

Community RF Sensing

MySignals: A Community Geographical Information System (GIS)

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Thesis Purpose?

Where does he indeed “five by five signal?”
Που τελικά έχει «Σήμα Καμπάνα»;;;



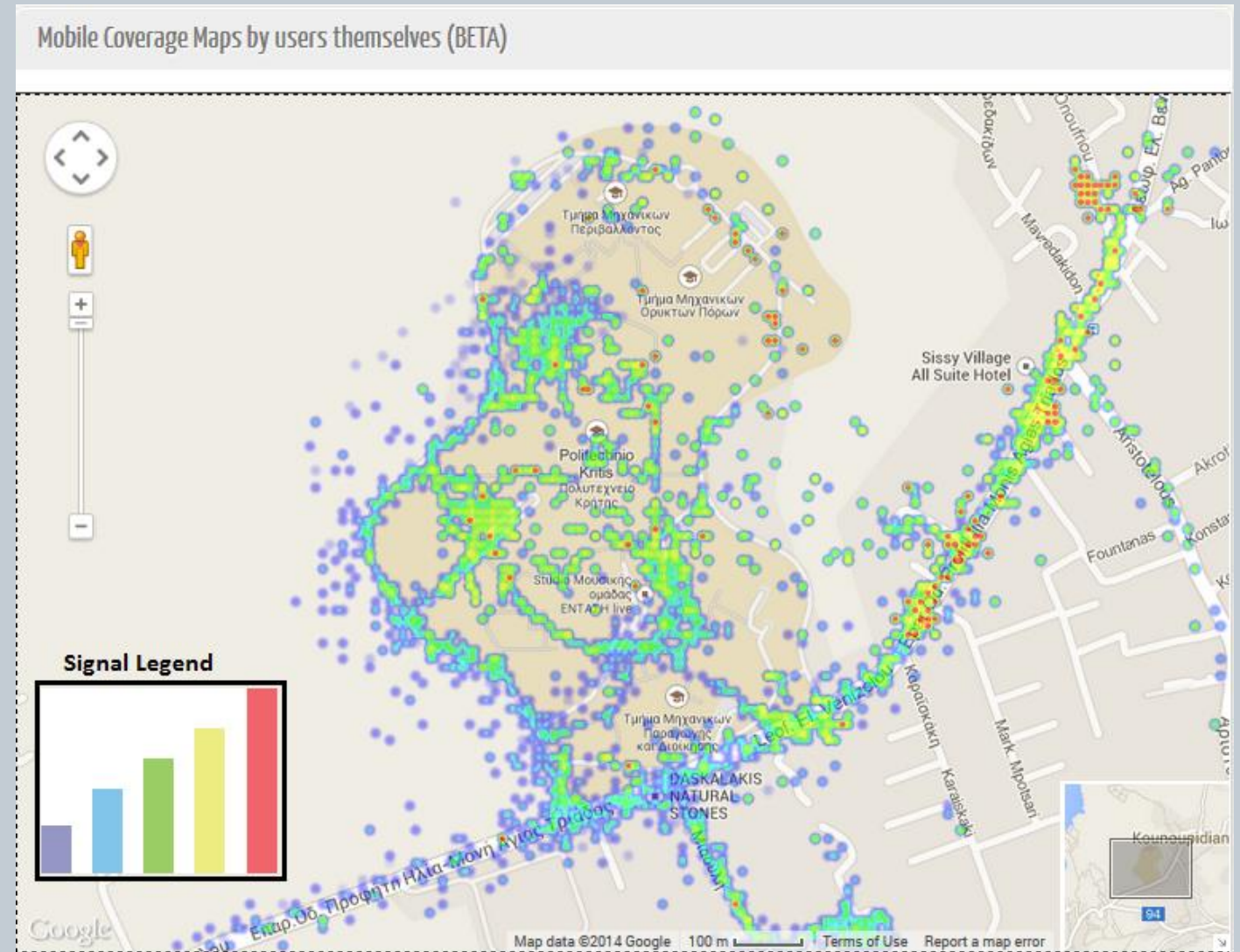
Source: Cosmote, Advertisement Campaign, 2010



THE BIG PICTURE

- How can we record mobile's signal quality per region?
- ✓ Using as a sensor for signal the user's mobile itself.

A mobile coverage map from user themselves:



Thesis Outline

1. Motivation, Contribution and Related Work.
2. Introduction to the Mobile Telephony.
3. Implementation: A Community Geographical Information System (MySignals GIS).
4. Evaluation of MySignals.
5. Conclusion, Ongoing and Future Work.



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Motivation

- Cellular Mobile Telephony: Over 4 billion users worldwide.

- In Greece everybody uses a Mobile Phone,
... but only a minority understands the basic principles of its operation!

- Necessity of Received Signal Strength (RSS) recording networks.
For Example:
 1. Cellular Telephony Coverage can be determined.
 2. Best Network Carrier can be chosen.
 3. Regions with Poor signal can be discovered .
 4. Network Carrier arrange the appropriate upgrades .
 5. Study Various Research Topics.



Scientific RSS Recording Networks



Hermes Project by NTUA and AUTH.

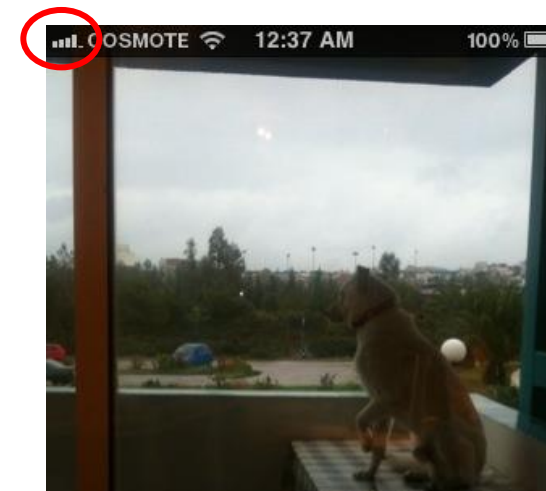
1. Fixed Measuring Stations.
2. Measures signal's power at whole RF Band.
3. Not Focused on creating Mobile Coverage Maps.



Source: <http://hermes.physics.auth.gr>

➤ How can a RSS-reading network be implemented for Cellular Telephony?

- Mobile Phone itself can be a sensor for RSS.
- Exploiting Smartphones Capabilities (GPS, RSS Indicator etc).
- RSSI: $y(dBm) = 10 \log_{10}(z/1mW)$



Implementation Platform: iPhone VS. Android



Source: www.blog.qarea.com

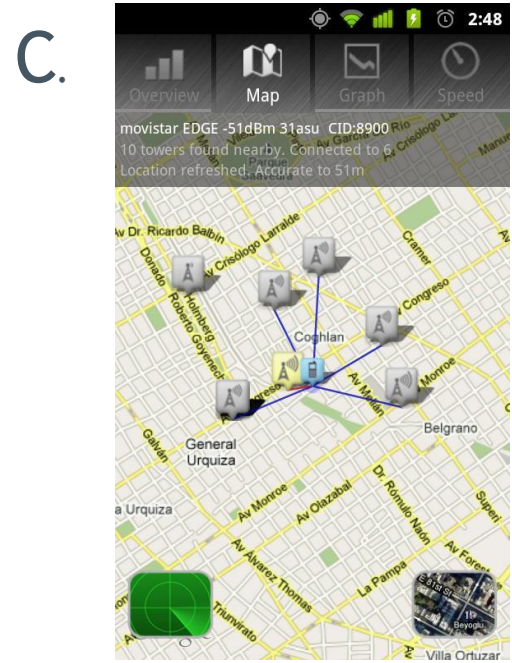
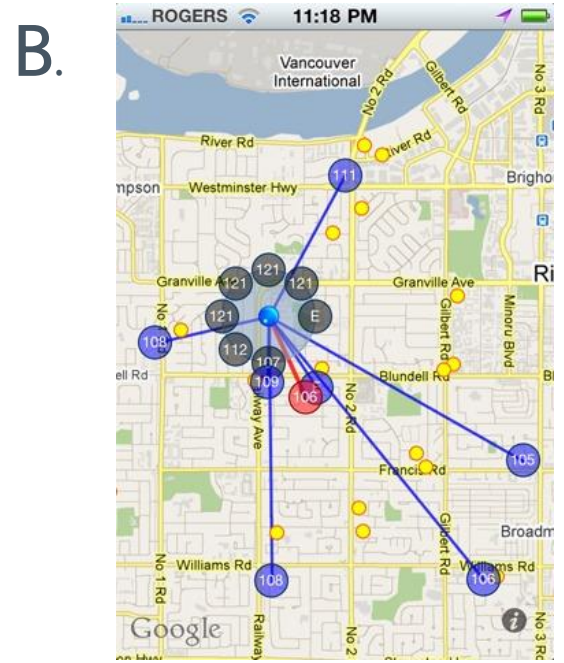
➤ ...Definitely iPhone

1. Everybody has an iPhone (250 million worldwide).
2. iPhone addiction is for real (according Stanford Survey).
3. **Great Challenge: Apple's restrictions.**
 - RSSI and Cellular Information are hidden to programmers.

Related Work



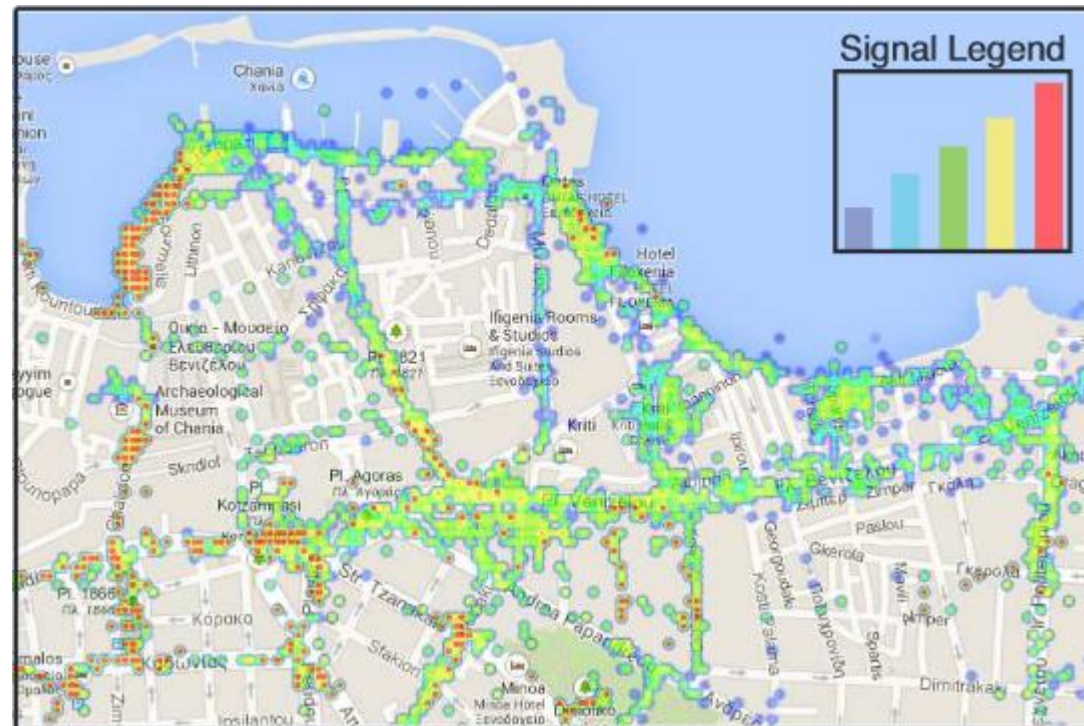
- A. Scientific RF observation Networks (Hermes, fasma program...).
- B. iPhone Signal, Cydia Store (...no mobile coverage maps).
- C. OpenSignalMaps, Android Store, www.opensignalmaps.com.
- D. Tawkon, Cellumap etc.



MySignals Contribution



- A. A Social, Informational and Educational Tool.
 - A Mobile Coverage Map by users themselves.
 - Users Understand Cellular Mobile Telephony Principles.
- B. A Scientific, Engineering and Research Tool.
- C. Most Important: The First RF Sensing Community from iPhone Users!



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Introduction to Cellular Mobile Telephony



- GSM (2G) Introduced in Europe in 1992
 - Global System for Mobile by ETSI (European Telecommunications Standards Institute).
 - Nowadays, adopted by over **4 billions users**.
 - 2G: only Voice Services.
 - 2.5G (GPRS/EDGE): Internet Cellular Data (up to 400kbits/sec)

- UMTS (3G) Introduced by 3GPP

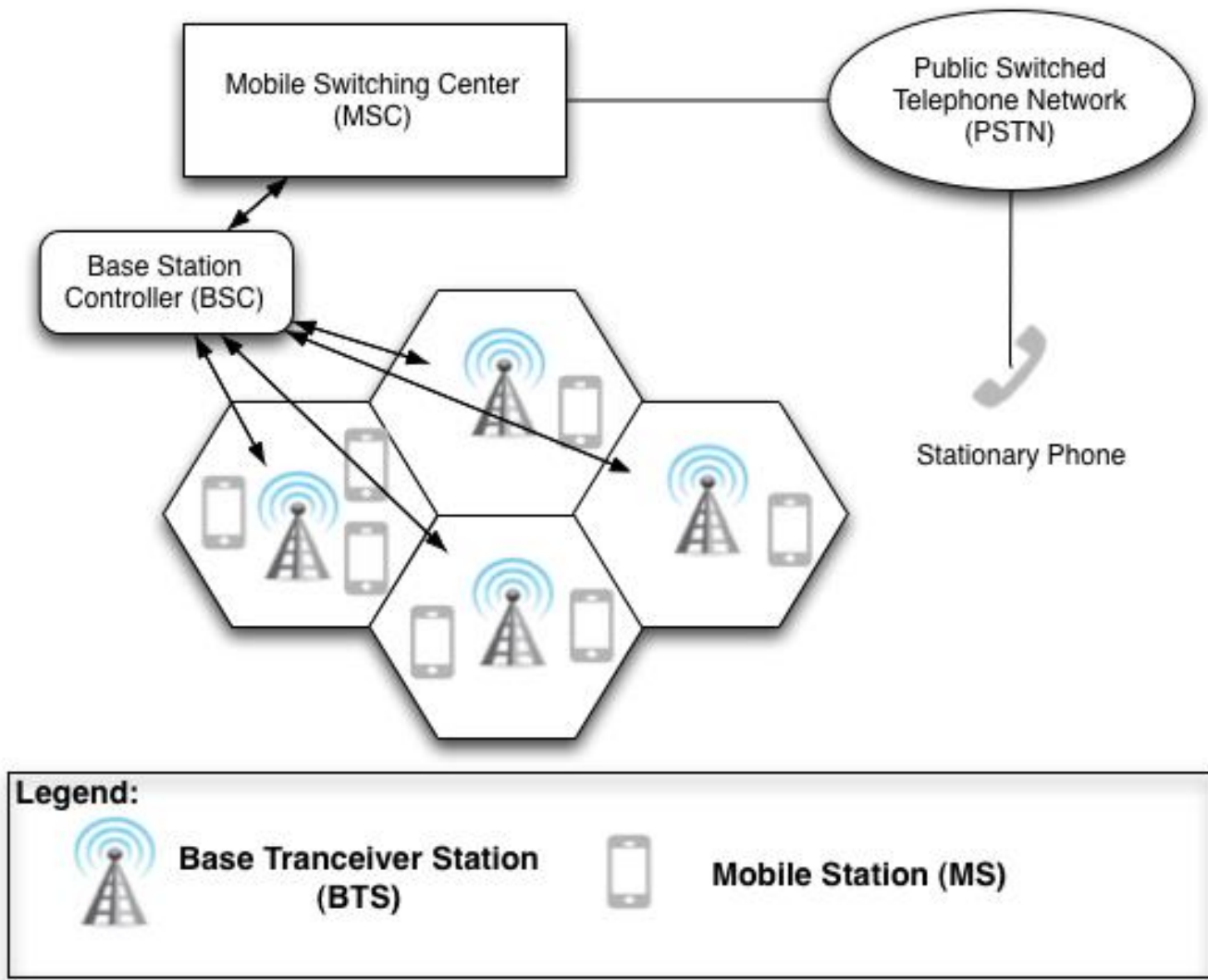
- Higher Data Rates
- Multimedia Services etc.

- The basic network structure is the same...





Source: www.eeae.gr

A Typical Cellular Telephony System (GSM or UMTS)



Legend:

	Base Transceiver Station (BTS)		Mobile Station (MS)
---	---------------------------------------	---	----------------------------

Smartphone iPhone



- Introduced in 2007
- Whole industry has adopted the iPhone patterns.
- **iPhone SDK (Software Development Kit)**
 - Cocoa Touch APIs (Application Programming Interfaces)
 - XCode IDE, Mac OS X, Objective C programming

- **Official App Store**

- Apple REJECTS private APIs



Source: Apple

- **Unofficial Cydia Store**

- Everything is allowed after Jailbreaking.



Source: cydia.saurik.com/

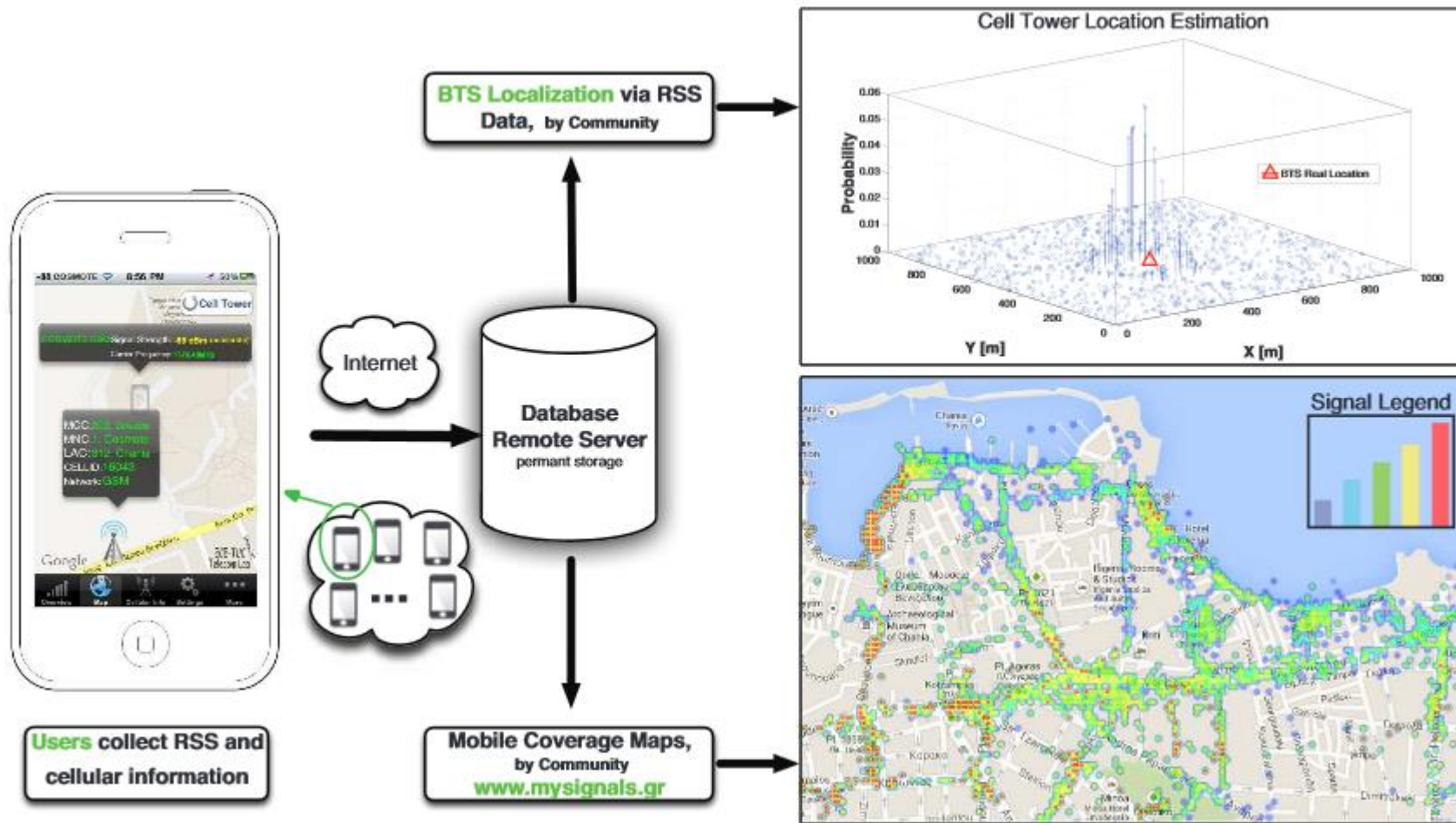
- Deploying Apps bypassing paid Apple Developer program.

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Community GIS: Software Components Overview

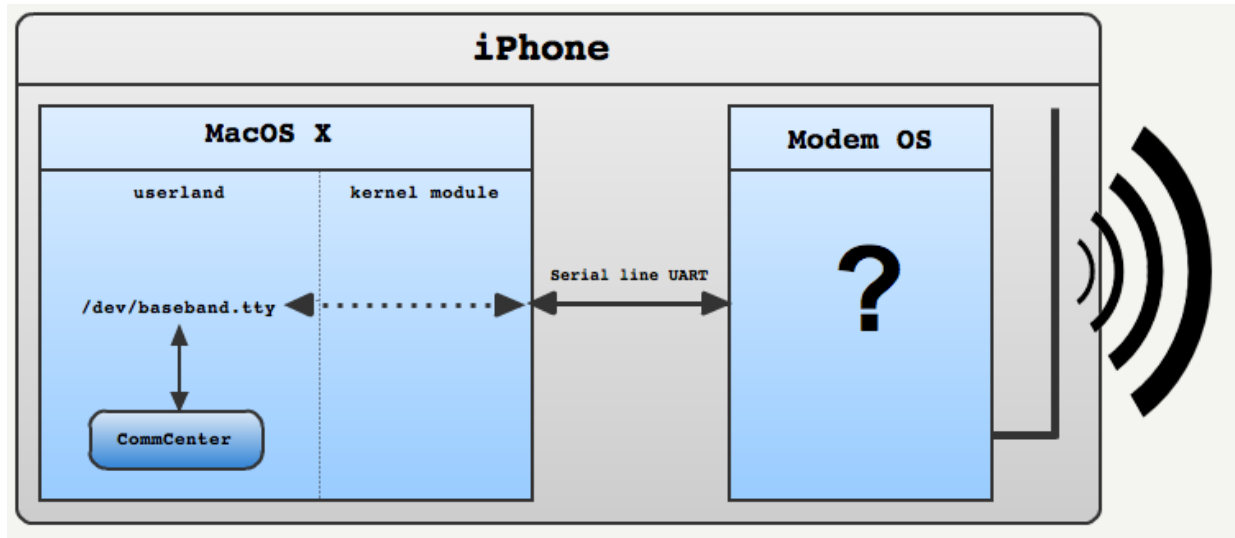


MySignals iPhone: Access Cellular Information?



- Apple does not include Field Test Information to official SDK!
 - How these restrictions were bypassed ?

1. Querying AT Commands to iPhone's modem.

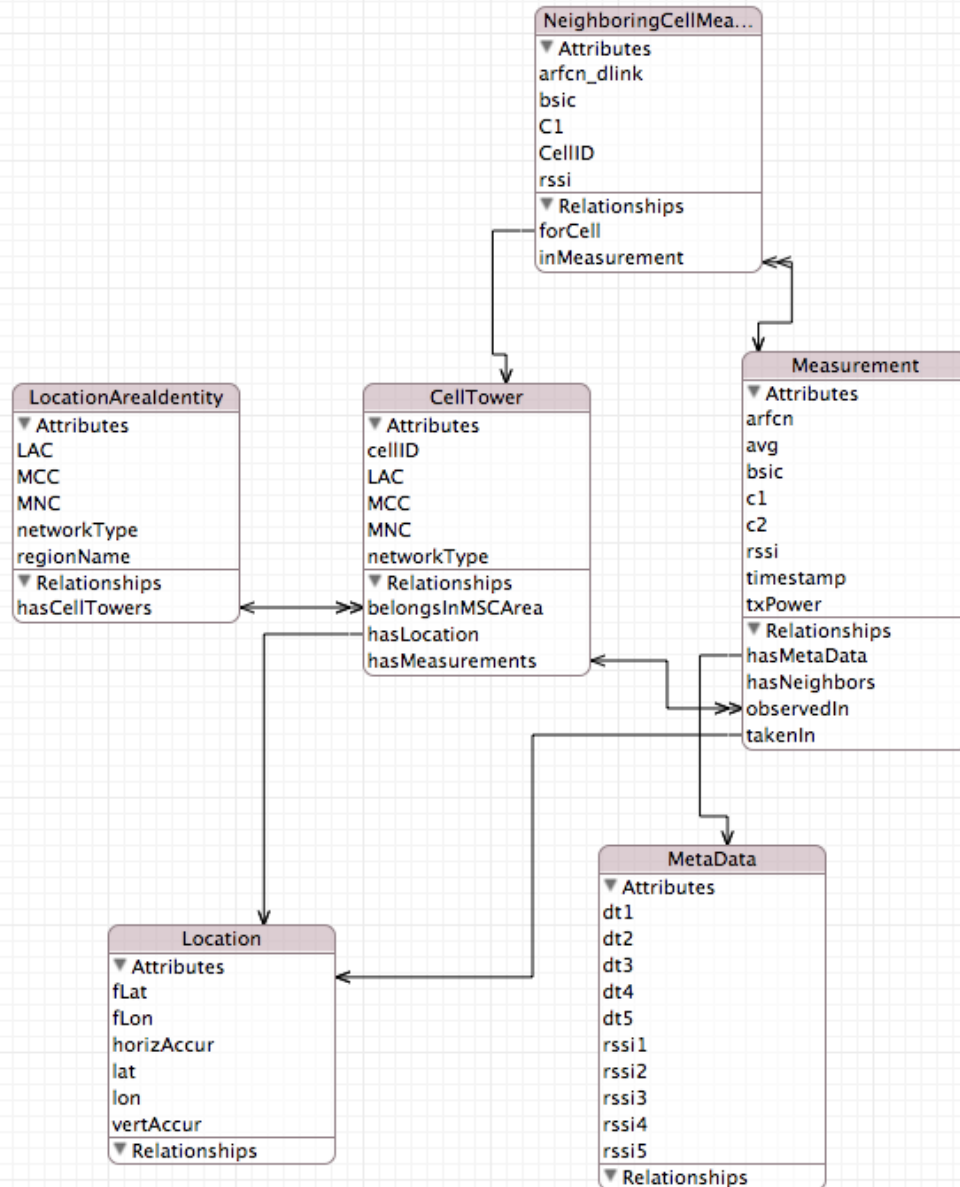


- "AT+CSQ": gives RSSI
- "AT+CGED=0": Cellular Info.

Source: not available any more

2. Using iOS private APIs.

MySignals iPhone: Measurements Saving



- Core Data: An SQLite (DB) Wrapper
- Saves measurements locally.
- What is recorded?
 - 1) RSSI and Transmit Power.
 - 2) Network Type (RAT).
 - 3) Mobile Network Carrier (MNC).
 - 4) cell-ID, LAC (Location Area Code).
 - 5) ARFCN (Absolute Radio Frequency Channel) .
 - 6) ARFCN provides **uplink** and **downlink carrier frequencies**.
 - 7) Mobile's **coordinates** using a-GPS.
 - 8) Timestamp (for time analysis)
 - 9) Several other Cellular Information details.



MySignals iPhone: Functionality (1/7)

- Most of the Field Test Variables are encoded
 - Data Interpretation Library implemented by MySignals!
 - GSM Technical Specification Sheets were followed
 - For example, RSSI (encoded in ASU) and ARFCN are encoded!

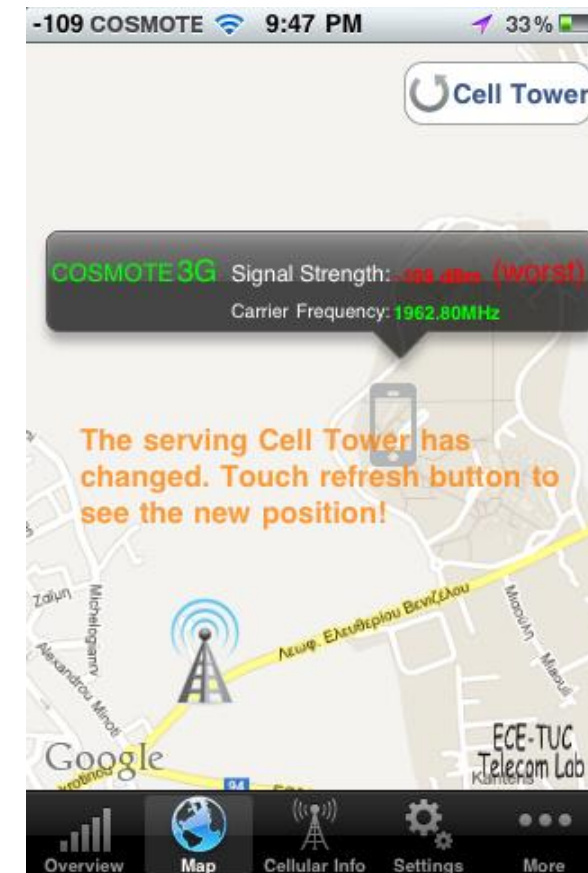
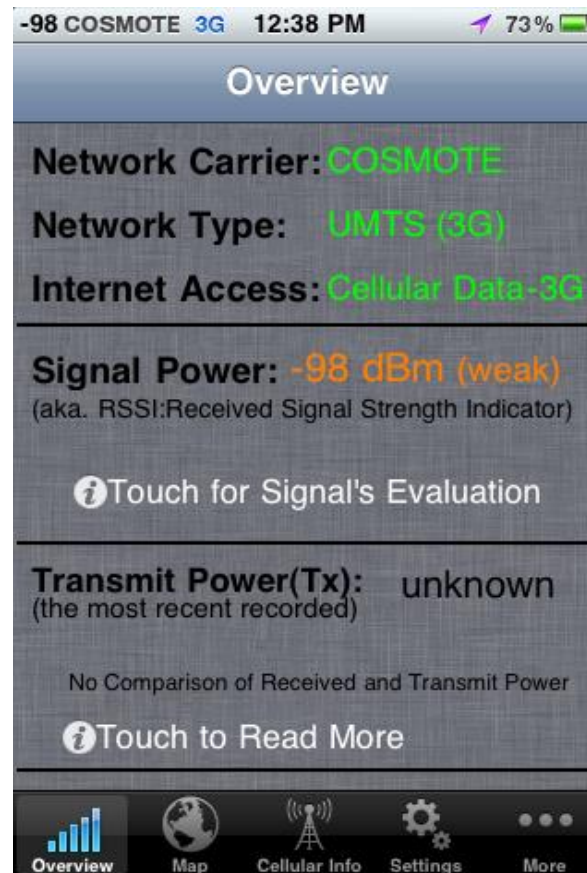
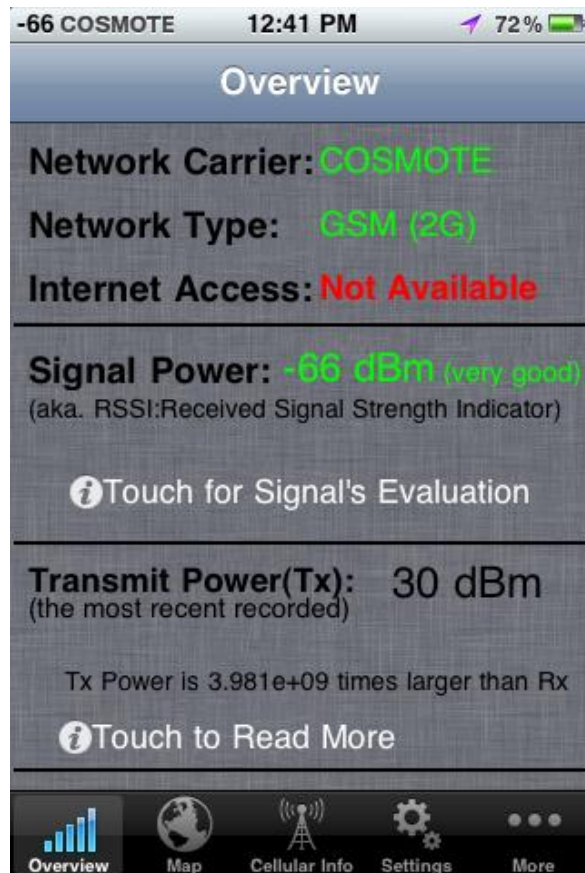
ASU	GSM Networks	UMTS Networks
Range	0 ... 31	-5 ... 91
RSSI formula	$RSSI(dBm) = 2ASU - 113$	$RSSI(dBm) = ASU - 116$
Unknown - not detectable	99	255
Notes	ASU encodes RSSI	ASU encodes RSCP which matches RSSI in UMTS.

	Uplink Frequency (MHz)	Downlink Frequency (MHz)
PGSM-900	$f_{UP} = 890 + 0.2ARFCN$	$f_{DL} = f_{UP} + 45.0$
EGSM-900	$f_{UP} = 890 + 0.2(ARFCN - 1024)$	$f_{DL} = f_{UP} + 45.0$
GSM-1800	$f_{UP} = 1710 + 0.2(ARFCN - 511)$	$f_{DL} = f_{UP} + 95.0$
UMTS-2100	$f_{UP} = UARFCN/5$	$f_{DL} = f_{UP} + 190.0$

MySignals iPhone: Functionality (2/7)



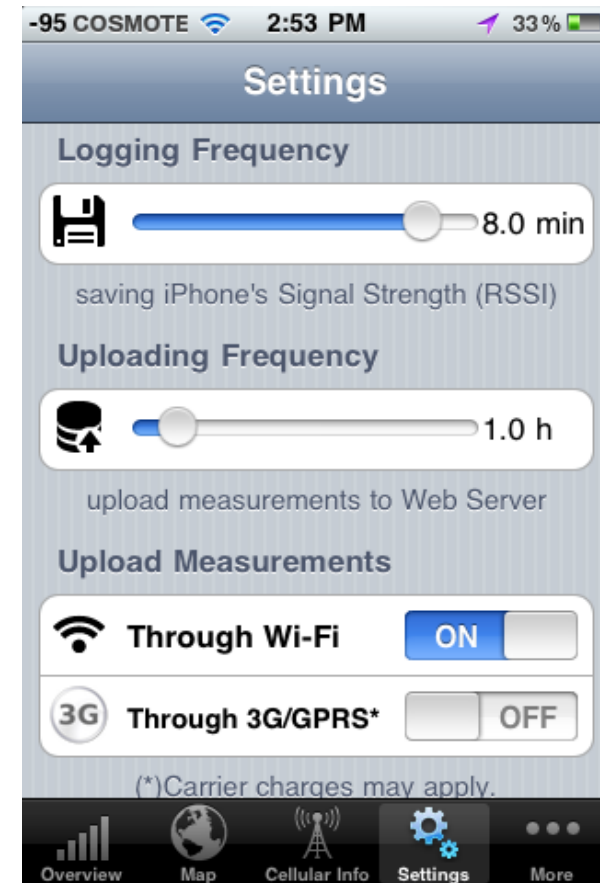
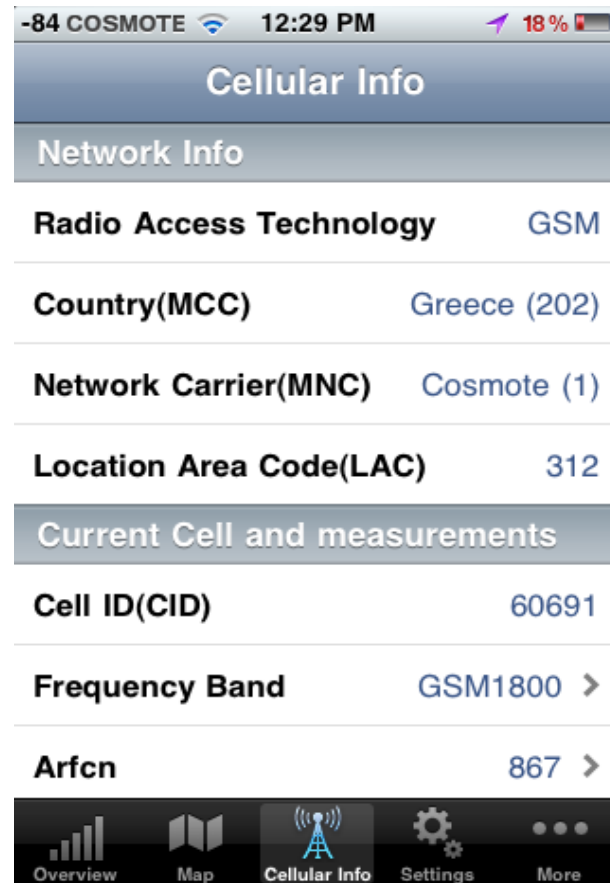
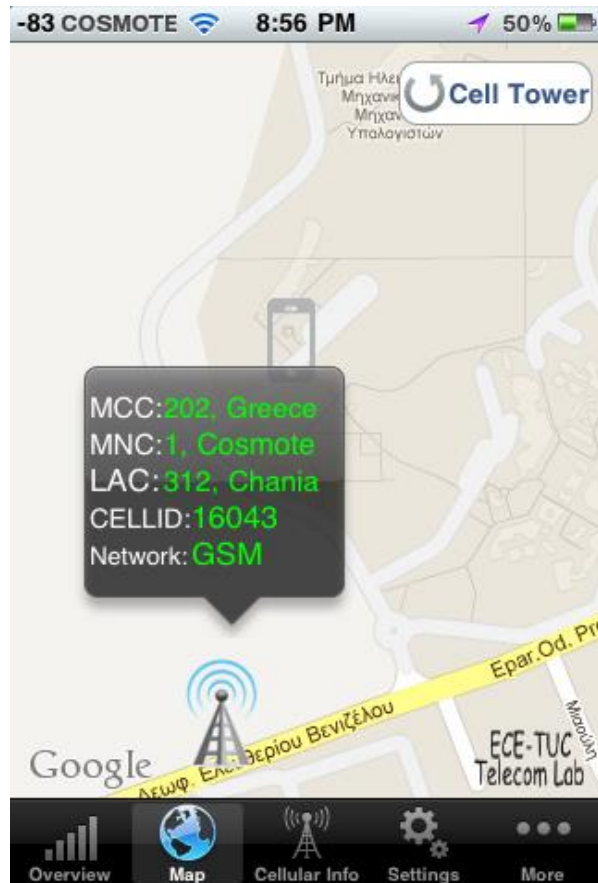
- Records and Saves Measurements
- While provides Cellular Information to the users!
- Users are informed for the quality of the providing mobile services.





MySignals iPhone: Functionality (3/7)

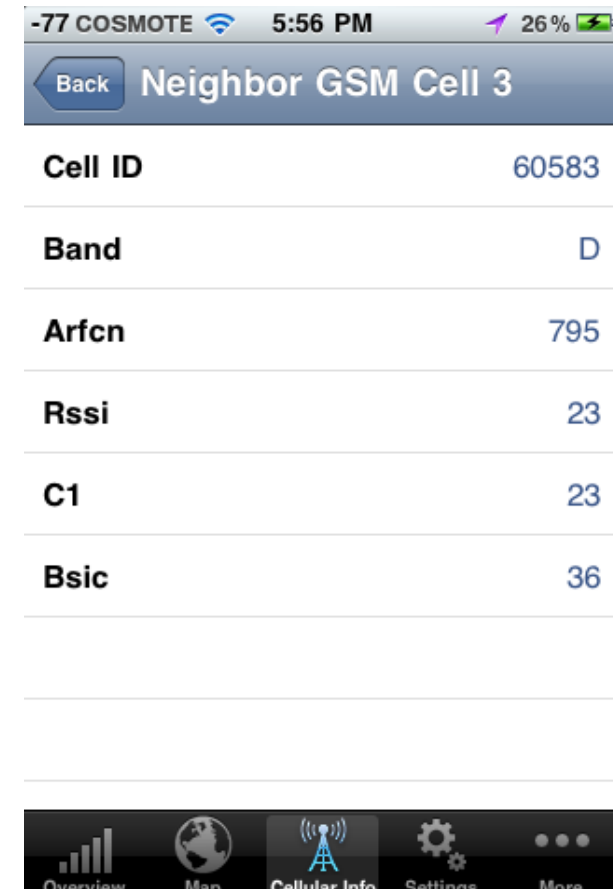
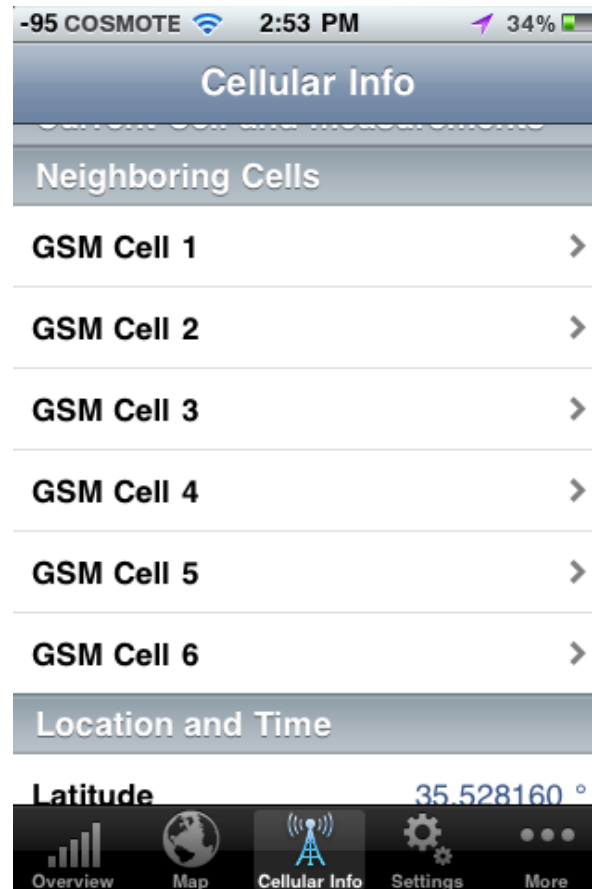
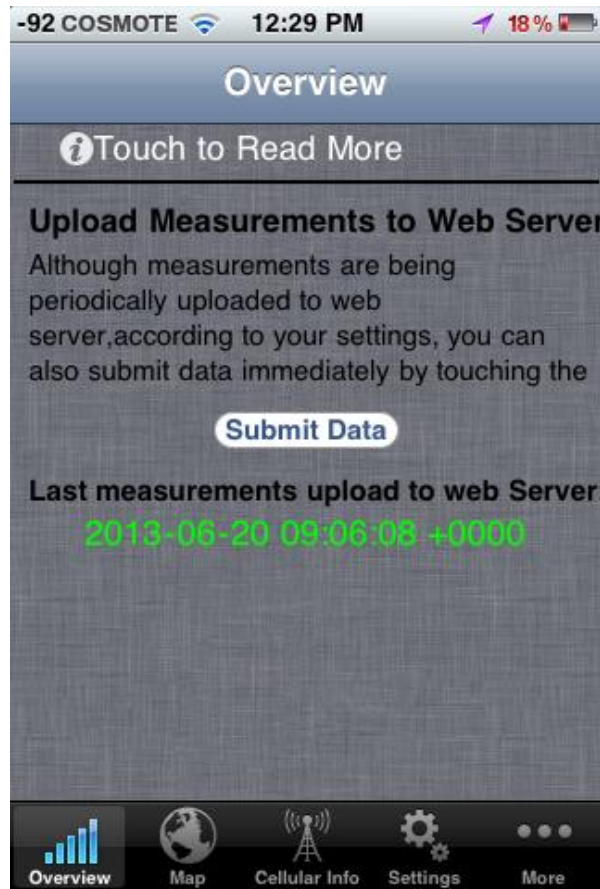
- Also a Cellular Information Screen is available: Engineering Oriented
- Users define measurements settings through an appropriate screen



MySignals iPhone: Functionality (4/7)



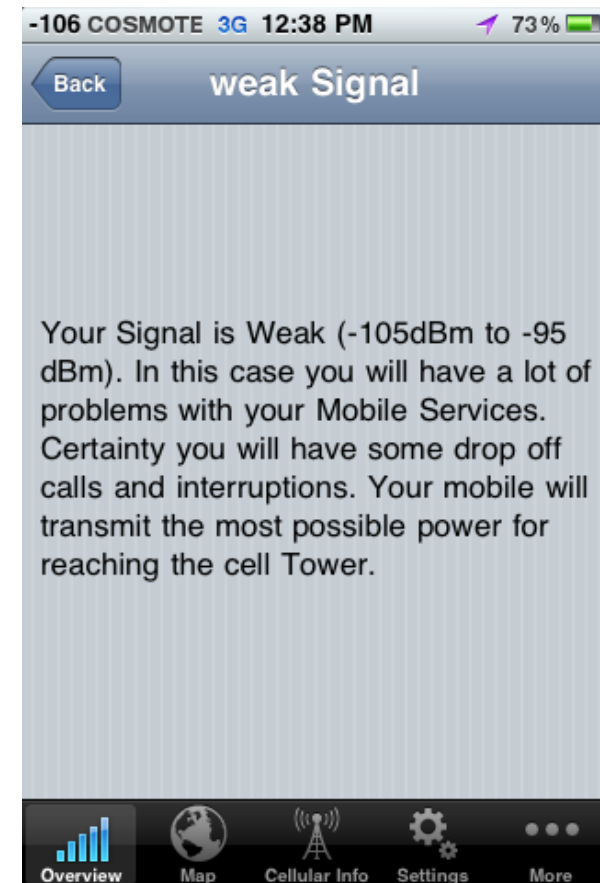
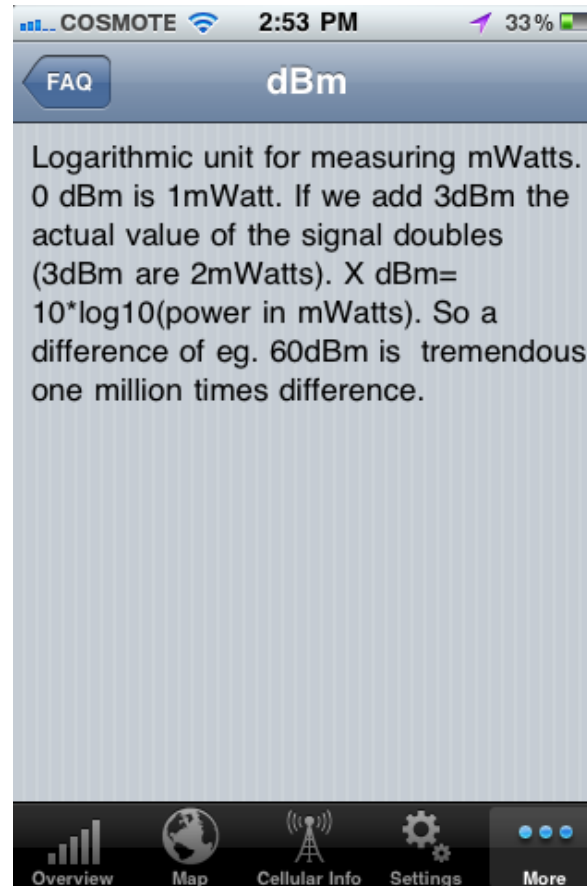
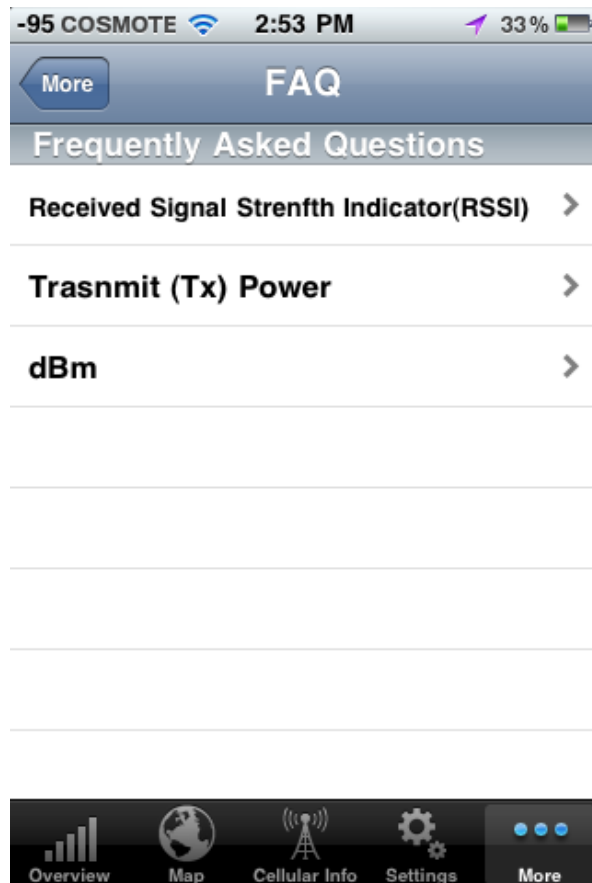
- Users can submit their measurements to MySignals web Server!
- At Cellular Info screen detailed information about GSM cells are available!



MySignals iPhone: Functionality (5/6)



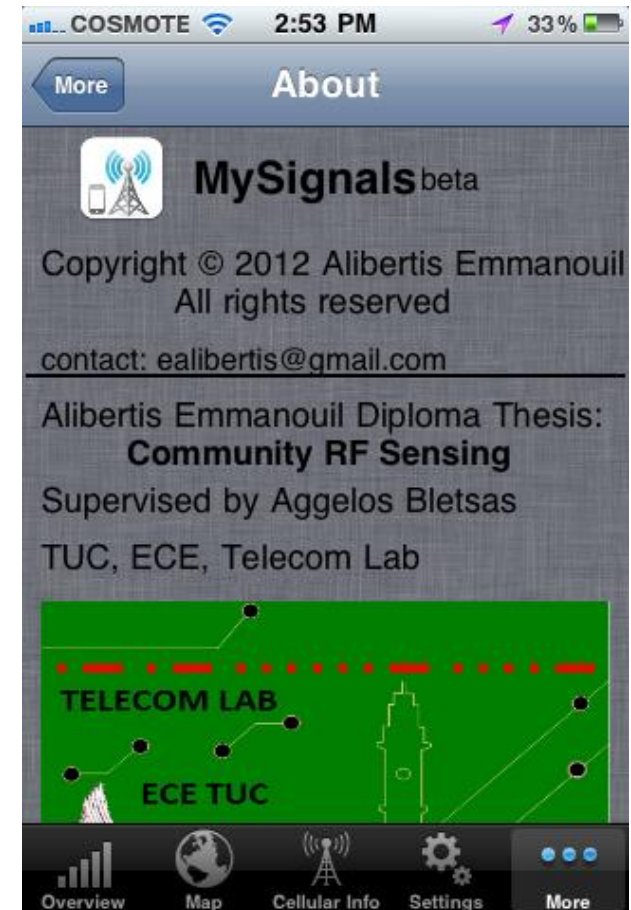
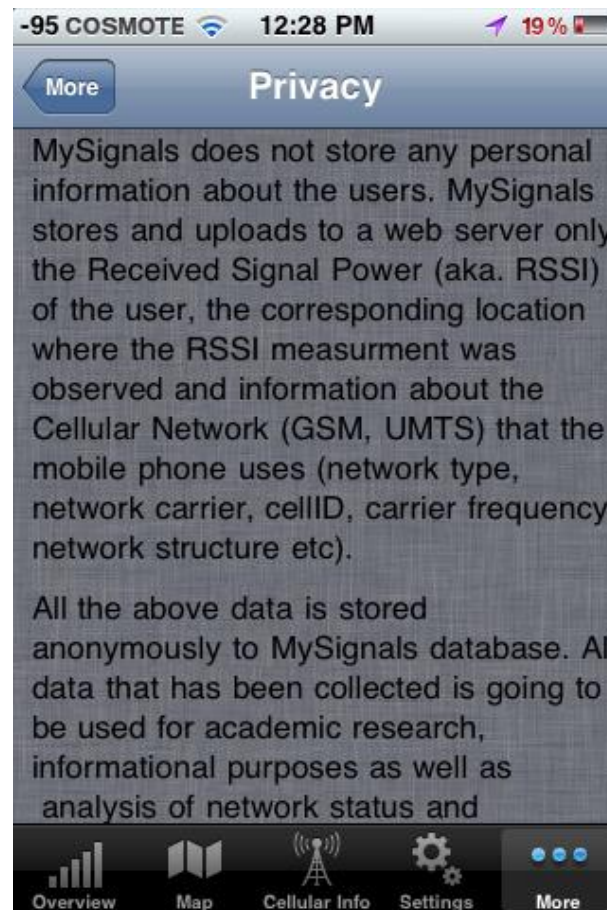
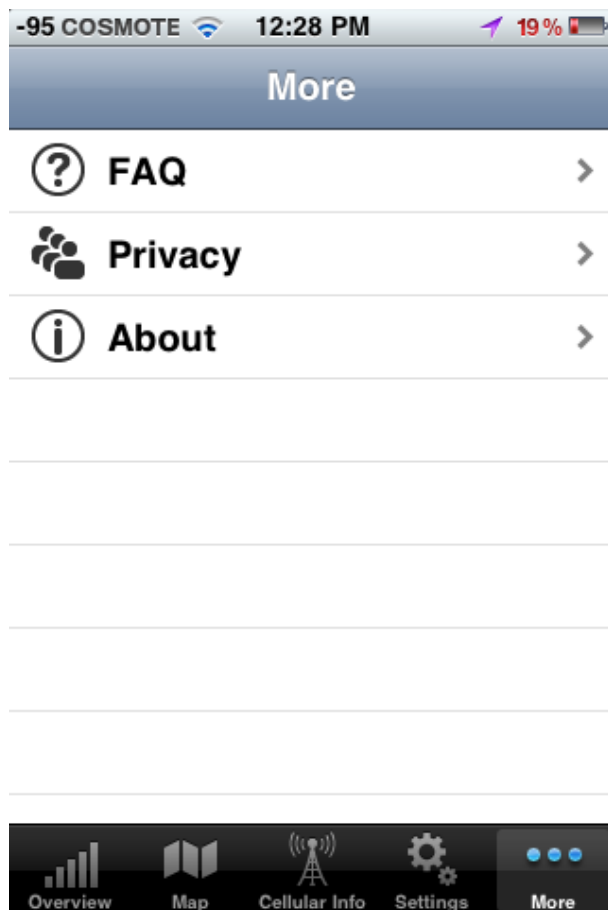
- User can explore and be familiar with mobile phone operation and parameters. (FAQ and explanation of Mobile terms)



MySignals iPhone: Functionality (6/7)



➤ More screenshots from the application!



MySignals iPhone: Functionality (7/7)



➤ More screenshots from the application!

-84 COSMOTE 12:29 PM 18%

Cellular Info

Current Cell and measurements

Cell ID(CID)	60691
Frequency Band	GSM1800 >
Arfcn	867 >
Uplink Frequency	1781.20 MHz
Downlink Frequency	1876.20 MHz
RSSI	-84 dBm
Transmit Power	No Transmission
Bsic	39

Overview | Map | Cellular Info | Settings | More

-92 COSMOTE 12:29 PM 18%

Cellular Info

Location and Time

Latitude	35.530990 °
Longitude	24.067309 °
Horizontal Accuracy	65.00
Vertical Accuracy	unknown
Timestamp	2013-06-20 09:29:25 +0000

System Info

iPhone Model	iPhone 3GS
iOS Version	4.2.1

Overview | Map | Cellular Info | Settings | More

-92 COSMOTE 12:29 PM 18%

Overview

Network Carrier: **COSMOTE**
Network Type: **GSM (2G)**
Internet Access: **Wi-Fi**

Signal Power: **-92 dBm (moderate)**
(aka. RSSI:Received Signal Strength Indicator)

Touch for Signal's Evaluation

Transmit Power(Tx): **unknown**
(the most recent recorded)

No Comparison of Received and Transmit Power

Touch to Read More

Overview | Map | Cellular Info | Settings | More



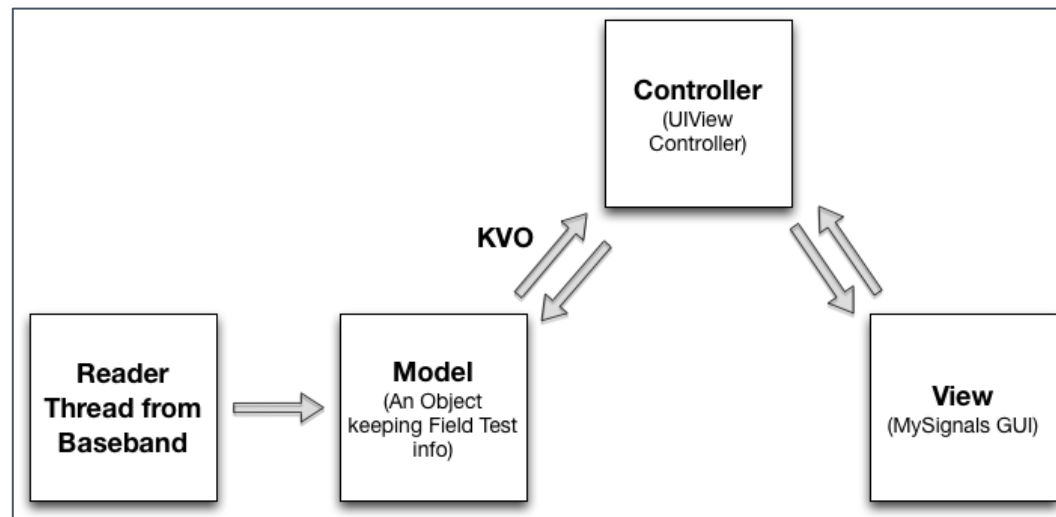
MySignals iPhone: Implementation Details

➤ Several implementation restrictions, concerning:

1. iPhone's Baseband.
2. Core Data.
3. GUI.

➤ Solution: Applying Model View Controller Pattern (MVC) and multithreading cooperation of operations to ensure:

1. Correct GUI Handling.
2. Code reuse.
3. Easy code upgrades.



An Overview of Supported models



	iPhone 3G	iPhone 3GS	iPhone 4	iPhone 4S/5
Baseband Chip	Infineon X-Gold 608	Infineon X-Gold 608	Infineon X-Gold 618	Qualcom MDM6610
Supported RAT	GSM/EDGE (850,900,1800,1900MHz) UMTS/HSDPA/HSUPA(4S) (850,900,1900,2100 MHz) LTE (4G) iPhone 5, CDMA models@USA			
Supported iOS	4.0 - 4.2.1	4.0 - 6.1.2		5.0.1 - 6.1.2
Field Test Mode (AT Commands)	SUPPORTED			<i>Not Supported</i>
CoreTelephony Private Callbacks	i)RSSI ii)cell-ID iii)MNC, MCC, LAC iv)RAT supported , iPhone 4S is currently under development			
Notes (socket etc.)	/dev/tty.debug		/dev/dlci.spi -baseband. extra_0	<i>Not Supported</i>

MySignals Web Server: Considerations



- For creating Mobile Coverage Maps:
 - 1: Upload Measurements to a central web server.
 - 2: Save them in a central MySQL Database.
- Upload direct measurements from iPhone to DB: **WRONG.**
- Implement an **intermediate Web Service** for inserting to DB.
- Data Packed with JSON (JavaScript Object Notation Format)
 - Inter-platform communication.
 - For example:

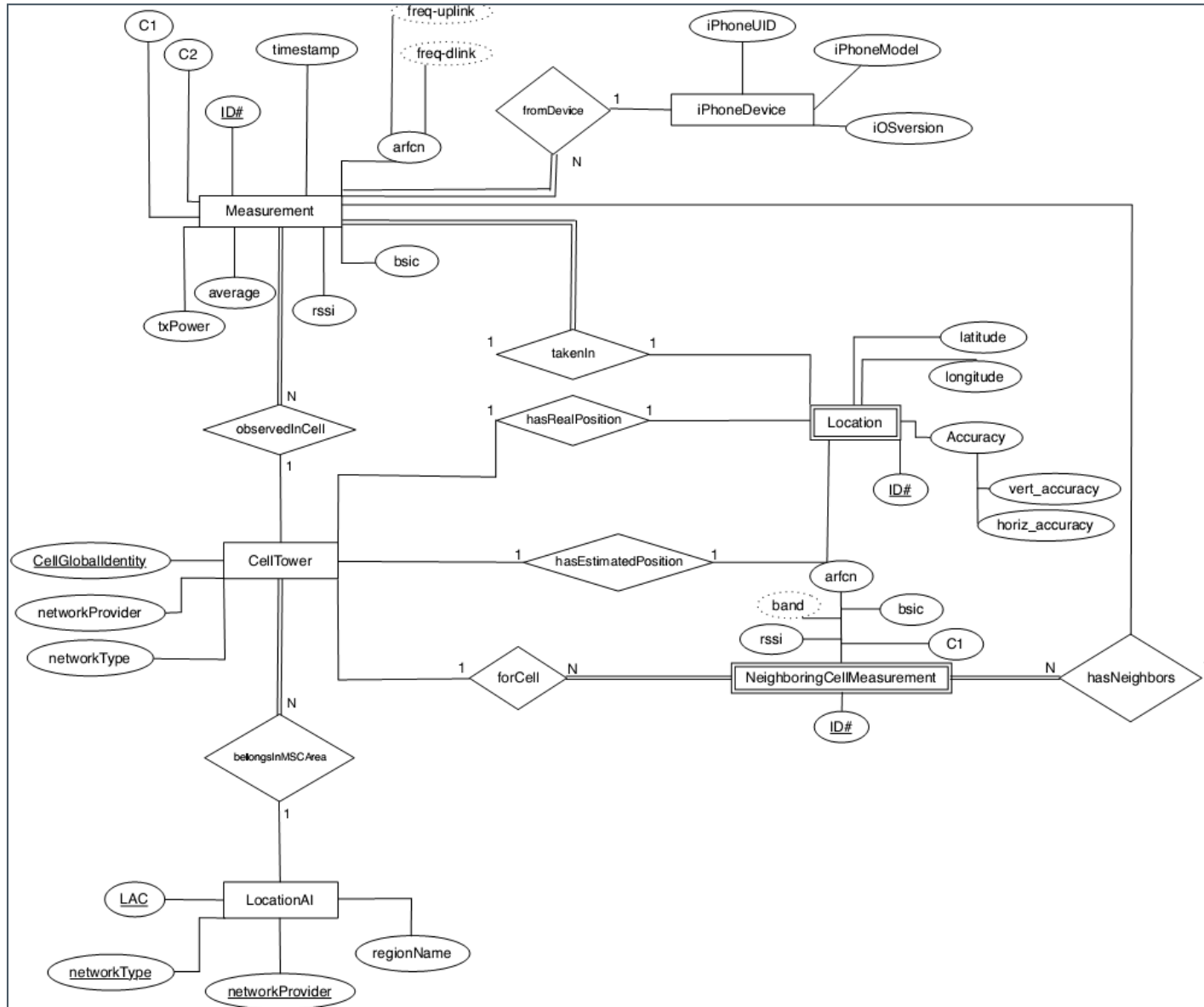
```
{  
  "MNC": 1,  
  "networkType": "GSM",  
  "hasCellTowers": [  
    { . . .
```

MySignals Web Server: upload from iPhone



- iPhone SDK does not convert JSON automatically.
- Our custom approach:
 1. Core Data Locks, new measurements waits in a FIFO.
 2. Convert Core Data Object Graph to NSDictionary.
 3. Convert NSDictionary to JSON string.
 4. Submit JSON string to the Web Server.
 5. Wait for the Web Server to respond for success or fail.
 6. Unlock Core Data, measurements insertions in FIFO Queue will served.
- Web Server: a PHP server
 - 1: Read JSON, data format is Straightforward
 - 2: Execute insertions to DB.

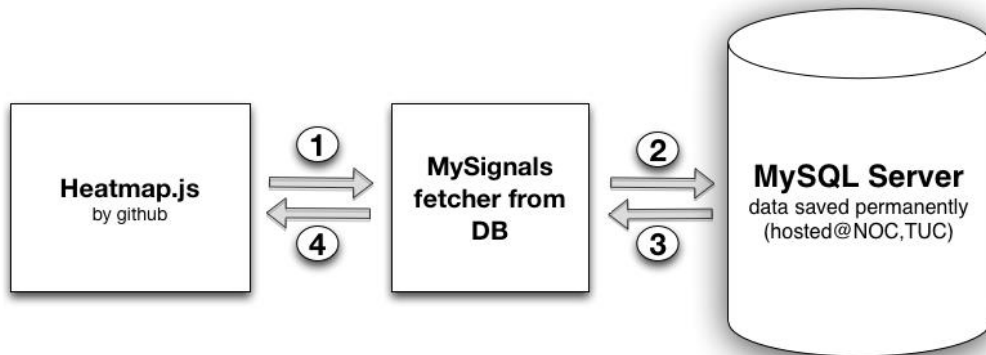
MySignals Web Server: ER Schema



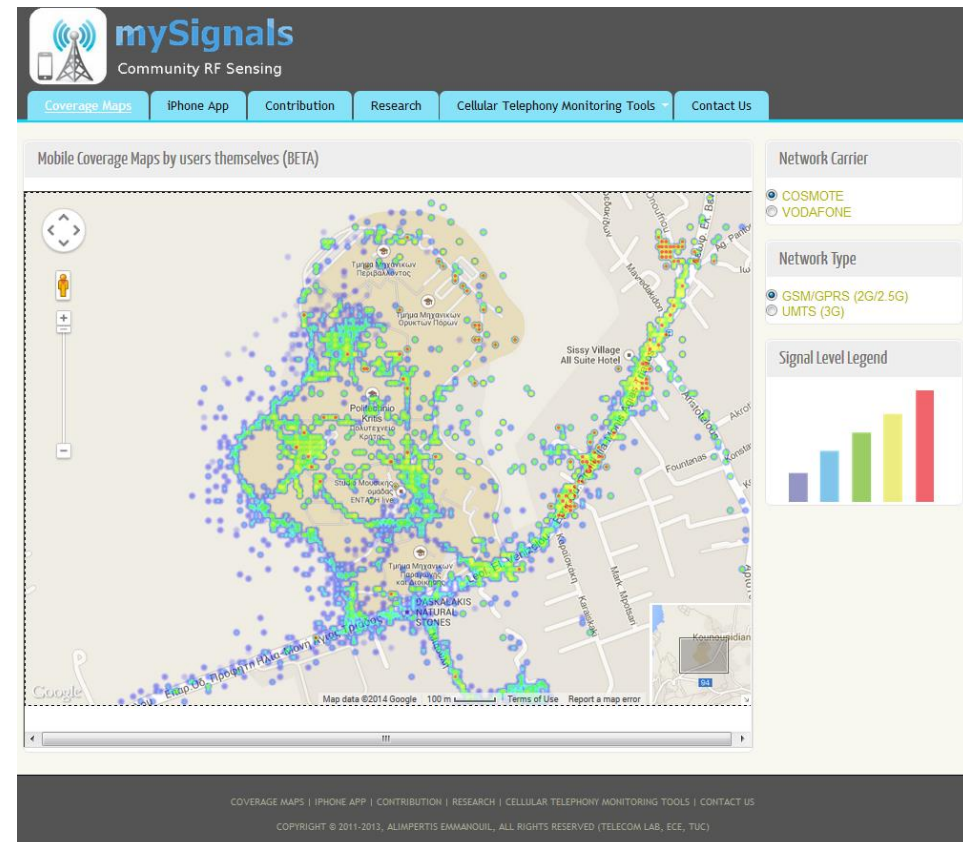
MySignals Web Site: Mobile Coverage Maps



- Intuitively display collected RSSI to their corresponding position.
 - Using color Coding -in other words: A Heatmap



<i>RSSI</i>	Qualitative Level	Color Coding
$RSSI > -55$ dBm	Best, Perfect Signal	Red
-55 dBm < $RSSI$ < -65 dBm	Excellent Signal	Yellow
-65 dBm < $RSSI$ < -75 dBm	Very Good	Green
-75 dBm < $RSSI$ < -85 dBm	Good Signal	Cyan
-85 dBm < $RSSI$ < -95 dBm	Moderate Signal	Open Blue
-95 dBm < $RSSI$ < -105 dBm	Weak Signal	Purple
$RSSI < -105$ dBm	Worst Signal	Transparent Purple



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MySignals GIS: Evaluation

- Deploying on Users an App which is accessing iPhone Hardware is a real hard process.
 - iPhone hardware fragmentation and iOS inconsistencies
- Measurements collected from seven users for over three weeks!
 - Thanks to the users, for draining their battery (iOS Restriction)

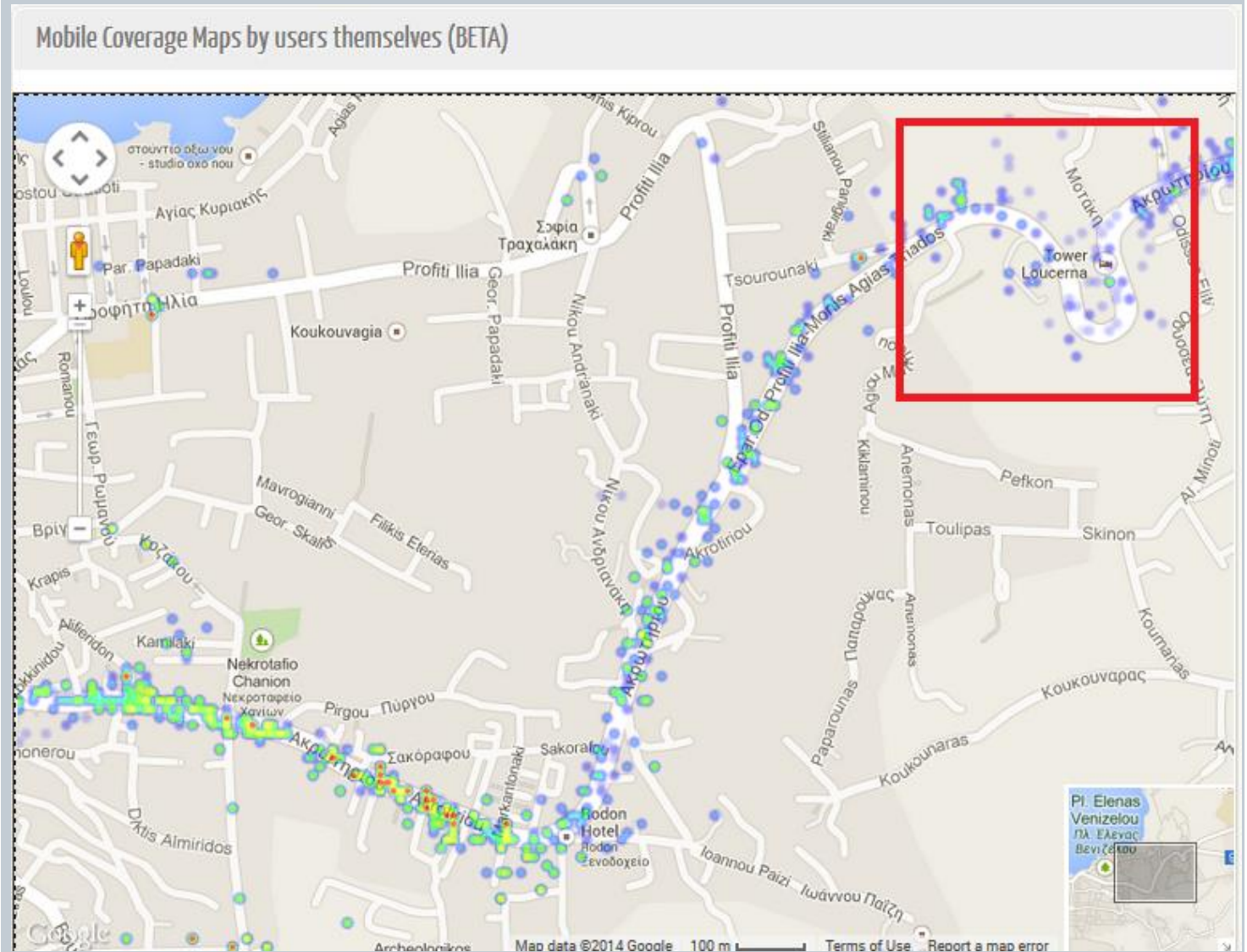
iPhoneUID	iPhone Model	iOS Version	Network Carrier
22223276 ...	iPhone 3GS	4.2.1	Cosmote
51063500 ...	iPhone 3GS	4.1	Vodafone
7023889b ...	iPhone 4	5.1.1	Cosmote
7cbc37da ...	iPhone 4	4.3.3	Cosmote
8fb4fd3d ...	iPhone 3GS	5.0.1	Vodafone
a841f74e ...	iPhone 3GS	4.2.1	Cosmote
bba30992 ...	iPhone 3GS	5.0.1	Vodafone

iPhoneUID	Network Carrier	No. Meas. (GSM)	% accepted <i>accur_{gps} < 450m</i>	<i>RSSI_{avg}</i> iOS API	<i>RSSI_{avg}</i> AT+CSQ
22223276 ...	Cosmote	4379	57.7%	-79.9 dBm	-76.8 dBm
51063500 ...	Vodafone	112	99.9%	-82.1 dBm	-76.5 dBm
7023889b ...	Cosmote	3713	75.9%	-79.3 dBm	-77.6 dBm
7cbc37da ...	Cosmote	11007	58.0%	-74.0 dBm	-72.4 dBm
8fb4fd3d ...	Vodafone	2030	68.0%	-93.8 dBm	-91.7 dBm
a841f74e ...	Cosmote	18773	82.3%	-77.8 dBm	-75.8 dBm
bba30992 ...	Vodafone	2407	94.8%	-75.5 dBm	-72.8 dBm
Total	42777 Measurements		72.5%	-77.9 dBm	-76.5 dBm

RSSI vs. Space

- Users asked to leave open MySignals while:
 1. Driving
 2. Being Outside
 3. For several hours at their home.
- Chania - Kounoupidiana Route:
 1. GPS Errors.
 2. Good or moderate signal at whole route...but, not at Akrotiriou Turns.

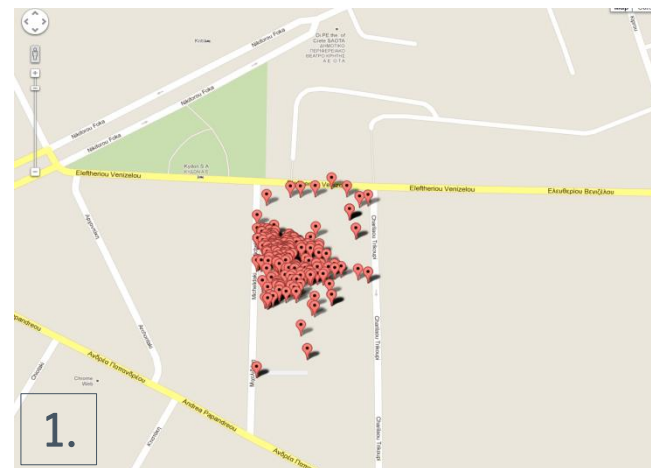
Poor Signal Discovered at Akrotiriou Turns



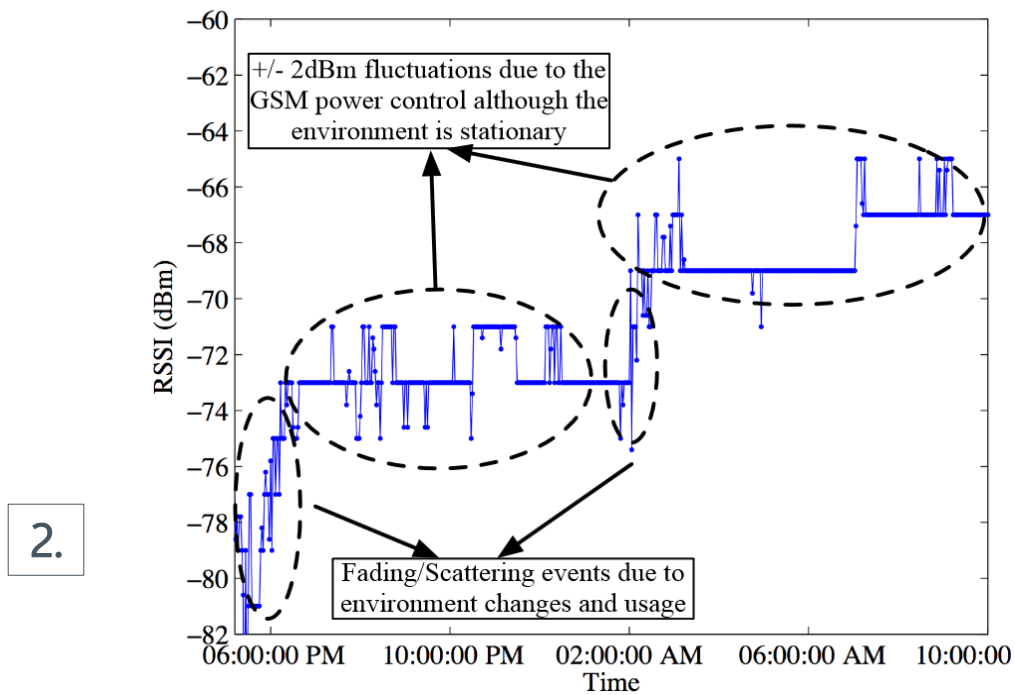
RSSI vs. Time



- Specific user at a fixed location.
 - Time Period: 06:00 PM– 10:00 AM (next day)
1. GPS Errors are perceivable
 2. Demonstration of GSM Control Power.



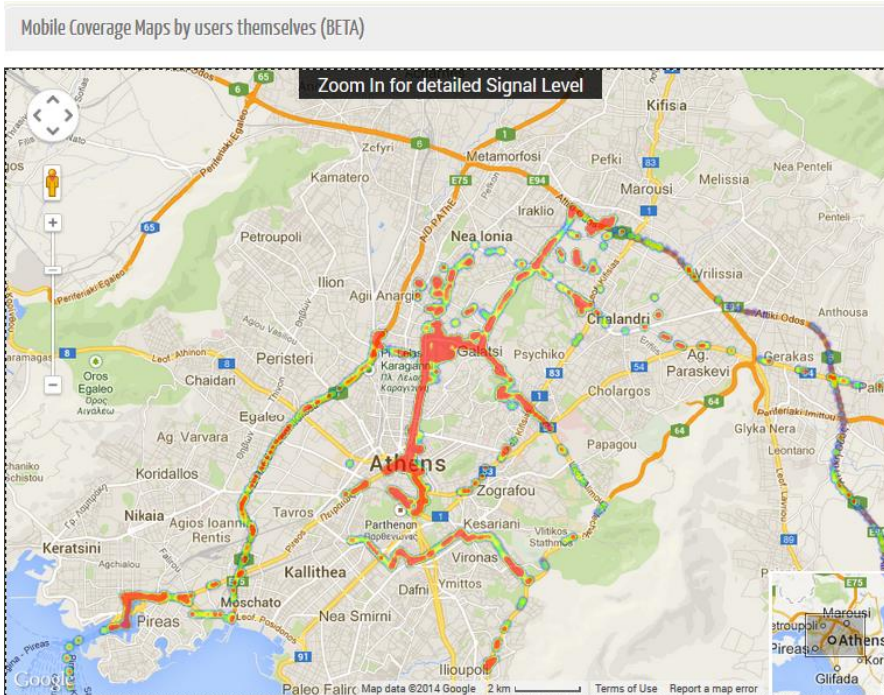
RSSI Demonstration at a Fixed Place



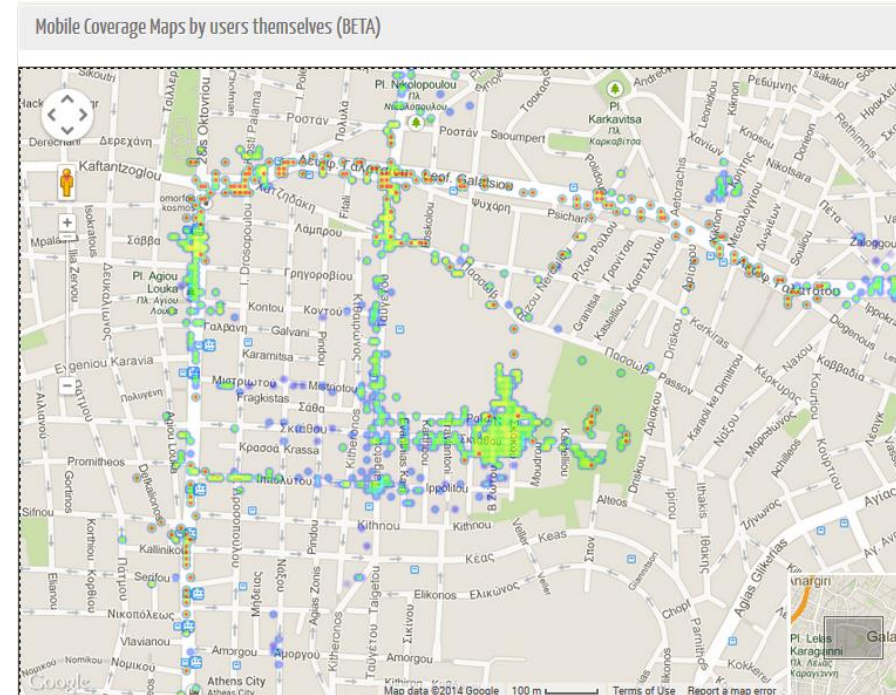
MySignals Evaluation: Attiki!!!



1.



2.



Network Carrier

- COSMOTE
- VODAFONE

Network Type

- GSM/GPRS (2G/2.5G)
- UMTS (3G)

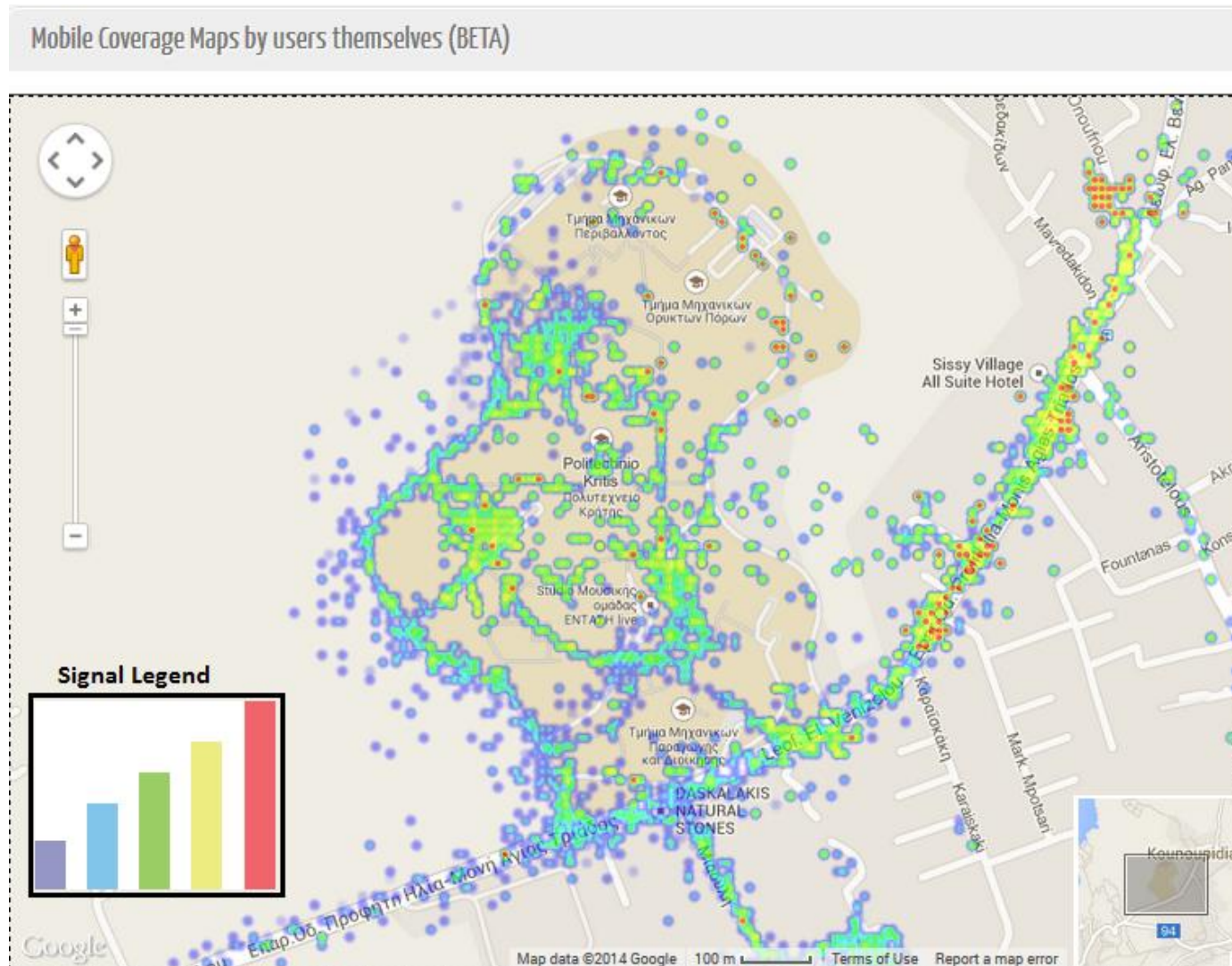
Signal Level Legend



MySignals Evaluation: TUC Campus



- MHXOP has line of sight communication with a BTS!



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Thesis Contribution and Conclusion



1. Mobile Coverage Maps can be created by users themselves.
2. User can understand Cellular Mobile Telephony Principles
 - Users Understand Cellular Mobile Telephony Principles.
3. A Scientific, Engineering and Research Tool.
 1. A lot of possibilities for research application with the collected dataset.
4. Most Important: The First RF Sensing Community from iPhone Users themselves!
5. GPS Problems: i) Drain the Battery ii) low accuracy

Future Work

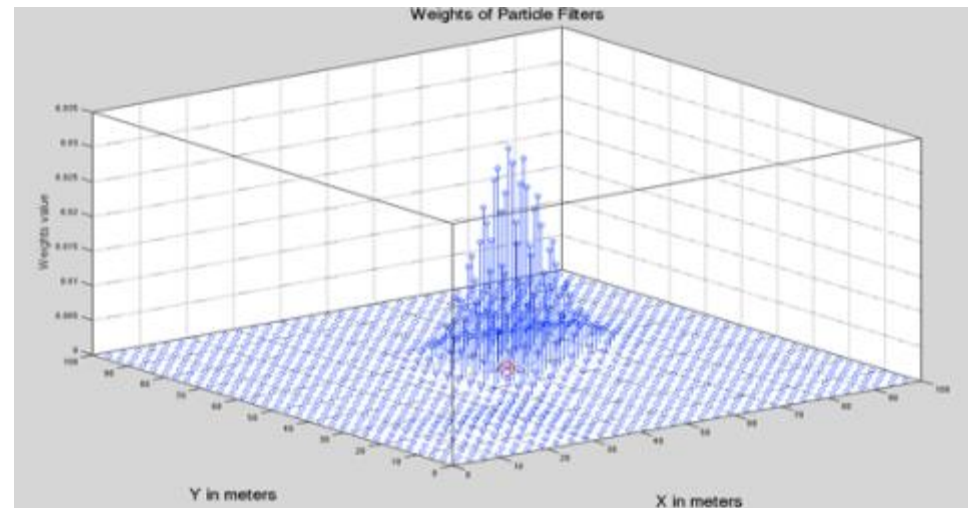
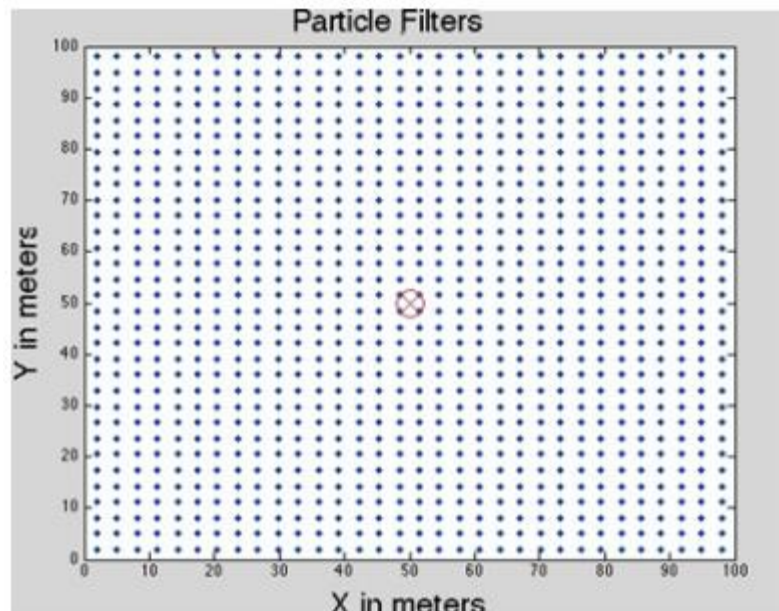


- MySignals aims to be ported on iPhone 4S (using private APIs)
- Exploit AT+Commands on iPhone 4S for full functionality.
- Introduce a **Social Game** for measuring RSS!
- Several new features to MySignals iPhone App.
- Introduce a REST API.
- Improvements to Heatmap Engine and Web Site
- MySignals aims to be adopted widely!

Future Direction: Discovering A Cell Tower Position



- A possible Research Application for collected RSSI data:
Cell Towers Position discovery can be considered by careful application of particle filtering!





Thank you
for your attention!!!!

Questions?