Mobile Location Technologies

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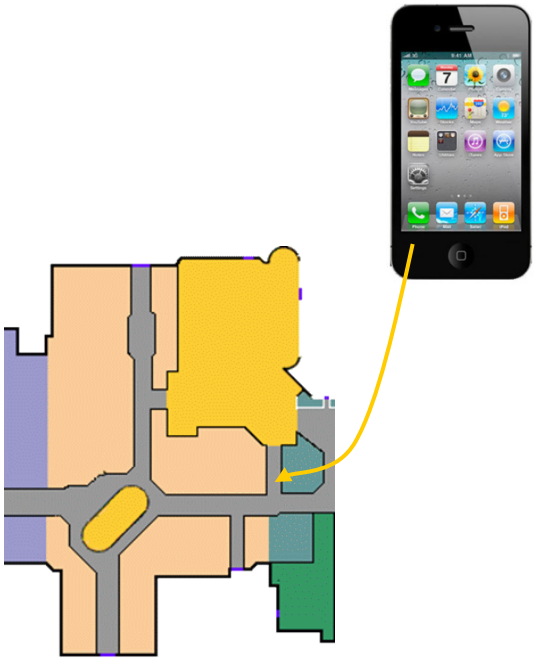
Intel Labs

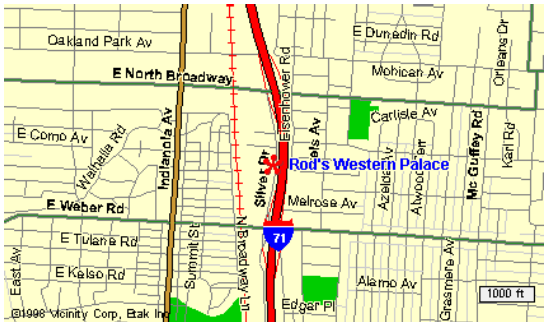
A smartphone without location sensing is like a laptop without WiFi.

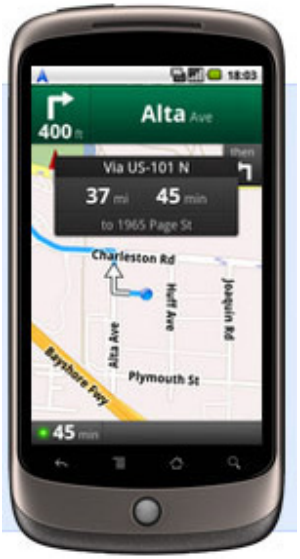


Why?

Maps and Way Finding

- Where am I?
  - Map View, Nearby stuff
- How do I get to X?
  - Directions & Navigation
- What is around here?
  - Nearest Starbucks
  - Local search





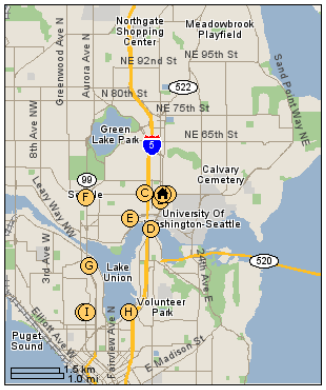
A. Edmond Menay **Hotel**
(206) 634-2000
4507 Brooklyn Ave NE
Seattle, WA 98105
0.1 mi E - Directions
References: universitytowerhotel.com - **978 more »**

B. Watertown **Hotel**
(206) 826-4242
4242 Roosevelt Way NE
Seattle, WA 98105
0.1 mi S - Directions
References: watertownseattle.com - **650 more »**

C. University Plaza **Hotel**
(206) 634-0100
400 NE 45th St
Seattle, WA 98105
0.3 mi W - Directions
References: universityplazahotel.com - **105 more »**

D. Four Seasons Homes Inc
(206) 568-7136
3302 Fuhrman Ave E
Seattle, WA 98102
0.7 mi S - Directions
References: thecityofseattle.com

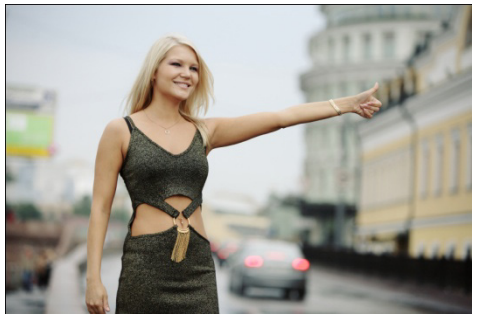
E. Emmg Hospitality Group
(206) 675-1424
3910 Sunnyside Ave N
Seattle, WA 98103
0.8 mi SW - Directions



Click on any point to re-center the map.

Social-Mobile Services

- Who is around here?
- Where do my friends go?
- What is a good exercise route?
- How far did I walk today?



MapMyRIDE BETA

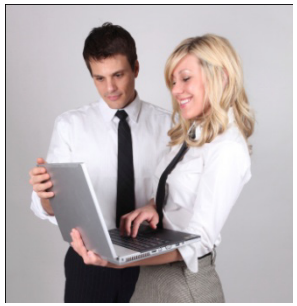
Places

Who. What. When. And now **Where.**

loopt Discover the world around you

IT Management & Asset Tracking

- Inventory Tracking
  - Finding lost and stolen devices
- Virus breakout tracking
  - Location as tool in computer virus epidemiology
- Controlling wireless network access
  - e.g. Access denied beyond 20m of building
- Monitoring device usage
  - Measure mobility, usage by device class



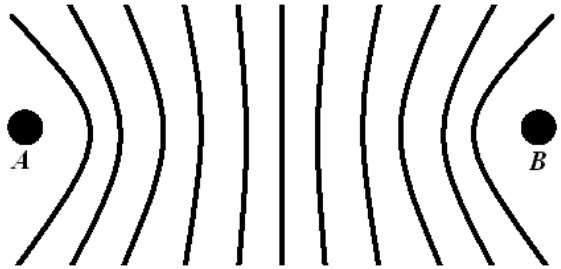
How?

Location Sensing Technologies

Technology	**Application Domain**
Satellite Positioning Systems	Outdoor navigation
Manual User-entry	Location-based web services
Cell-tower Triangulation	Web and Fee-based location transactions
802.11 Fingerprinting	Process management e.g. Hospitals
Beacon-based Location	Indoor and fast TTFF mobile computing

Long Range Navigation (LORAN)

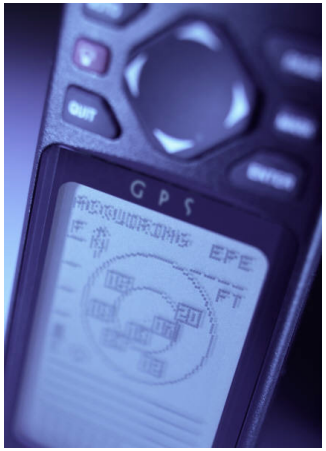
Coverage	Outdoors, high seas
Accuracy	200-400 meters
Infrastructure cost	High
Per-client cost	Low
Privacy	High
Application Domain	Aircraft & Vessels



Simplified LORAN TD lines

Global Navigation Satellite Systems (GNSS) (e.g. GPS, GLONASS, Galileo, Compass)

Coverage	Outdoors (line of sight)
Accuracy	10m
Infrastructure cost	High
Per-client cost	Medium
Privacy	High
Application Domain	Outdoor navigation



GPS Variants

- WAAS (LAAS)
  - Improve accuracy to 3 meters (LAAS to 10cm)
- Assisted GPS (A-GPS)
  - Uses data network, faster lock times, comparable coverage
- “Relaxed” GPS
  - Loosen the GPS algorithm requirements improve coverage at the cost of some accuracy
  - Can work indoors, but with >50m error
- Soft-GPS
  - GPS antenna + A/D + CPU
  - Slight improvement in coverage, time to lock

Manual Entry

Coverage	Populated Areas
Accuracy	10m-50km
Infrastructure cost	Low
Per-client cost	Low
Privacy	High
Application Domain	Location-based web services

Cell-Tower Triangulation

Coverage	Populated Areas
Accuracy	50-150m
Infrastructure cost	Low
Per-client cost	Medium
Privacy	Low
Application Domain	Web services and Fee-based location transactions

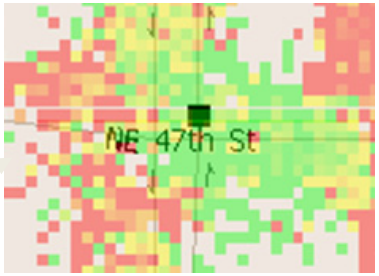
802.11 Fingerprinting

Coverage	Indoor, Campus
Accuracy	2-10m
Infrastructure cost	High
Per-client cost	Low
Privacy	Low/High
Application Domain	Process Management (*e.g.* hospitals)

MSR RADAR

ekahau

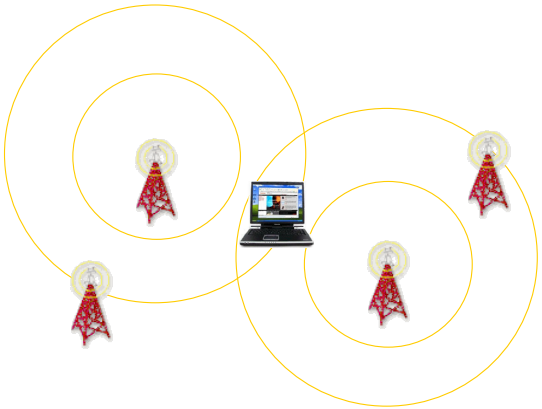
Access Point	RSSI
00:0f:f7:0c:e9:c0	-80 dB
12:0f:f5:82:22:19	-96 dB
00:0f:34:ab:0c:e0	-65 dB

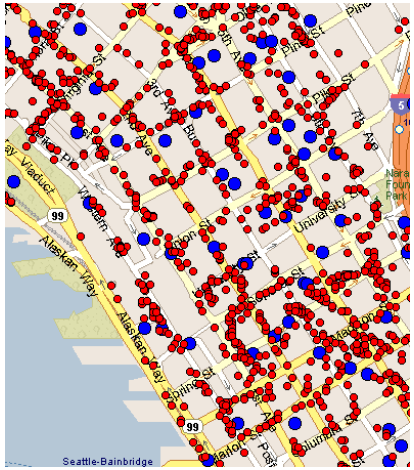


Exploit radio's temporal stability and spatial variability

Radio Beacon Location

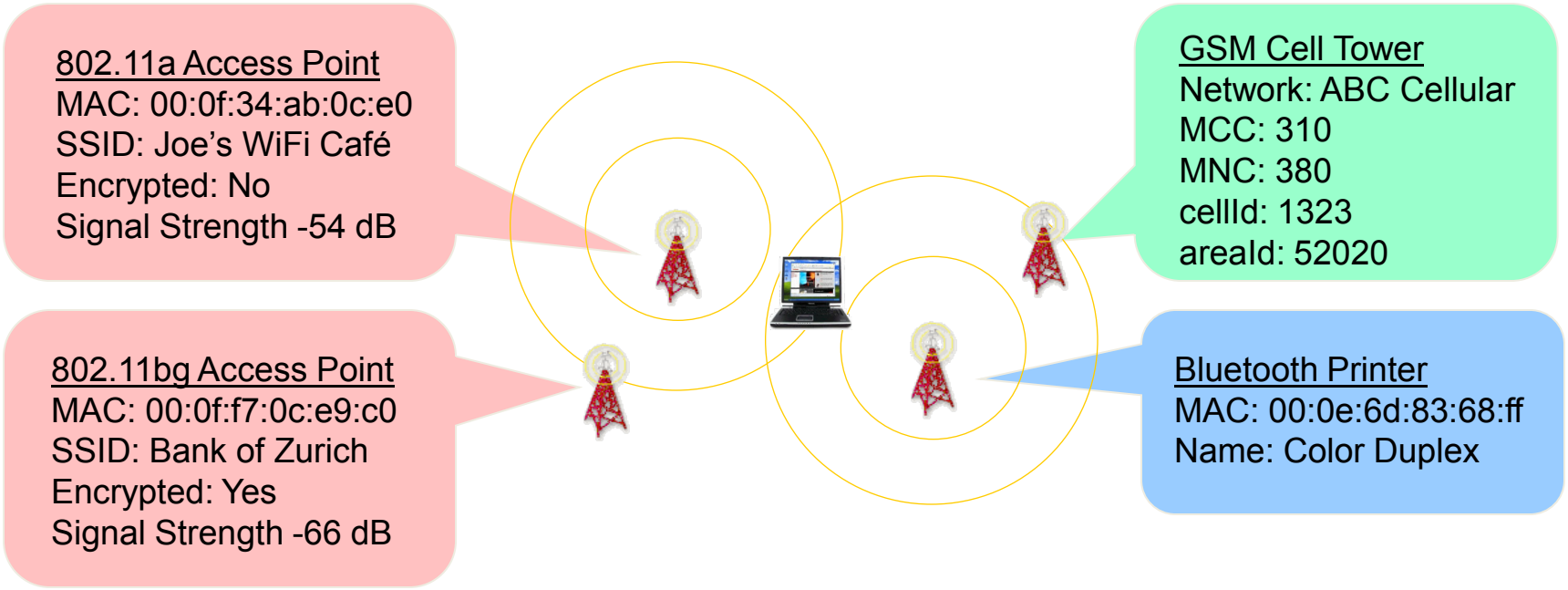
Coverage	Populated Areas + Outdoors
Accuracy	5-150M
Infrastructure cost	Low
Per-client cost	Low
Privacy	Low-High
Application Domain	Mobile computing, fast TTFF





SKYHOOK WIRELESS

Locate with Beacons in the Wild



Basic Operation

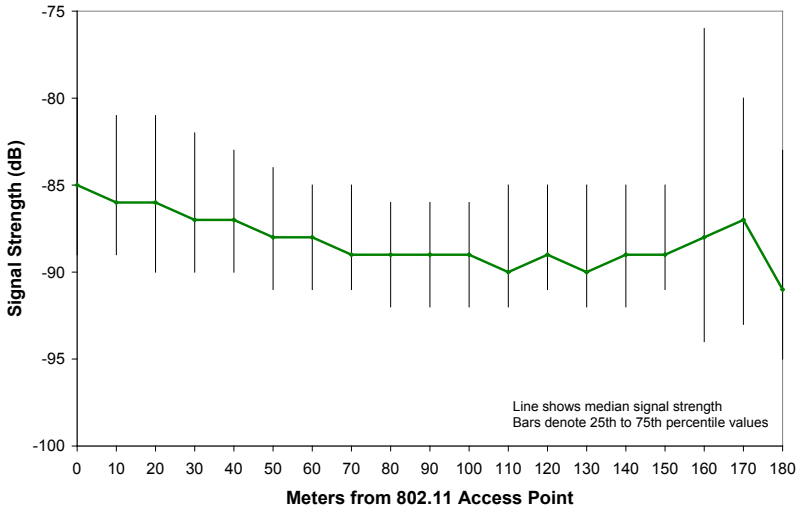
1) Store and updates radio database
2) Scan for radio sources
3) Combine observations sensibly

Database of known radio sources

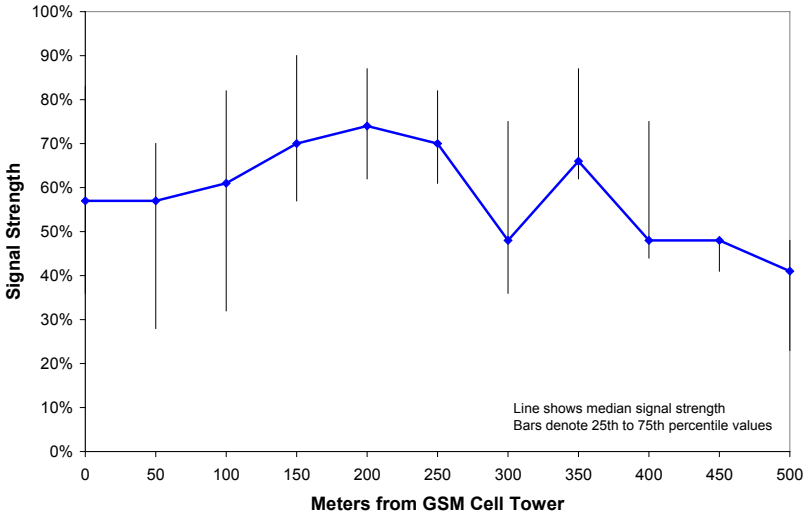
Beacon ID	Latitude	Longitude
00:0f:f7:0c:e9:c0	47.6411	-122.3079
00:0f:34:ab:0c:e0	47.6409	-122.3075
00:0e:6d:83:68:ff	47.6461	-122.3081
310:380:1323:52020	47.6456	-122.3078
…		

Signal Strength is a Mediocre Indicator of Distance

802.11 signal strength by distance



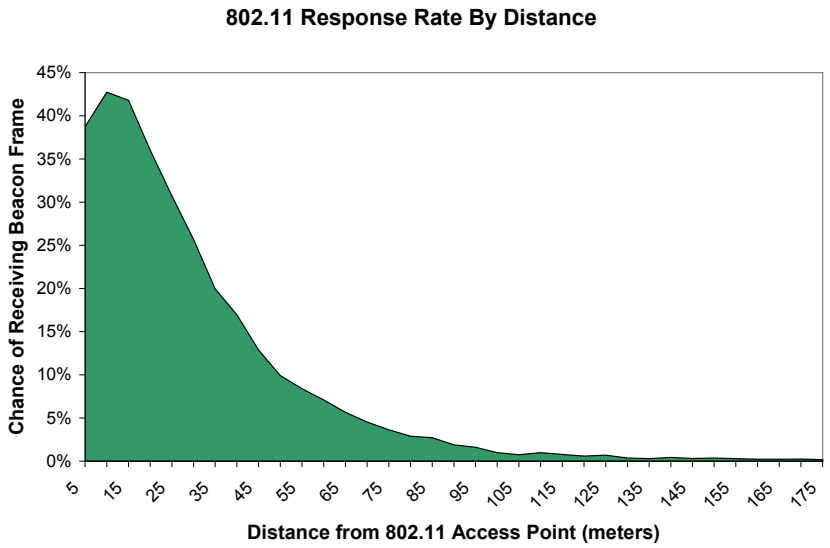
GSM signal strength by distance



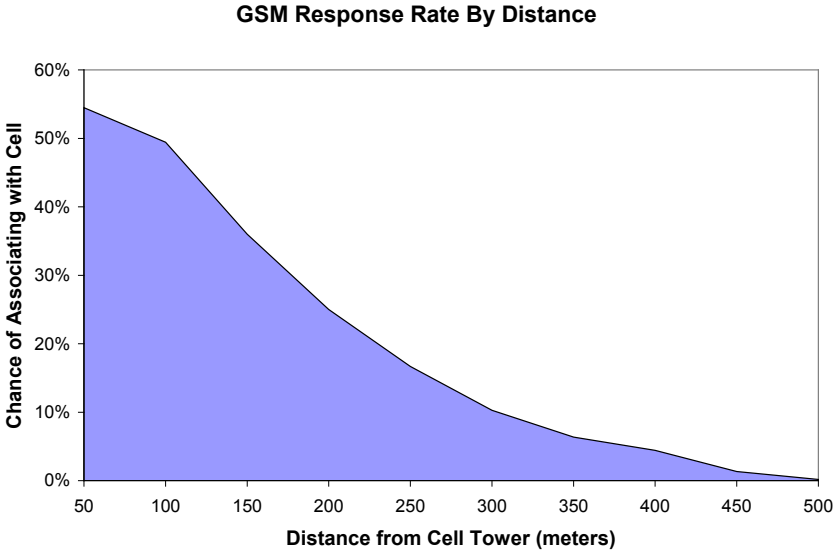
Response Rate Another Indicator of Distance

Response rate = 1 - loss rate of beacon frames

802.11 response rate by distance



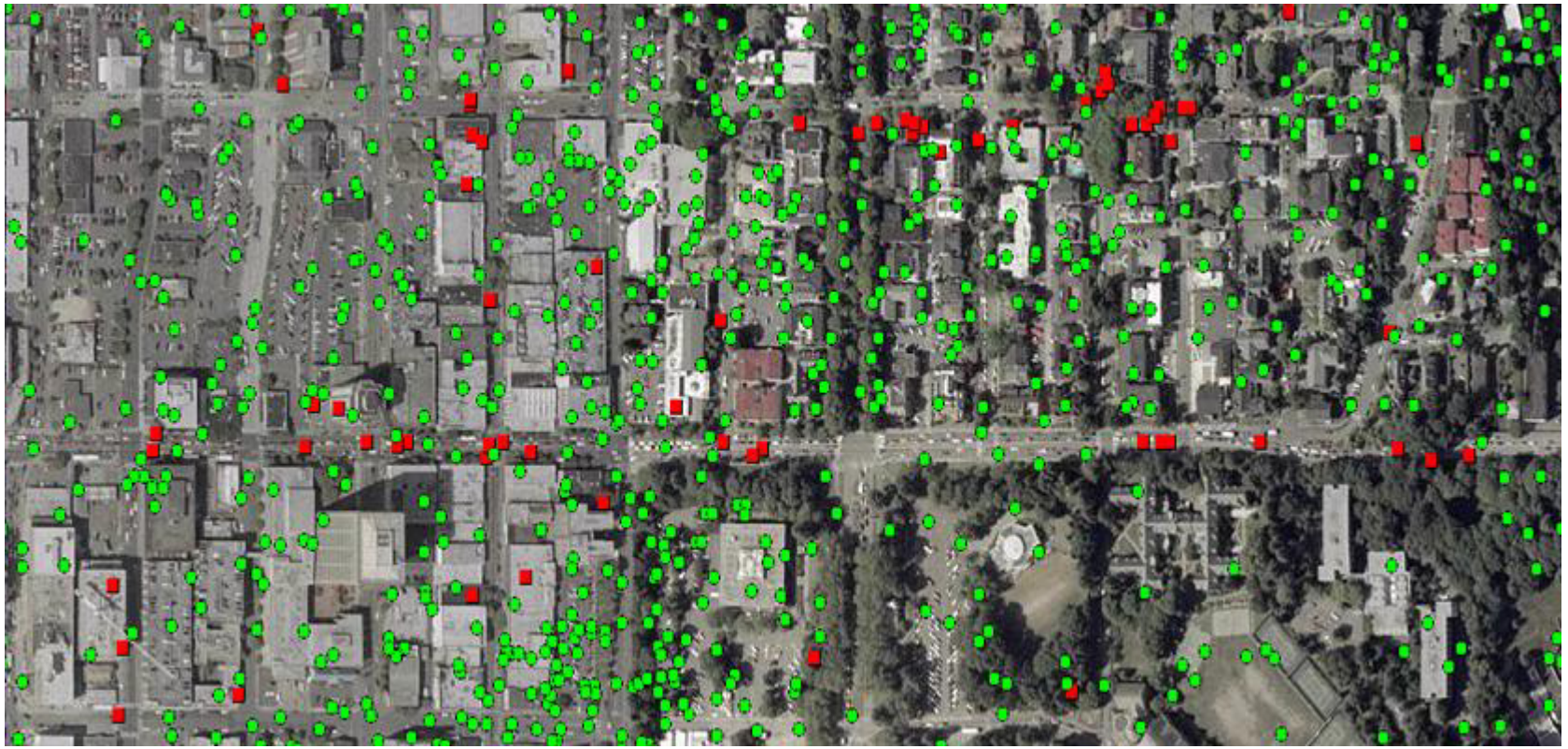
GSM response rate by distance



Self-Mapping Radio Beacons

- Grows beacon database using everyday radio traces

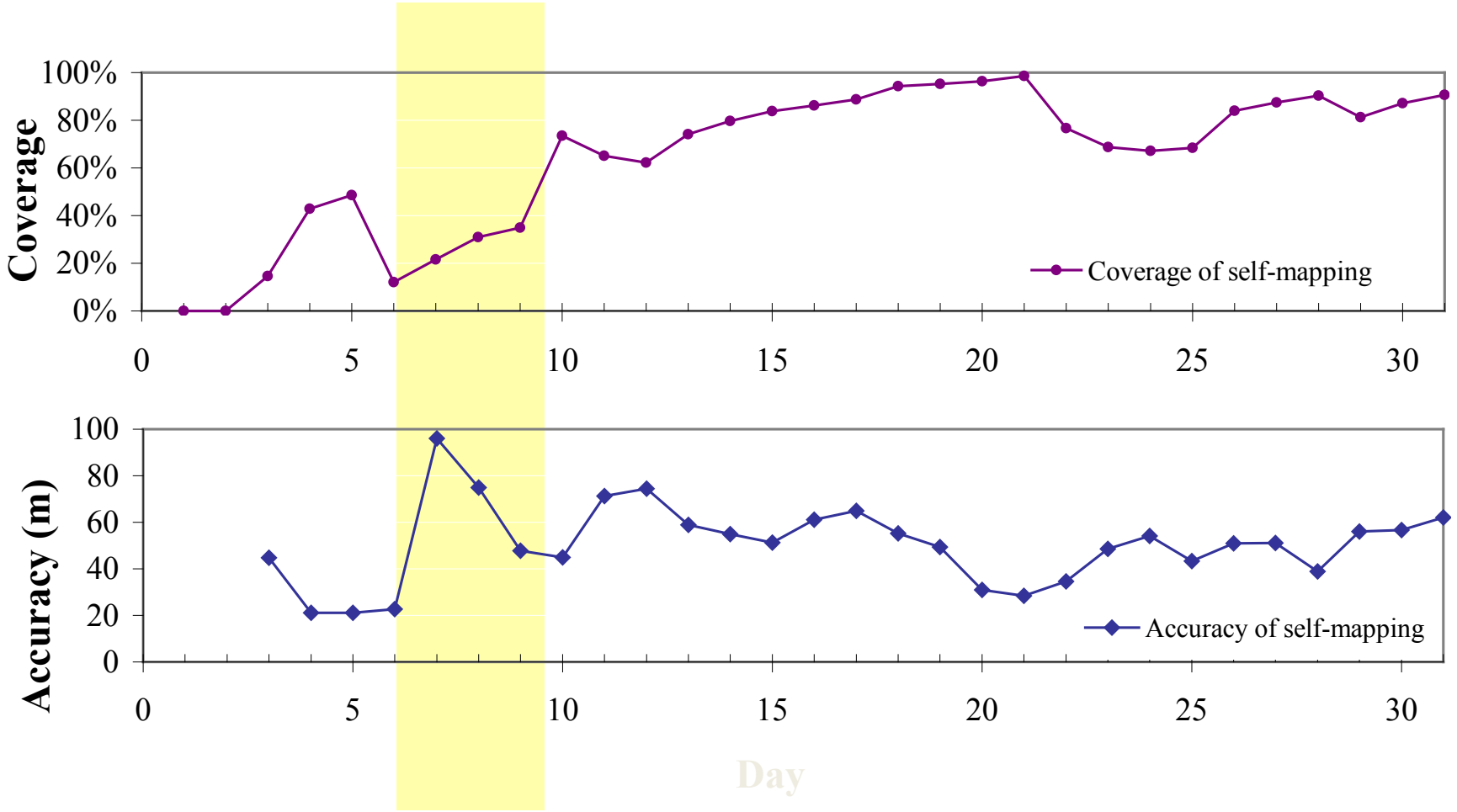
- Accuracy and coverage improve over time



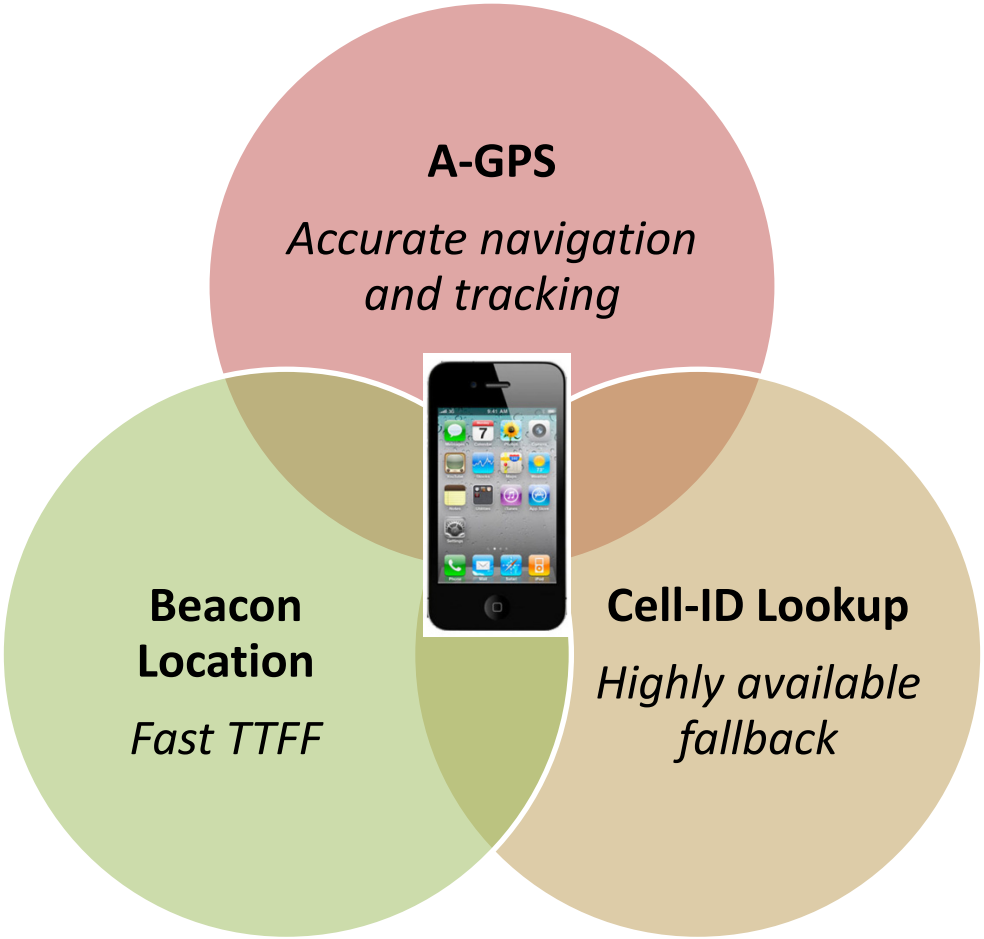
Known beacon **Inferred beacon**

One User's Experience with Self-Mapping

Self-mapping with sporadic GPS for one volunteer



Location in Today's Smartphones

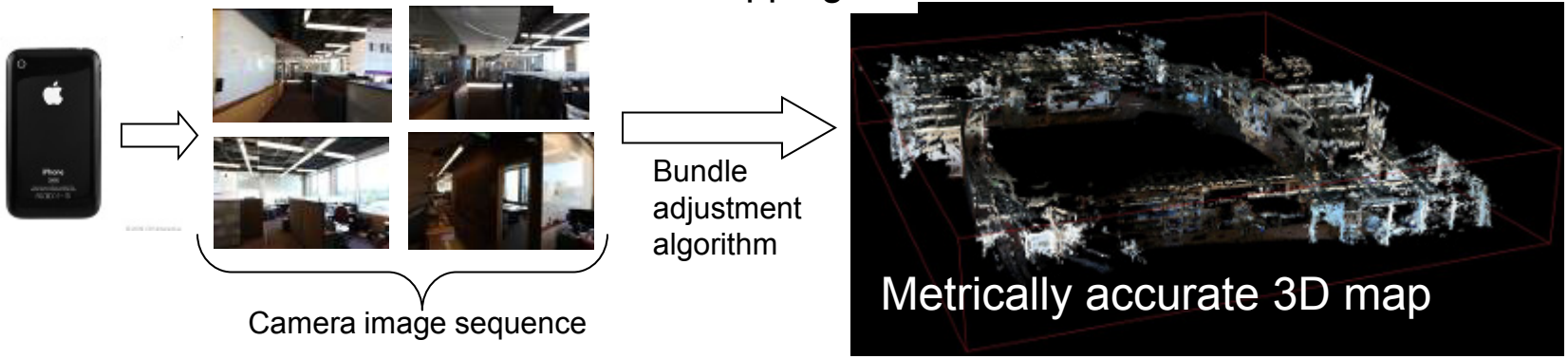


Hot Topics in Mobile Location

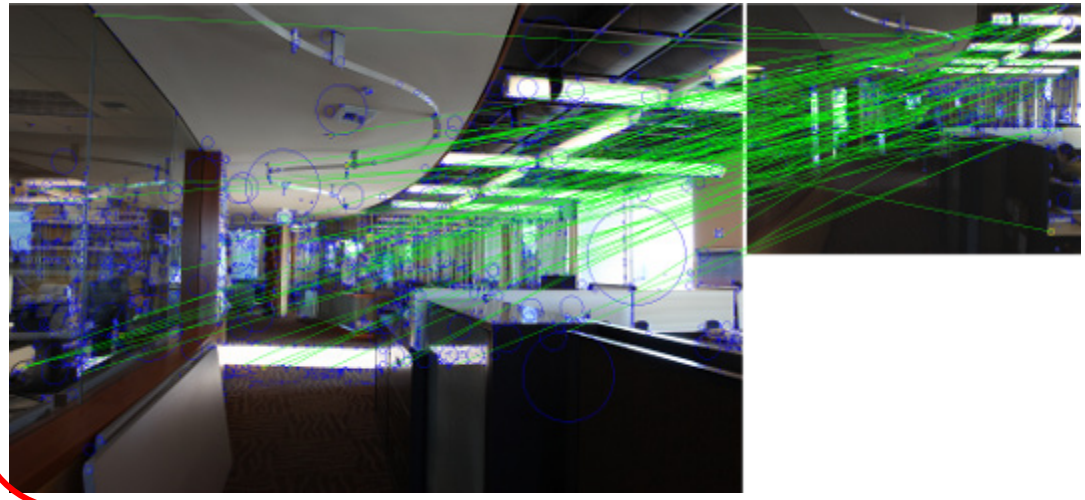
- Computer vision and Indoor Location
- Mobile Augmented Reality
- Discovering the Places people go
- Mobile [Push] Advertising

Computer Vision Location

3D mapping



3D localization

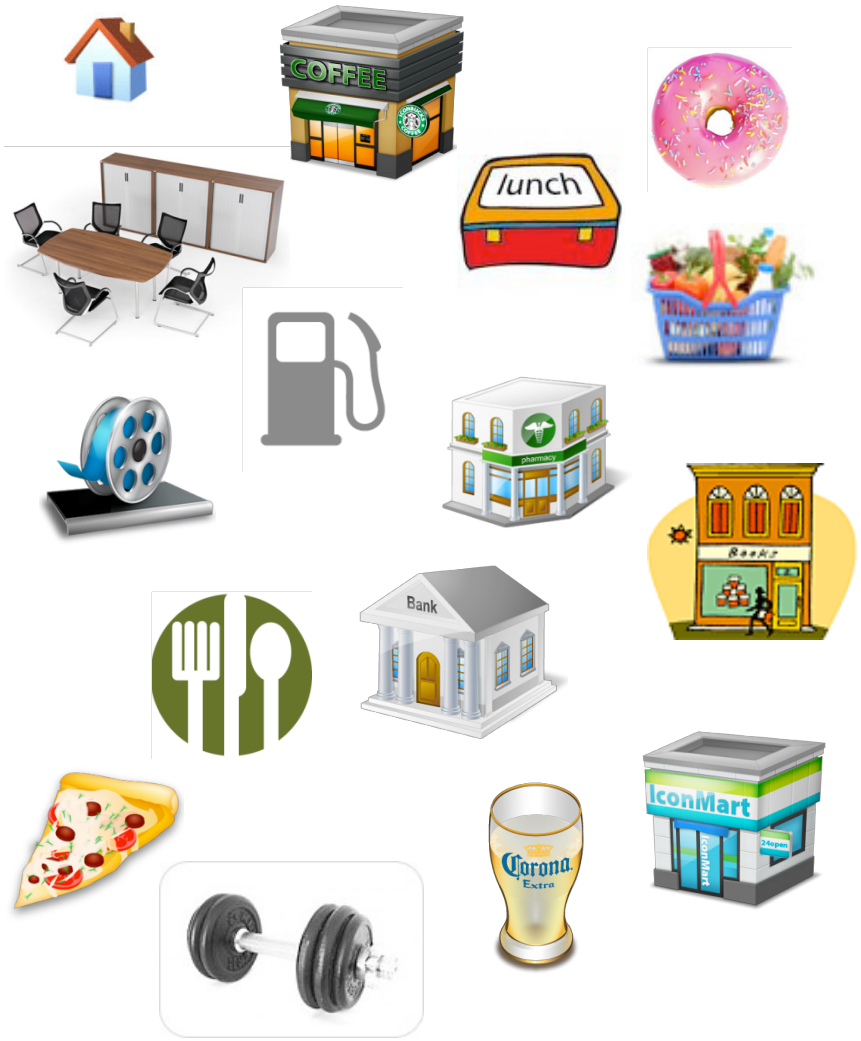


- Accuracy of 30cm and 10^{o}, 80% of the time
- 4 fps with GPU
- Google starting major 3D indoor mapping effort, startup out of Cambridge

Mobile Augmented Reality

Use your mobile phone's camera to estimate location/orientation and find web content about where you are right now!

Discovering the Places People Go



Knowing types and sequences of places we go is valuable

- Predict likely destinations
- Build personal quick-lists
- Develop behavior models and detect changes

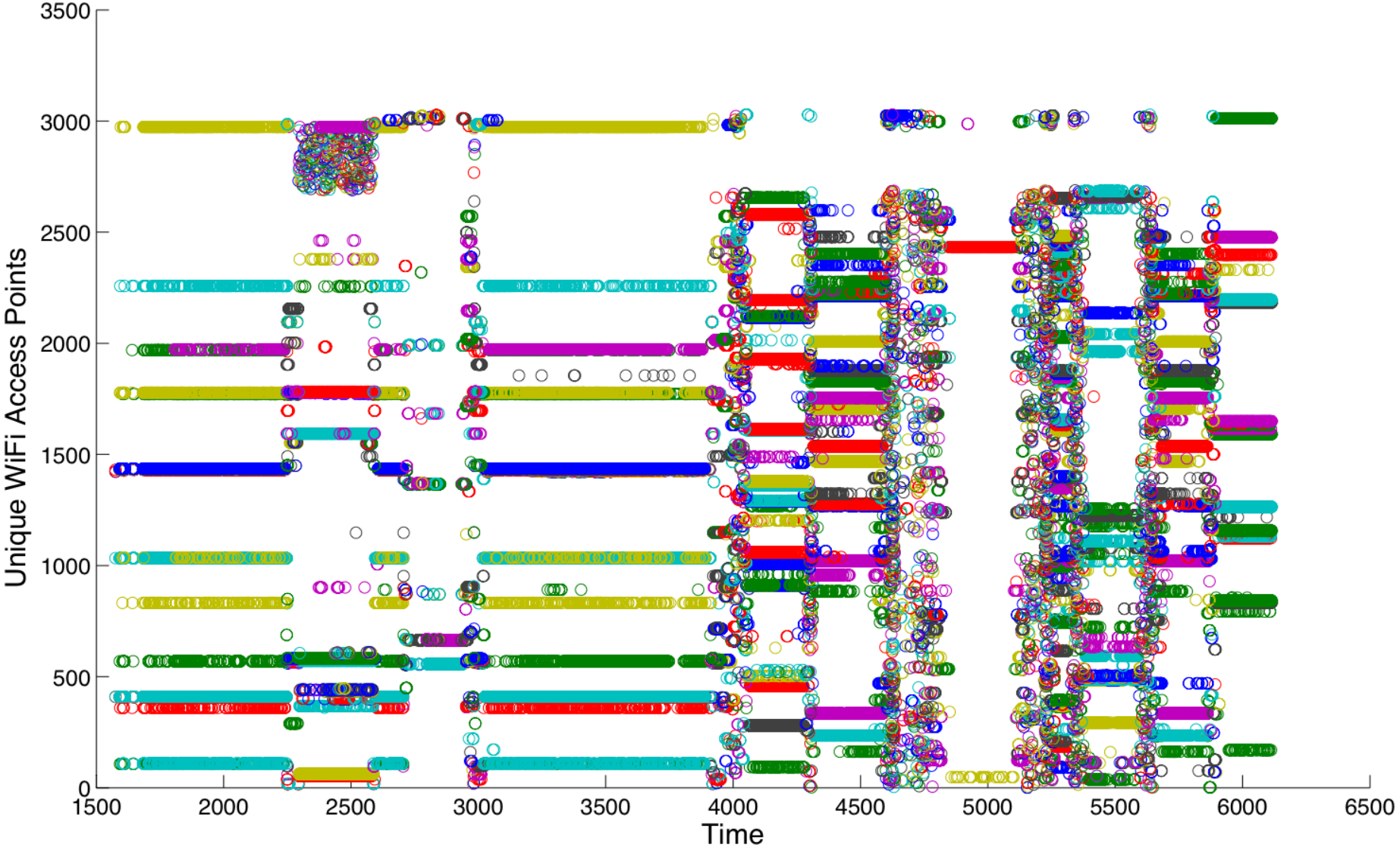
Manual “Check-ins” to places is the commercial state-of-the-art approach

Research underway to augment check-ins with automatic methods for place ***detection*** and ***recognition***

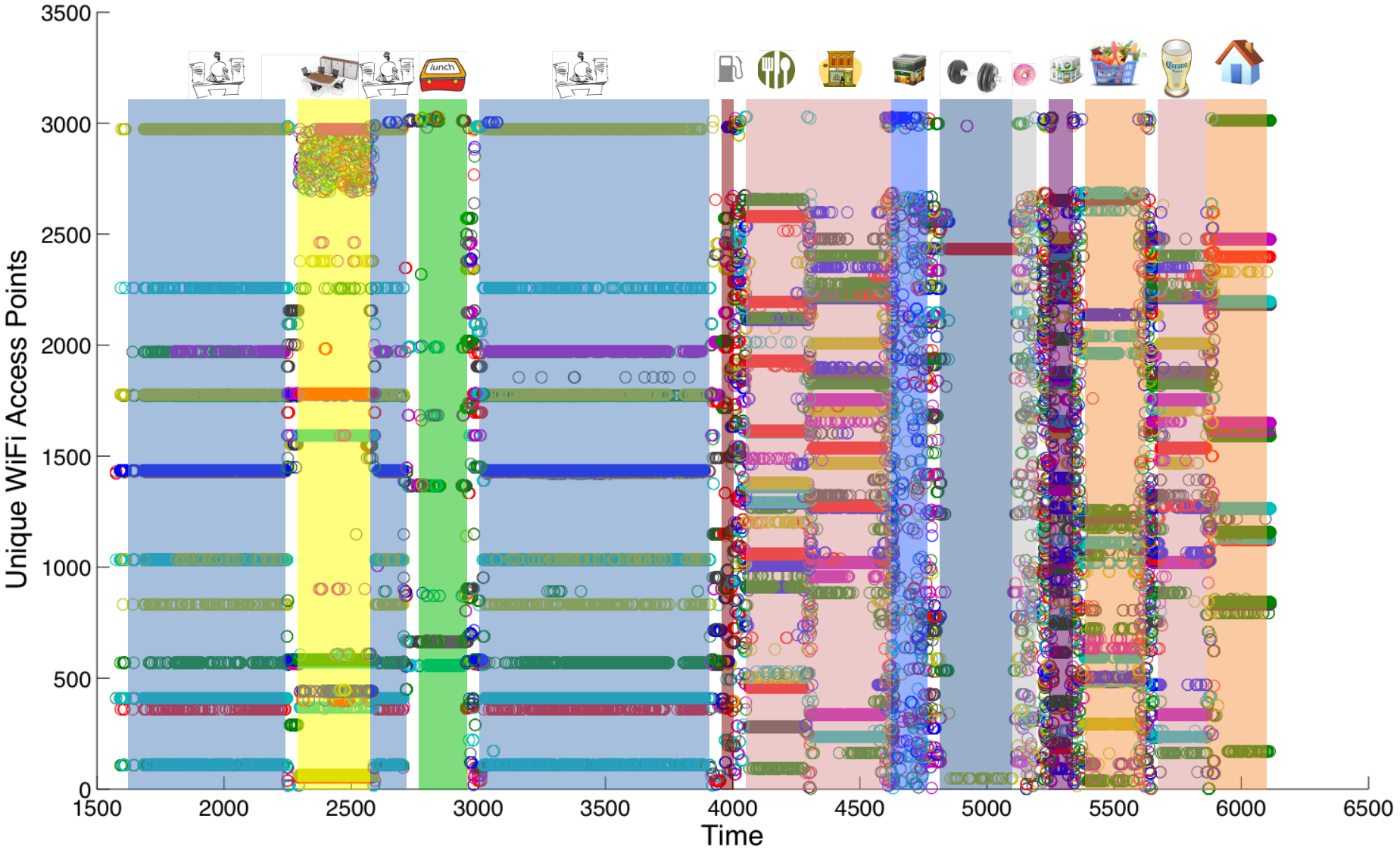
Place Learning – Two Approaches

	Geometry-based	Fingerprint-based
Input	Location coordinates (e.g., GPS, WiFi/Cell tower triangulation)	Radio environment (e.g., currently visible cell towers, WiFi access points)
Pros	Tightly coupled with the geographical location of the place	Does not depend on the underlying positioning system's accuracy (especially indoors)
Cons	Depends on the underlying positioning system's accuracy and availability	Radio environment may change over time (affecting recognition, not necessarily detection)

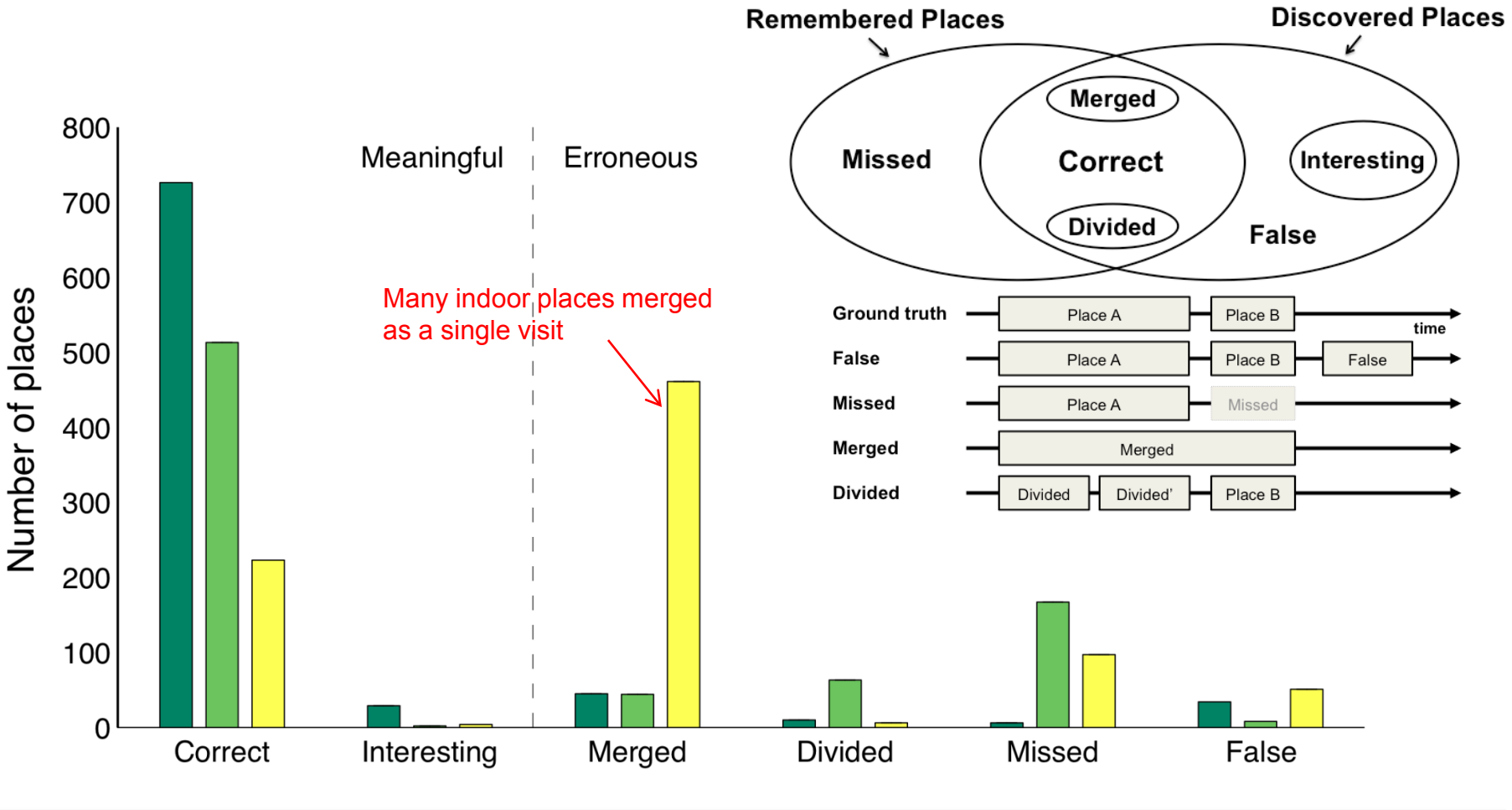
Sample Trace of WiFi APs encountered



Sample Trace of WiFi APs encountered



Results from a 4 week place learning experiment



Fingerprint-based techniques outperform geographic techniques due to the challenge of accurately clustering coordinates