell battery)
  - Lower cost
  - Lower complexity
  - 40 Channels, 2 MHz separation (37 data, 3 advertising)

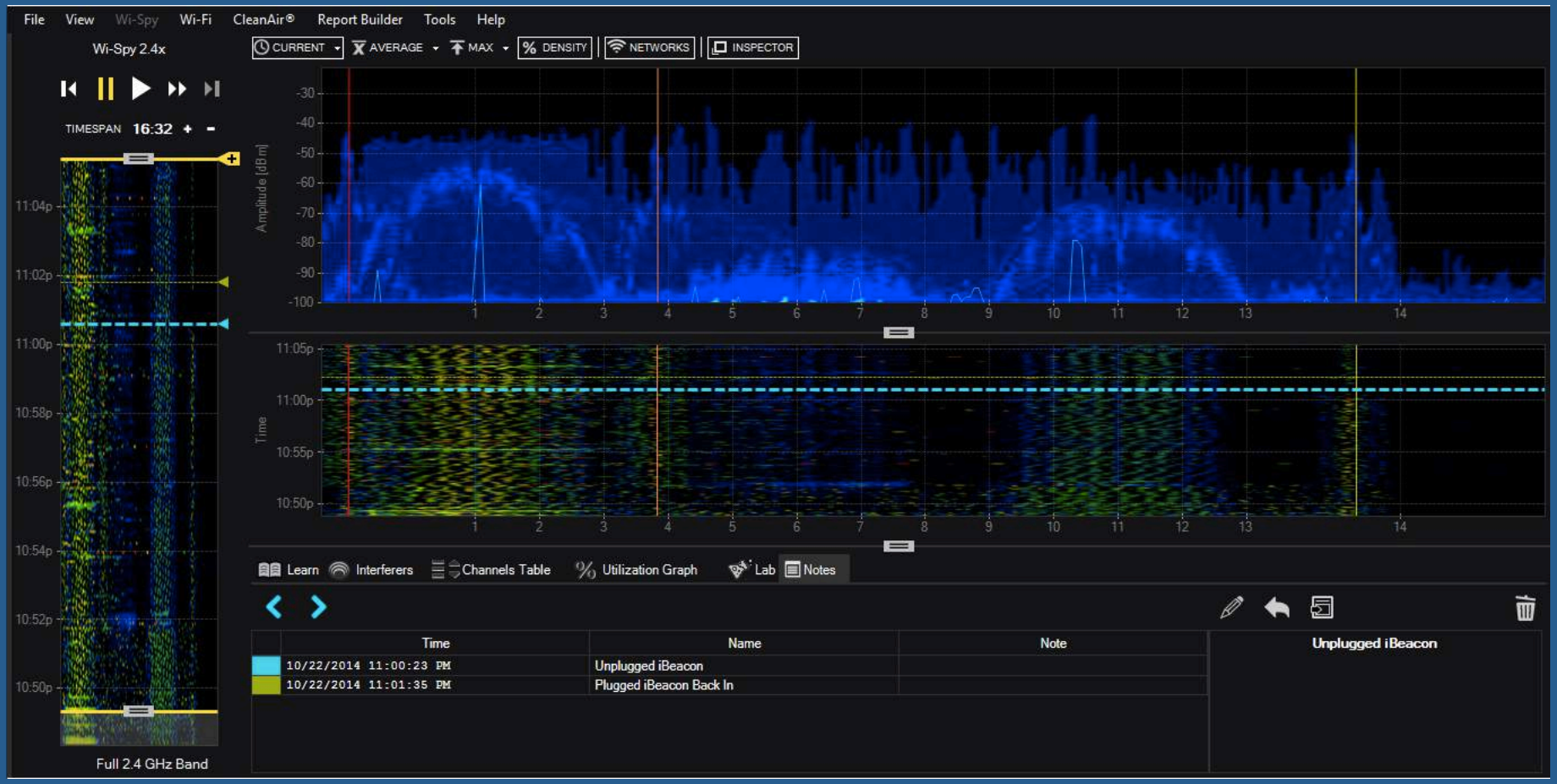
BT 4.2 pages 168-180
https://www.bluetooth.org/en-us/specification/adopted-specifications

Do BLE Beacons Interfere with WiFi?

- 40 channels in 2.4 GHz
  - 37 data channels (0-10, 11-36)
  - 3 advertising channels avoid WiFi interference if 1, 6, 11 channel plan used



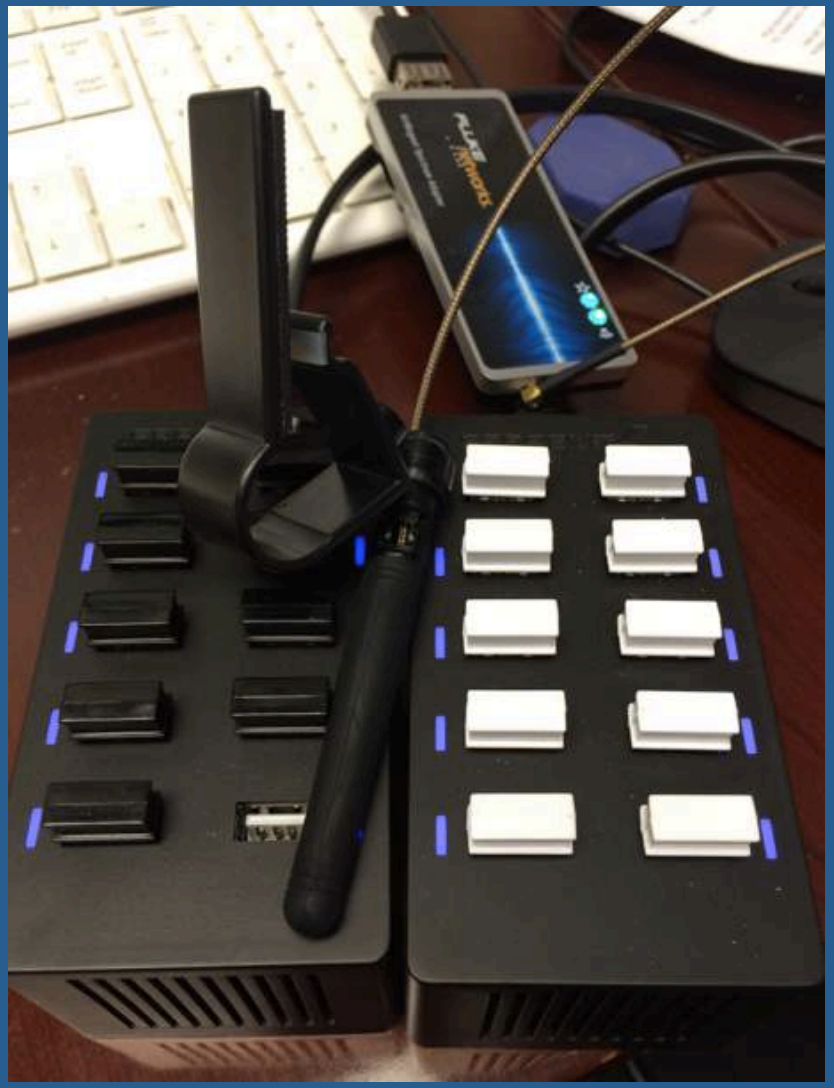
1 Beacon + Spectrum Analyzer



capture by Joel Crane @FuelCellWiFi

19 Beacons + Spectrum Analyzer

- 19 USB BLE Beacons
- Powered by two 10 port USB chargers
- Monitor 2.4 GHz using Fluke Spectrum XT
- No noticeable impact on WiFi on channels 1, 6, 11

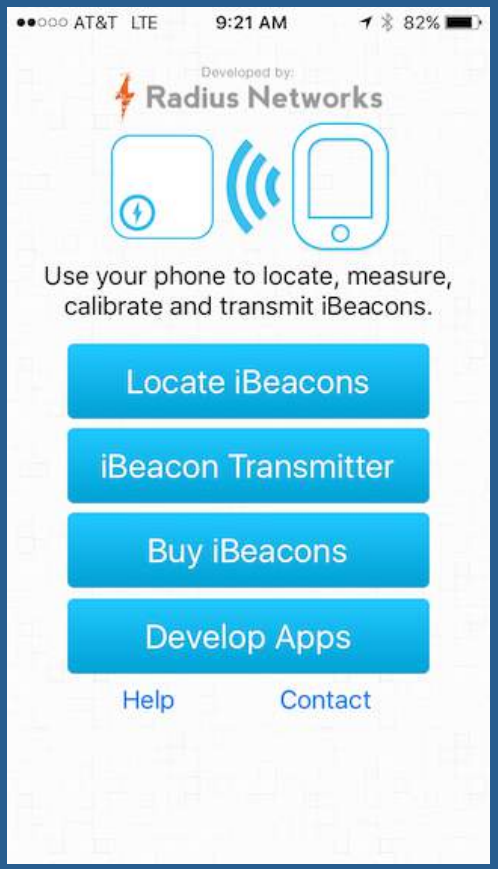


Crowdsourced Interference Testing

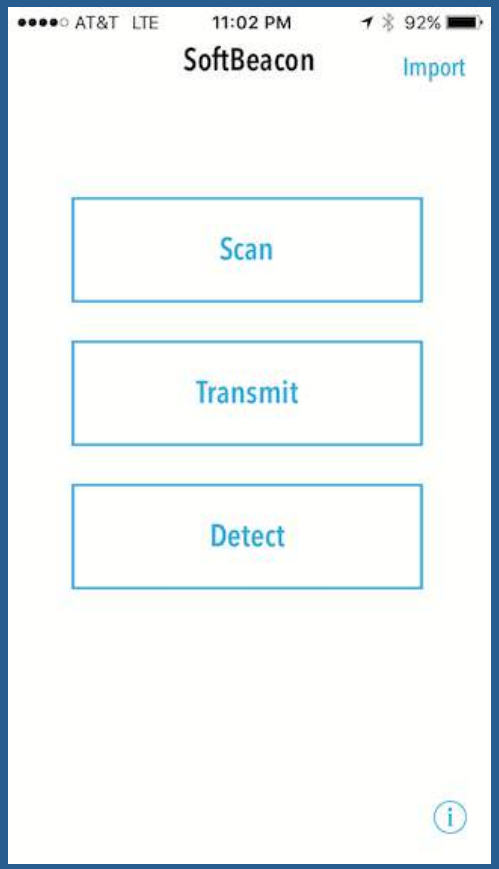
- Please Download “Locate” app by Radius Networks from Google Play or Apple App Store
- We will turn our devices into iBeacon transmitters and see if it impacts 2.4 GHz WiFi

Virtual Beacons Software $0

- Phone as an iBeacon (aka advertiser)
  - Many iBeacon Transmitter apps on Google Play and Apple App Store
  - Some allow custom UUID value (potential spoofing of UUIDs)
  - Download now before removed from app store by Apple



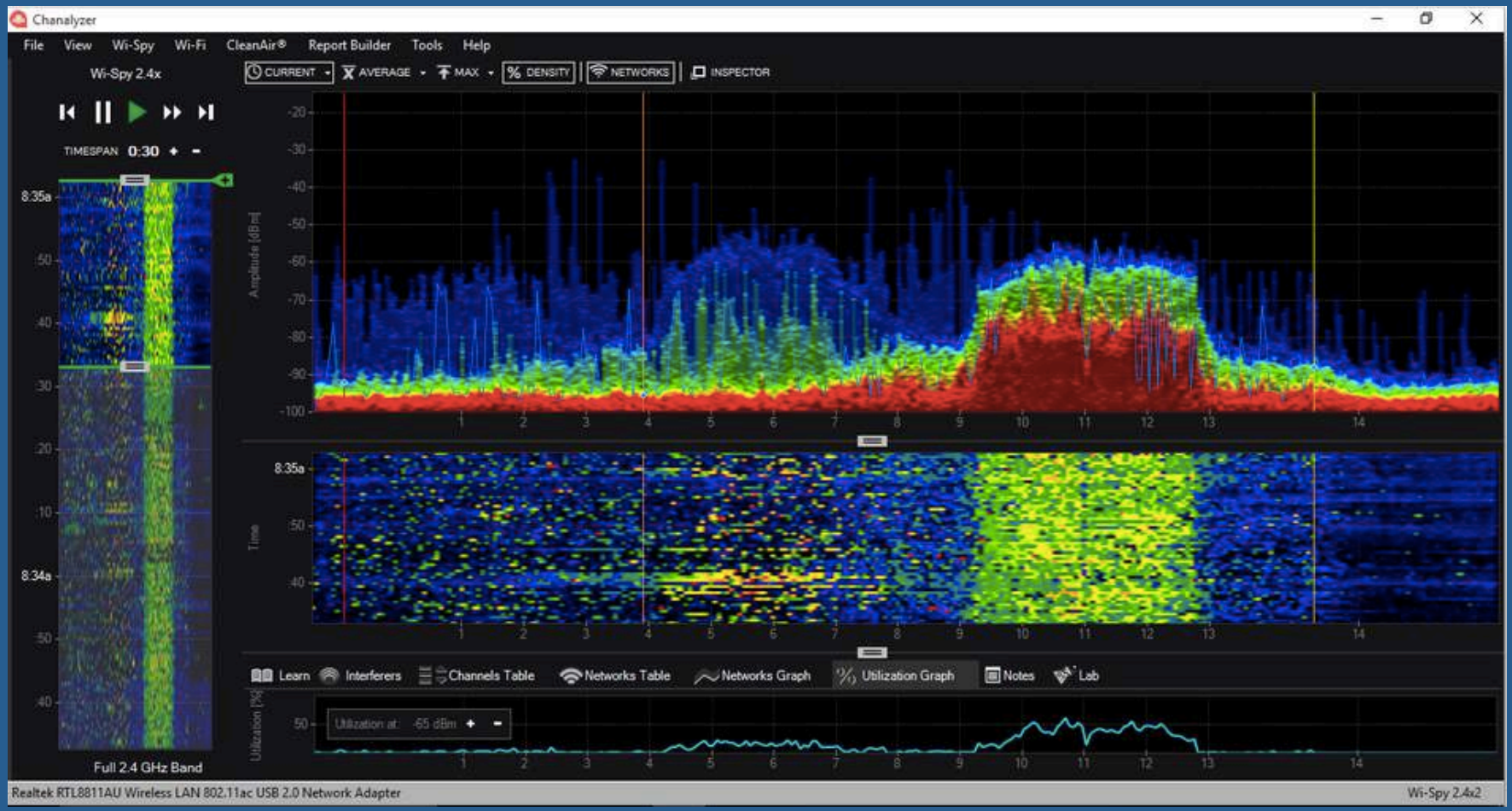
Locate App
Radius Networks



SoftBeacon App
AccessAgility
*Not on app store

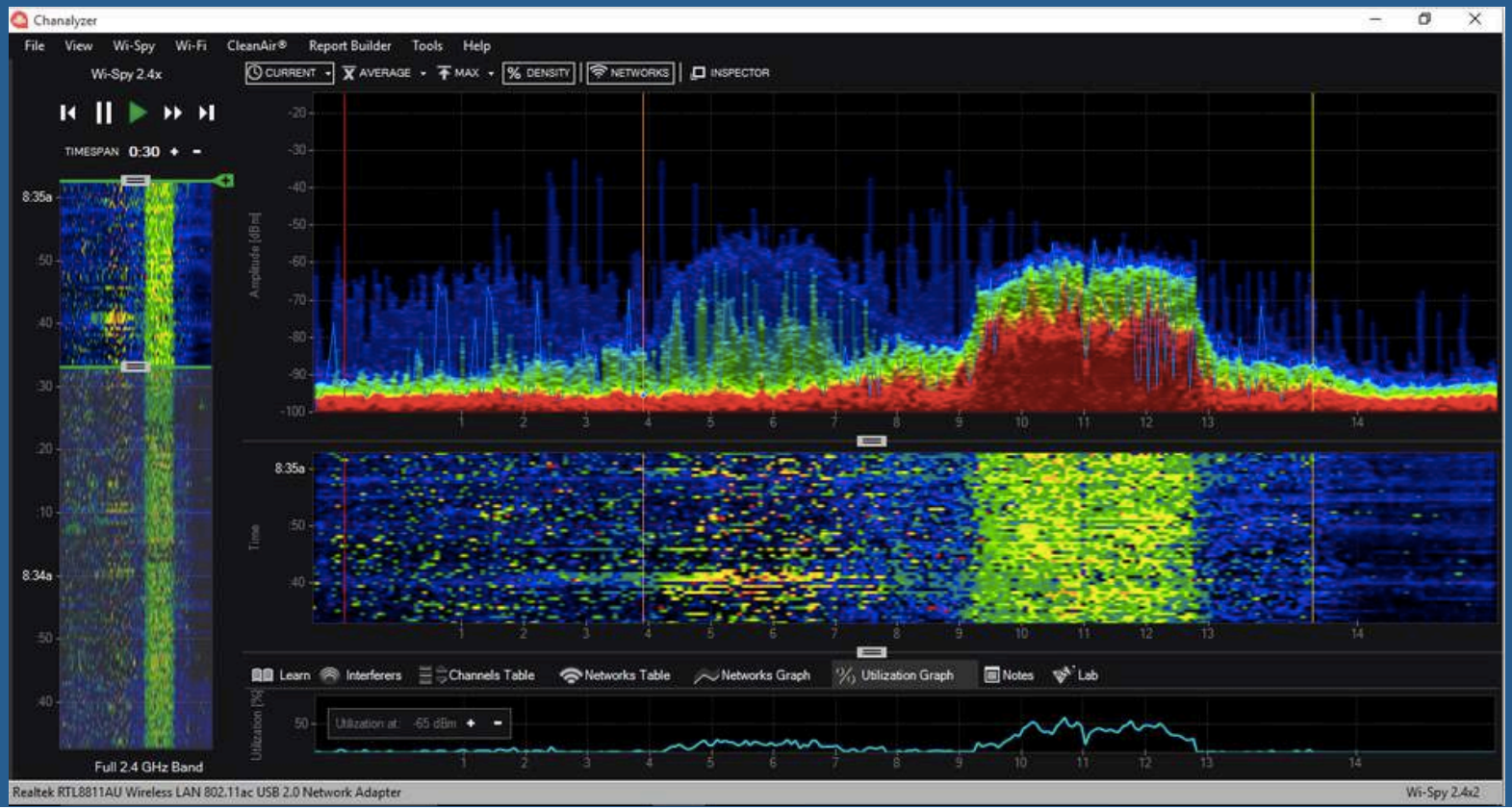
Pre iBeacon

- Three vertical lines. Minimal utilization



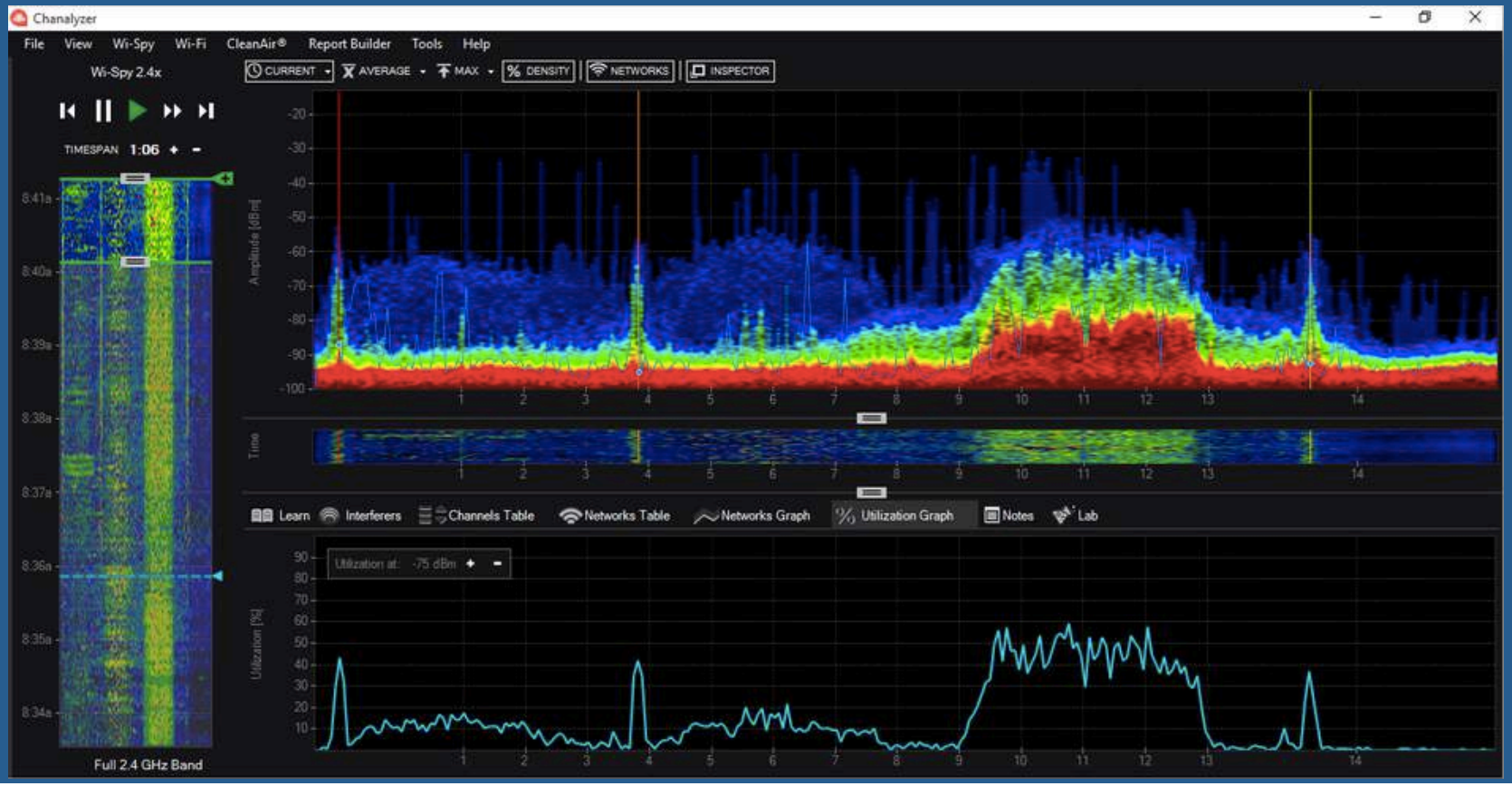
Post iBeacon

- Three vertical lines, 20% Utilization on BLE advertising channels



Post iBeacon

- Three vertical lines, 45% Utilization on BLE advertising channels at -75 dBm



Post iBeacon

- 45% Utilization on BLE advertising channels at -75 dBm (three marker lines removed)

Bluetooth Basic Rate & EDR (Boring Bluetooth)

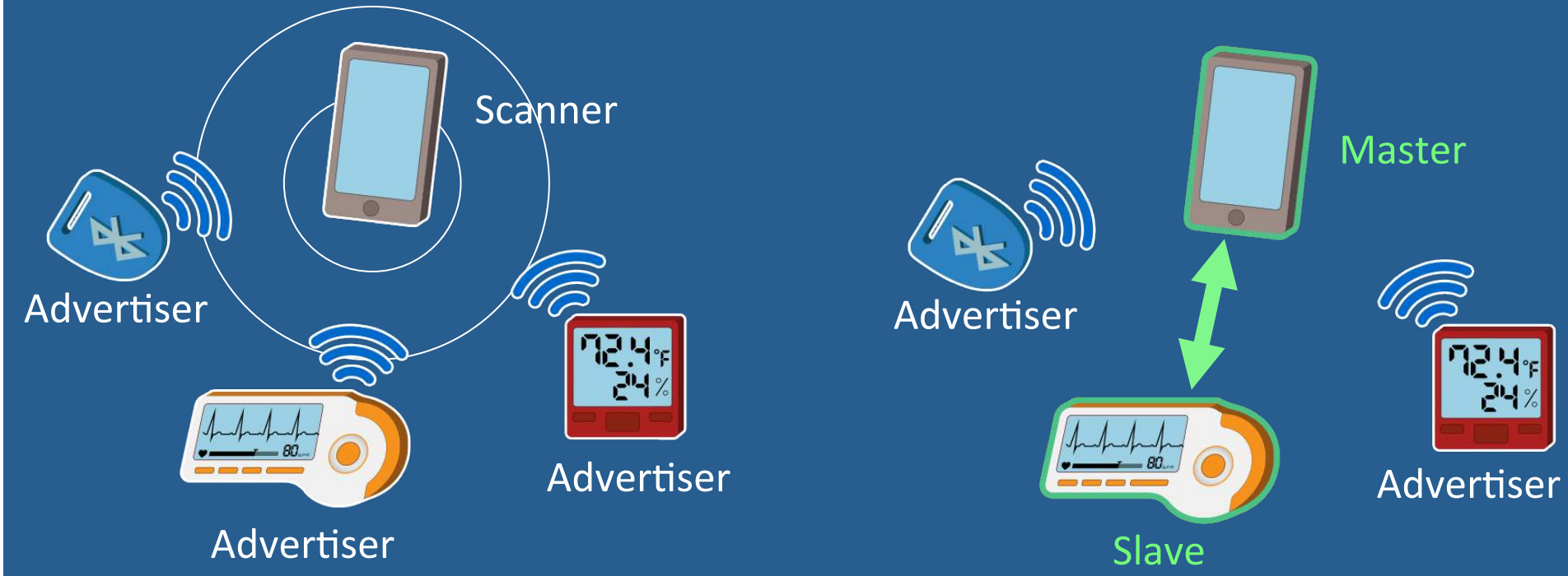
- Keyboard, Mouse, Headset, Printing & File Transfer (Wireless Networking)
- BT 1.0 - Wireless alternative to cables
- BT 1.2 – 721 kbps, avoid interference in 2.4 GHz
- BT 2.0 - 2.1 Mbps
- BT 2.1 – Secure Simple Pairing (SSP)
- BT 3.0 – Bluetooth High Speed (HS) – BT over 802.11

Bluetooth Low Energy (BLE) (Fun Bluetooth)

- BT 4.0 – 2008 / BT 4.2 - Dec 2014
- Lower power / Battery power
- Proximity Beacons
- Activity Monitors
- Thermostats
- Cameras
- Smoke Detectors
- Door Locks
- Internet of Things (IoT)

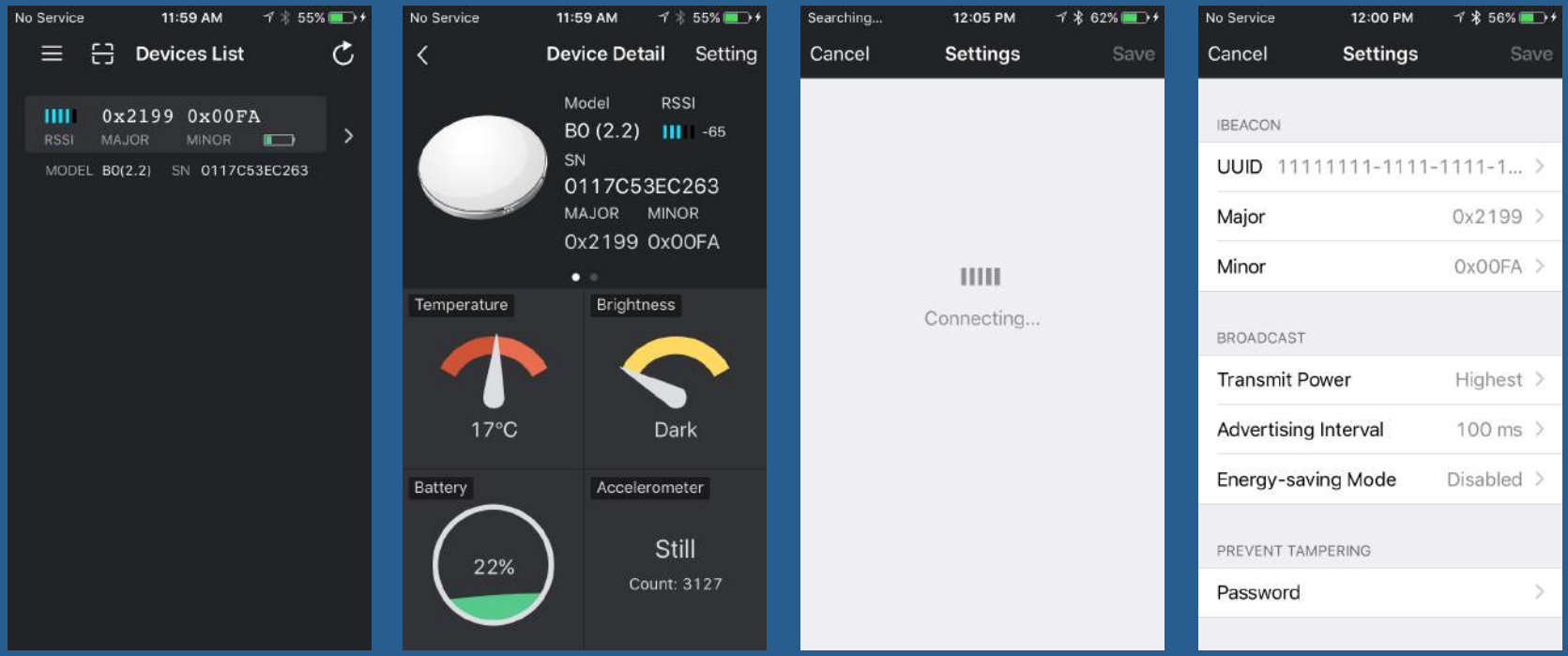
Bluetooth BLE Device Roles

- Scanner - A Bluetooth low energy device that listens for advertising events on the advertising channels.
- Advertiser - A Bluetooth low energy device that broadcasts advertising packets during advertising events on advertising channels.
- Initiator – Devices that initiate connections based on detecting connectable advertising packets
- Master – Initiator connects to advertiser it becomes master in piconet
- Slave – Advertiser devices becomes slave in piconet



BLE Scanner, Advertiser, Slave, Master

- Use BLE App to scan for BLE Devices (iPhone as Scanner)
- Monitor proprietary proximity beacon info (uses vendor SDK)
- Connect to Slave device (device no longer in advertiser role)
- Configure / view settings of Slave device



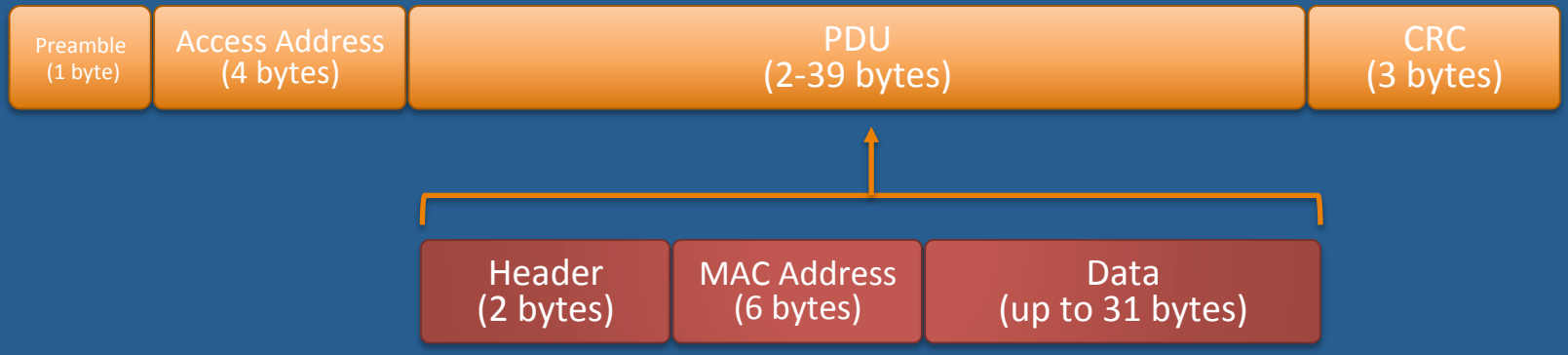
Proximity Beacons = BLE Advertiser

Beacons	Low power/battery powered Bluetooth transmitter, advertise short message at regular intervals
Proximity	**Distance calculation based on beacon RSSI**
Privacy	Beacons only unidirectional broadcasting Opt in model in apps (Privacy > Location Services in iOS)
Security	Clear text advertisement, susceptible to impersonation attacks
Usage	Mainly for indoor positioning, micro location, tracking tags
iBeacon	Apple's Proximity Beacon Specification 
Eddystone	Google's Proximity Beacon Specification 

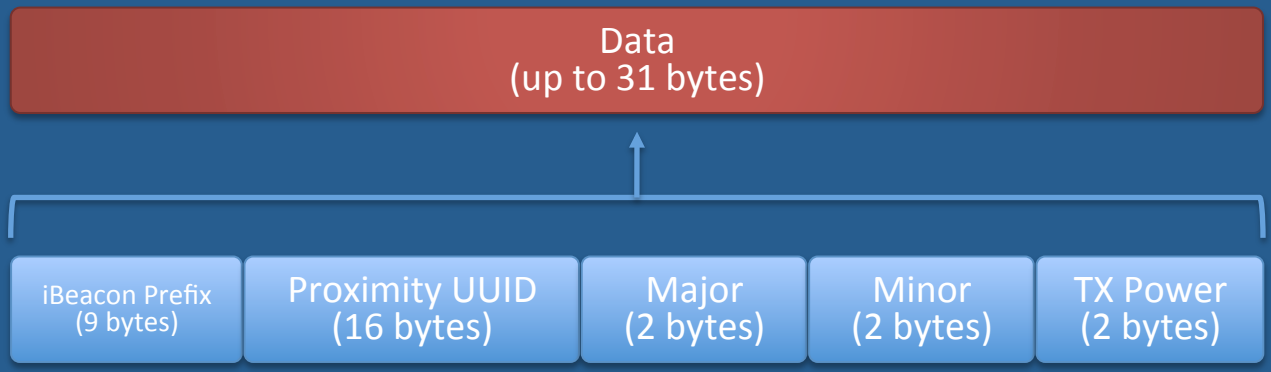
Proximity Beacon Types

	iBeacon	Eddystone	Proprietary
Range (Max)	~70 meters, ~230 feet	~70 meters, ~230 feet	~70 meters, ~230 feet
iOS Support	YES	YES	YES
Android Support	Unofficial	YES	YES
Multiple Vendors	YES	YES	NO
Information in Beacon(s)	16 byte UUID 2 byte major 2 byte minor 1 byte Tx Power @ 1m (Expected RSSI by iPhone 1m away from Beacon)	Eddystone-UID • 10 byte namespace • 6 byte instance • 1 byte Tx Power Eddystone-TLM • 1 byte – version of packet • 2 byte – temperature of beacon • 2 byte – beacon battery level • 2 byte – how long beacon has been powered on • 2 byte – how many packets beacon has sent Eddystone-URL • 17 byte – compressed URL (Chrome can detect)	?? • Beacon • Telemetry
Introduced	**July 2014**	**July 2015**	Various

BLE Packet



iBeacon Packet



iBeacon Region Example

Store Location		San Francisco	Paris	London
	UUID	11111111-1111-1111-1111-222222222222		
	Major	1	2	3
Minor	IPhones	10	10	10
	iPads	20	20	20
	Computers	30	30	30

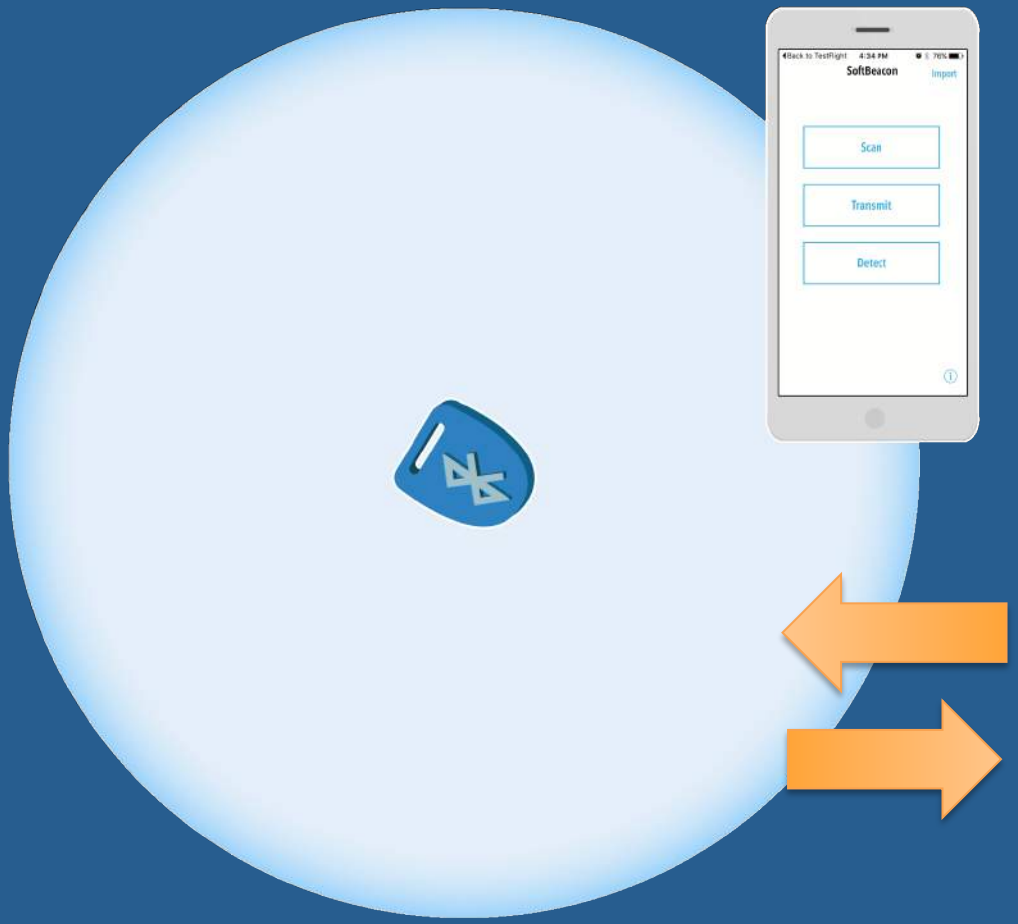
- Location IDs = 20 byte (UUID, Major, Minor)
- UUID = 16 byte
  - Major = 2 byte
    - Minor = 2 byte
- 11111111-1111-1111-1111-222222222222
  - Major – 1 (San Francisco)
    - Minor – 30 (Computers)

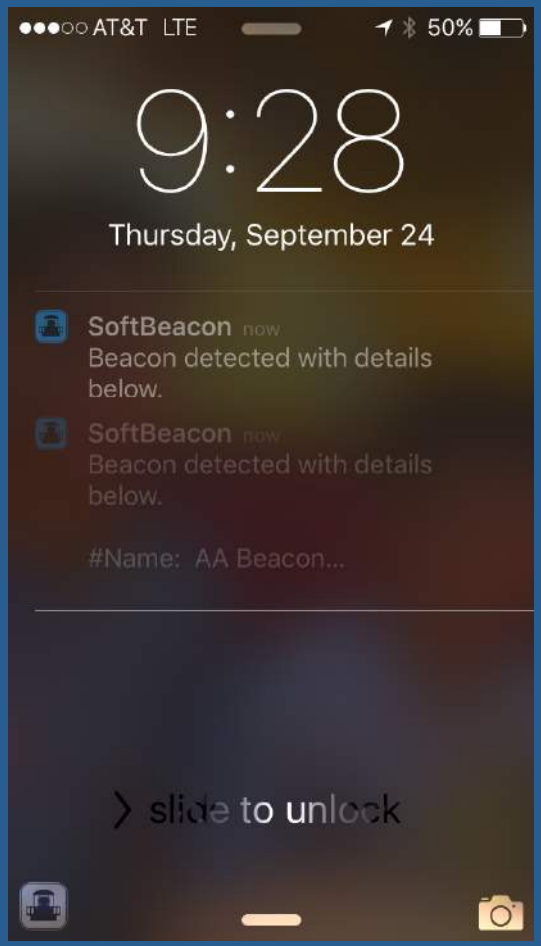
= a Region
(1 or more beacons)

iBeacon Region Monitoring and Ranging

- Region = UUID + major + minor, UUID + major, or UUID only.
- iOS allows monitoring of up to 20 regions (unlimited beacons)
- iBeacons allow for two basic interactions between apps and individual beacons or groups of beacons called regions:
  - Region monitoring: actions triggered on entering/exiting region's range; works in the foreground, background, and even when the app is killed. If app is not running at the time—it'll be launched into the background by iOS.
  - Ranging: actions triggered based on proximity to a beacon; works only in the foreground. Used by indoor wayfinding

Monitoring = Region Entry/Exit Events (Used for Notifications)





Notifications: Enter events triggers in few seconds, Exit events trigger up to 30 seconds

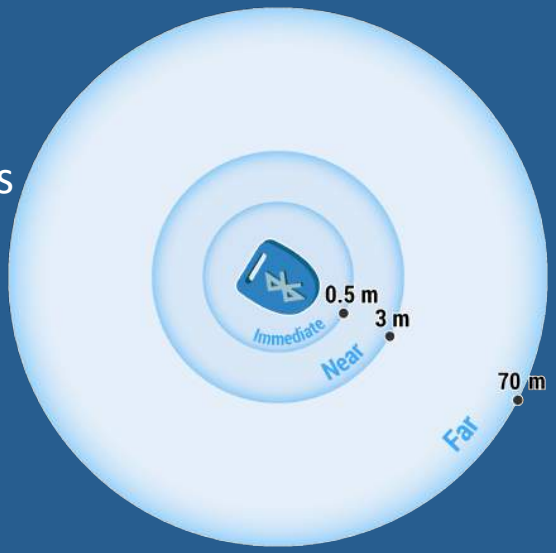
iBeacon Region Ranging

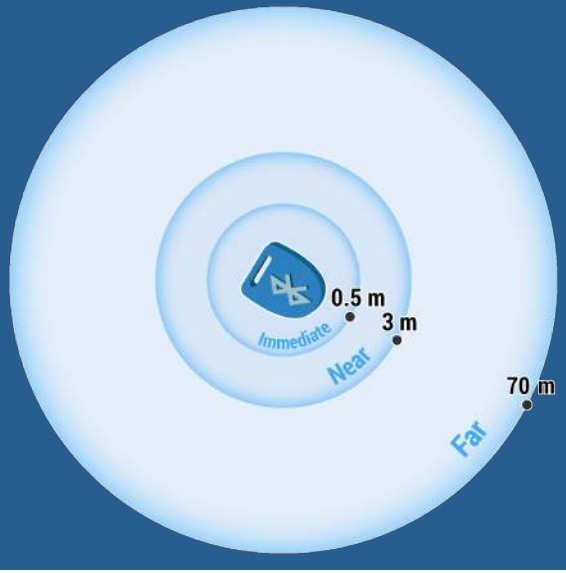
- Regions = UUID + major + minor, UUID + major, or UUID only.
- Ranging = Active scanning for regions (beacons)
  - No limit on # of regions that can be ranged
  - Ranging results in a list of beacons categorized into four *proximity zones based on RSSI*:
    - *immediate* (strong signal; usually up to a few centimeters)
    - *near* (medium signal; usually up to a few meters)
    - *far* (weak signal; more than a few meters)
    - *Unknown / Out of range* (usually when the signal is very, very weak)

Ranging = Scanning (Used in Wayfinding Apps)

Accuracy ≠ distance but….

- Immediate = centimeters
- Near = 1-3 meters
- Far = 3+ meters
- Unknown = not enough data to determine proximity





Back

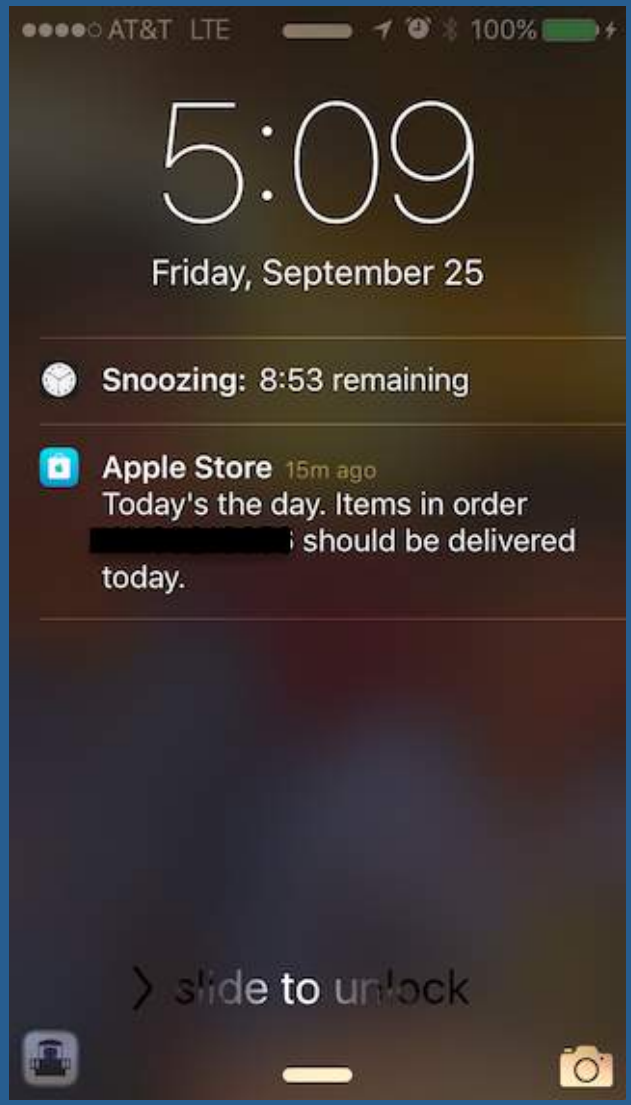
Scan

Scanning for active UUIDs from the UUID and SoftBeacon list...
Turn your device for landscape sorting.

Name	UUID	Major	Minor	RSSI
	4152554E-F99B-4A3B-86D0-947070693A78	0	0	-93
AA Beacon	11111111-1111-1111-1111-222222222222	8601	251	-73

Notifications

- Apple Push Notification Service (APN)
  - Forwards notifications from third party systems to Apple devices
  - Eliminates need for app background service improving battery life and resource usage
  - Doesn't require app to be running
  - Works in lock screen mode
- Local Notification – doesn't require any connection through APN
- Notifications logged in Notification Center on Phone



Best Proximity Beacon Hardware?

- How to test quality of proximity beacon?
- How to evaluate best proximity beacon / solution for projects?
- Which WLAN vendors have proximity beacon solutions?
- I have no budget for beacons what are my options to get familiar with technology?

Factors For Selecting Beacon Hardware

- Proximity Spec: iBeacon, EddyStone, multiple
- Functions: temperature sensor, light sensor, motion
- Cost: hardware investment, battery, maintenance
- Performance: stable signal, chip antenna, external antenna
- Security: configuration secured, hardware lock
- Deployment: mass configure, pre-configured
- Management: central manager, app manager, device status
- Integration: developer tools
- Certification: FCC, Bluetooth SIG, Apple, Google

Beacon Hardware - $$

http://www.aislelabs.com/reports/beacon-guide/

Beacon Testing

- Beacons just tiny low cost Bluetooth transmitters
  - Impacted by RF interference
  - Impacted by obstructions
  - Signal transmitted varies over time
  - Signal transmitted varies by orientation
- Compare Beacon Quality
  - RSSI at equal distance away vs. time
  - RSSI at equal distance away vs. rotating beacon X degrees
  - Accuracy – Immediate, Near, Far, Out of Range

Beacon Support Varies Per WLAN Vendor

WLAN Vendor	Solution
Aerohive	AP230 devices can be configured to be an iBeacon Transmitter and as an iBeacon Location Monitor using USB BLE dongle
Cisco Meraki	Cisco Aironet 3700 and 3600 Series, Hyperlocation Module Meraki MR32 and MR72 Integrated Beacon
HP/Aruba	Meridian Platform, Aruba USB Beacon, Aruba Battery Powered Beacon
Ruckus Wireless	ZoneFlex R710 indoor access point (AP) and ZoneFlex H500 have Gimbal hardware integration via USB port
Zebra (Motorola)	MPact Location and Analytics USB Beacon, Coin Battery Beacon, 2AA Battery Beacon

- Access points with integrated and “bolt on” Beacon/BT 4.0 adapters
  - Bluetooth detectors
  - Beacon health and configuration managers
    - Connect to beacons as a BLE Master
    - Monitor telemetry data from beacons
    - OTA Firmware updates
  - Beacon transmitters
  - Impact AP quantity and placement decisions (too many, too little, mounting considerations, location)

WiFi and Proximity Beacons

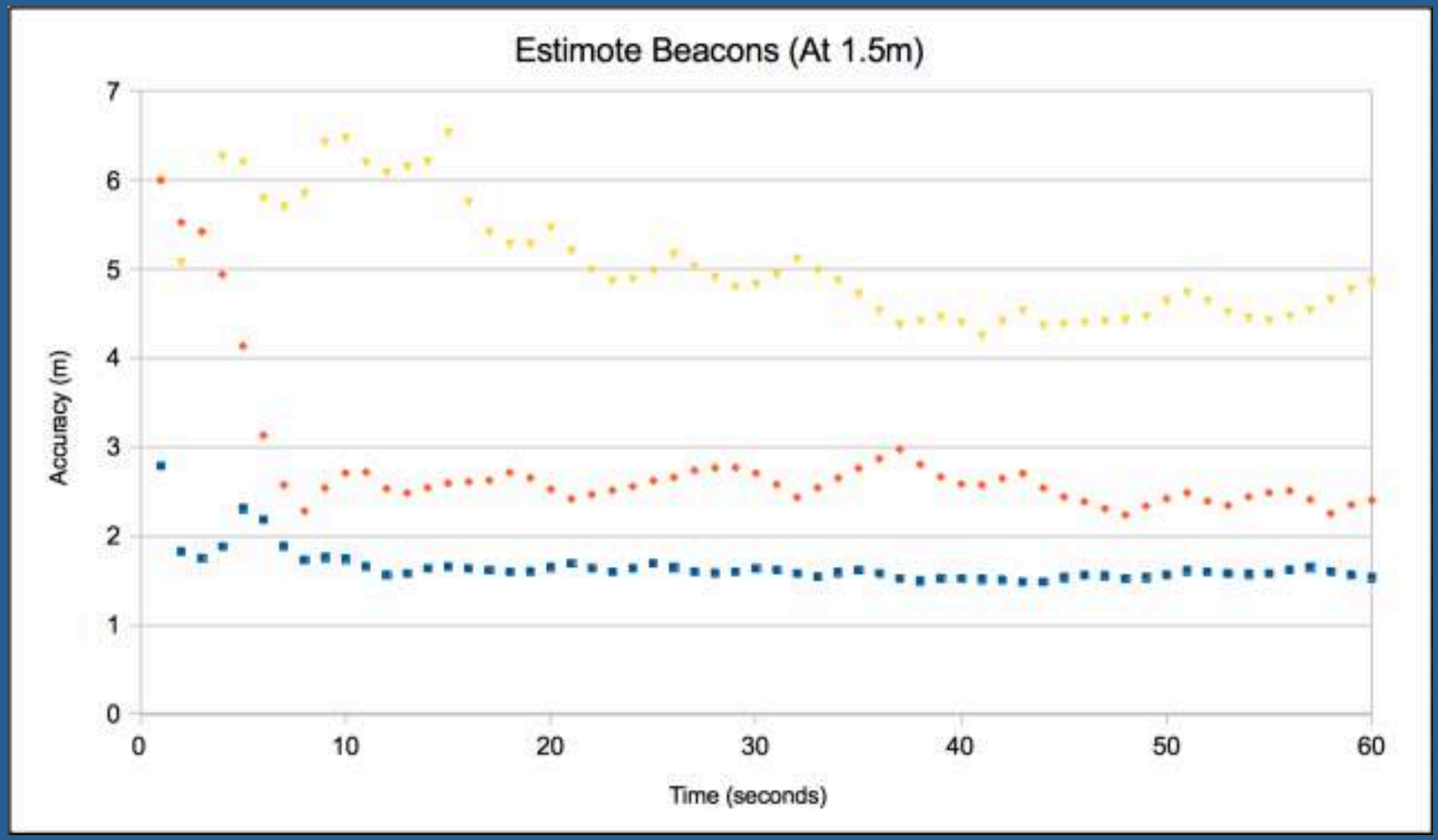
- BLE advertiser = proximity beacons do not interfere with 2.4 GHz WiFi by using channels that do not overlap with 1, 6, 11 and frequency hopping avoidance techniques
- Proximity beacon deployment process similar to WiFi
  - Research RF behavior of environment
  - Plan beacon location IDs and transmitter locations
  - Configure (beacon frequency, power, RSSI, UUID, major, minor)
  - Post install survey, continuous monitoring of beacons (signal , battery, failure)
  - Client/app testing

Summary

- BLE 4.0 has concept of advertiser, scanner, master, slave
  - Beacons are usually advertiser or slave role
  - In advertiser role beacons do not interfere with properly designed 2.4 GHz WiFi
  - In slave mode Bluetooth (BLE 4.0) uses FHSS interference techniques to reduce impact on/from other 2.4 GHz ISM technologies
- iBeacons is one of many types of proximity beacons
  - iBeacon, Eddystone, others
- Beacons don't know when they are detected
  - Beacons just advertiser/transmitter
- Beacons do not deliver content or trigger actions
  - Beacons require app for actions based on regions monitoring and ranging
  - Beacons are not full solution but just building block
- Beacon distance value is not always accurate
  - Depends on beacon interval
  - How often phone scans (monitoring, ranging)
  - Distance based on RSSI value without any knowledge of wall materials
- iBeacons are not secure or encrypted
  - Beacons can be spoofed
  - Beacons don't track users, apps track users

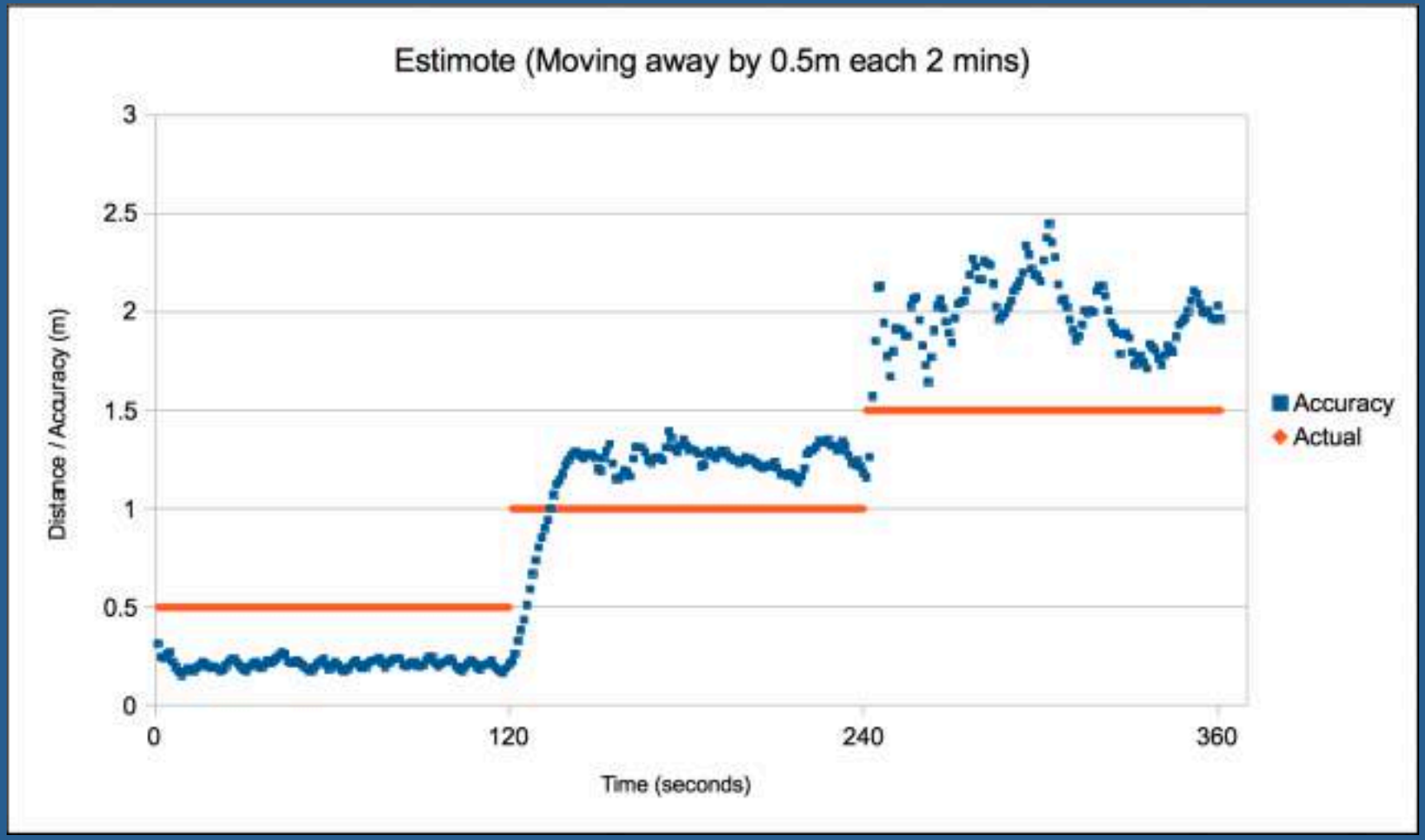
Backup

iPhone Accuracy Measurement vs. Time



http://blog.shinetech.com/2014/02/17/the-beacon-experiments-low-energy-bluetooth-devices-in-action/

iPhone Accuracy Measurement vs. Distance



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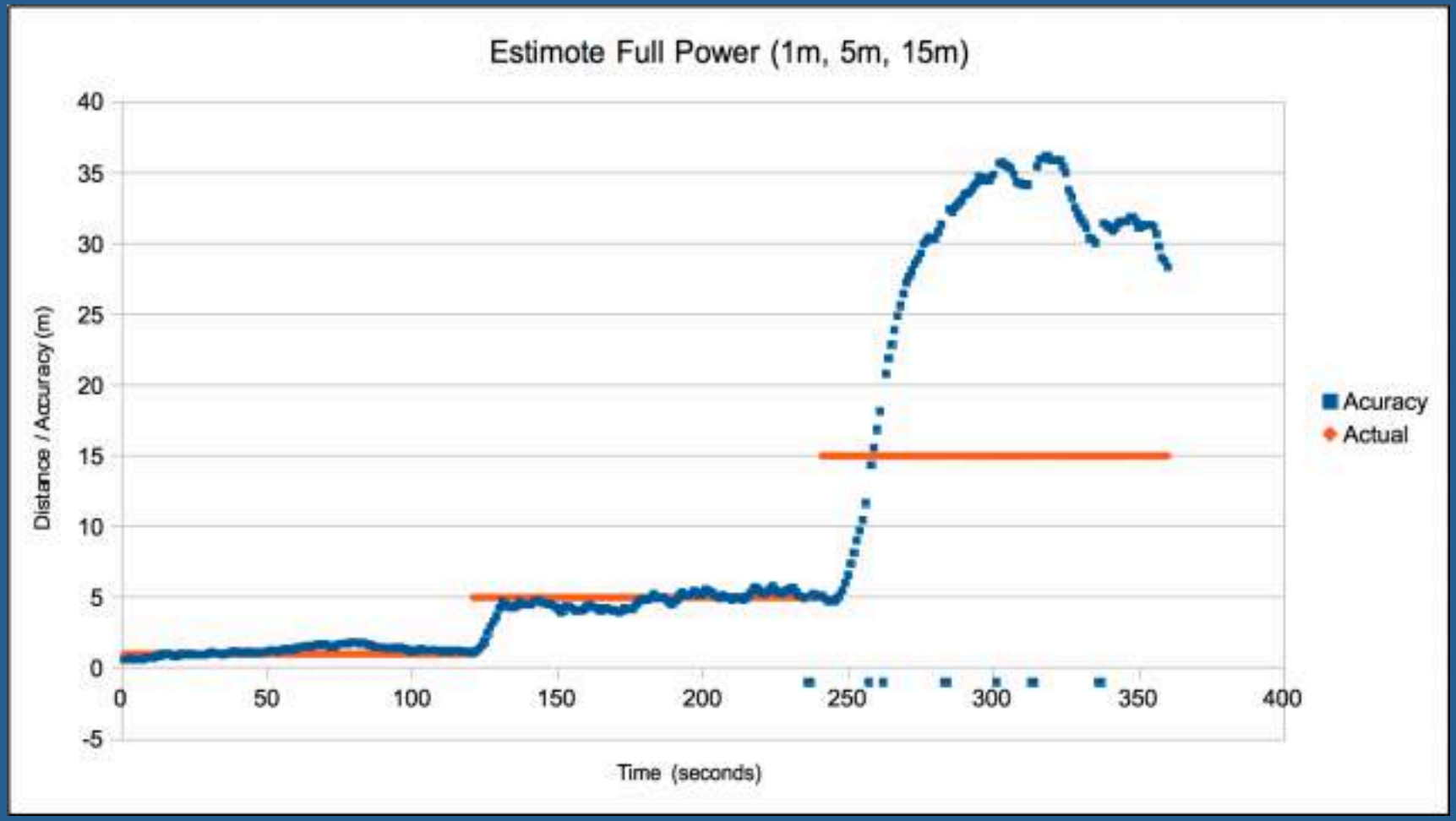
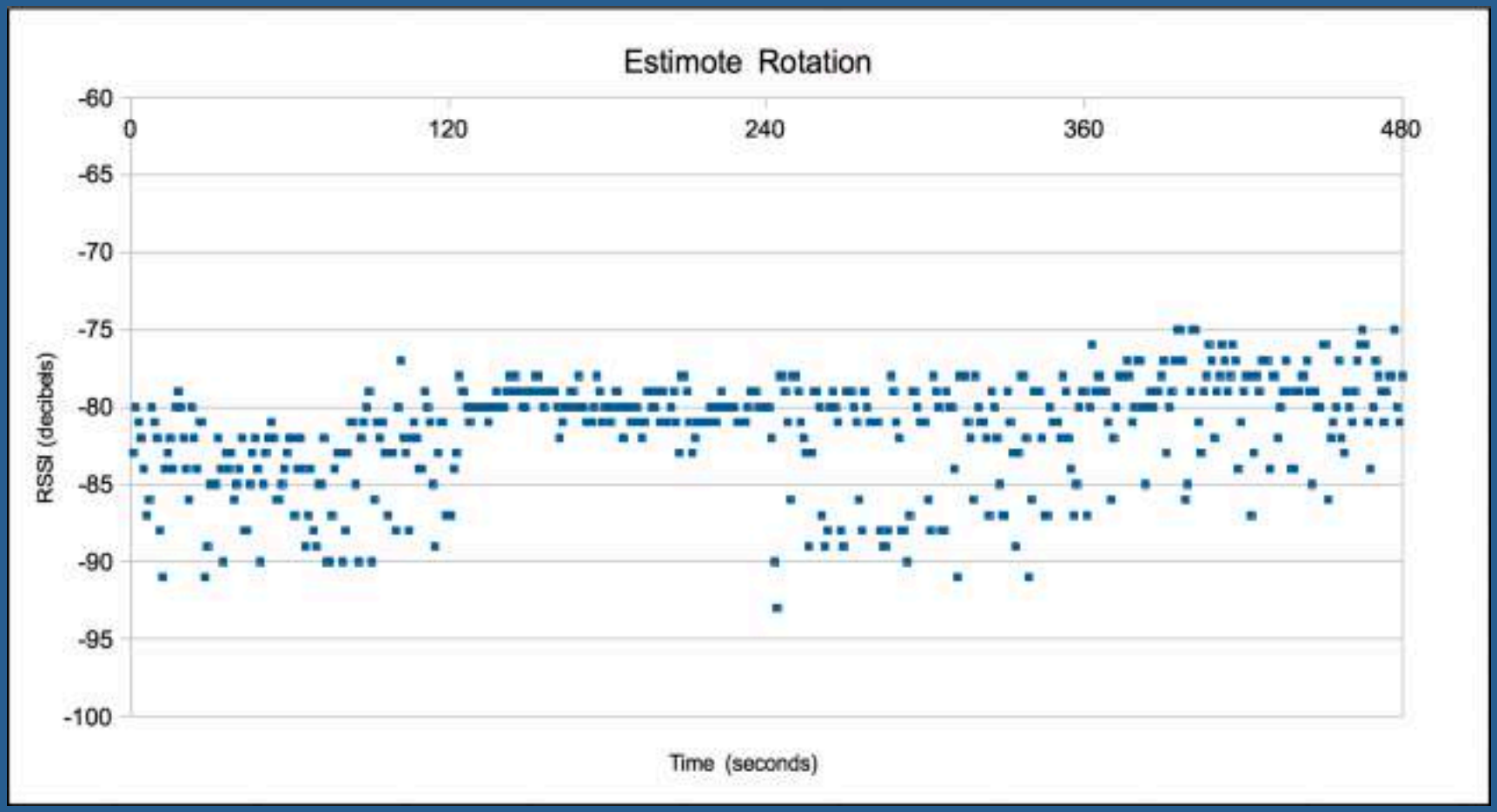
iPhone Accuracy Measurement vs. Distance (Beacon Full Power)



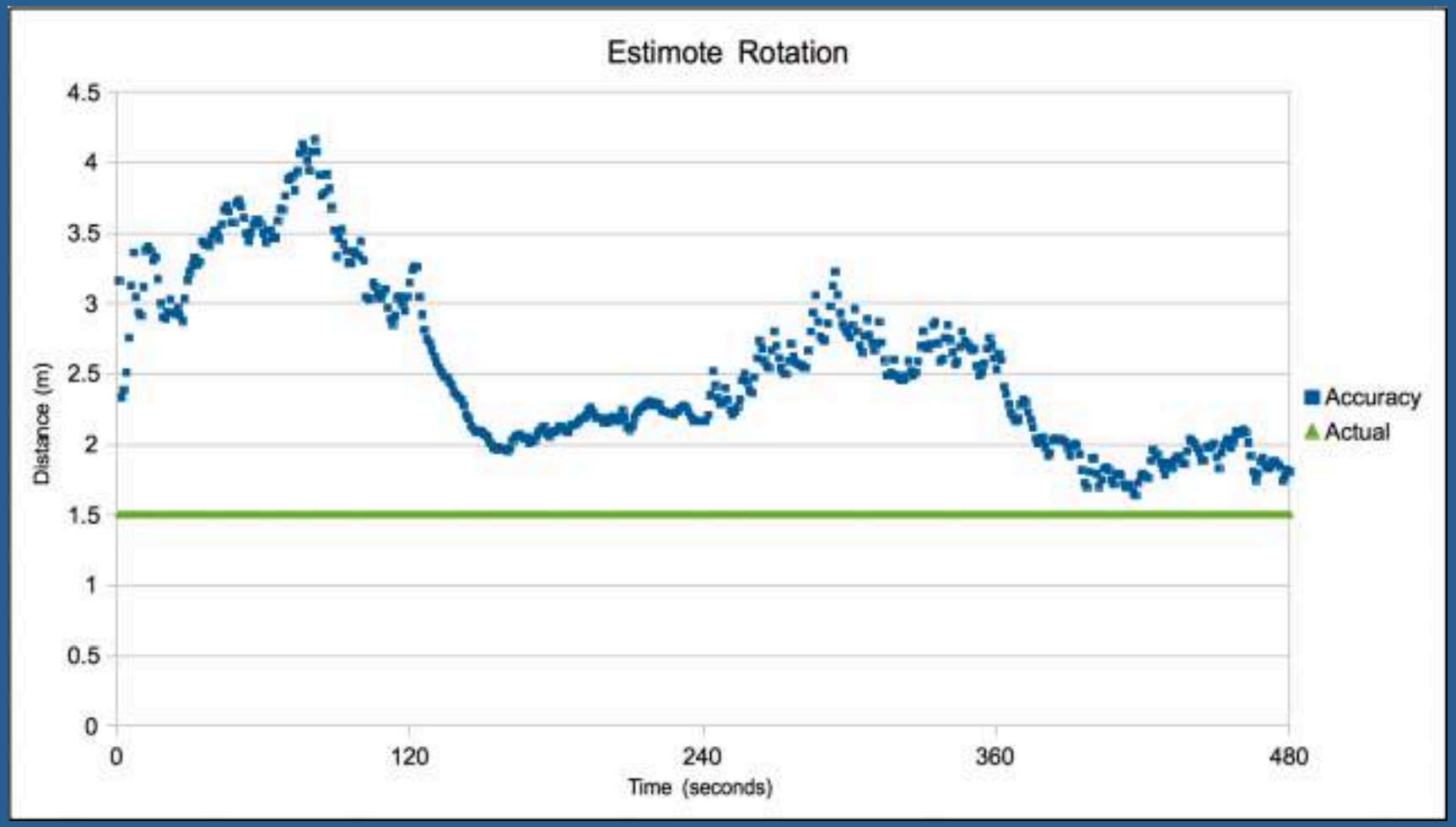
http://blog.shinetech.com/2014/02/17/the-beacon-experiments-low-energy-bluetooth-devices-in-action/

Beacon Rotation 90 Degrees Every 120 Seconds



http://blog.shinetech.com/2014/02/17/the-beacon-experiments-low-energy-bluetooth-devices-in-action/

Beacon Rotation



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