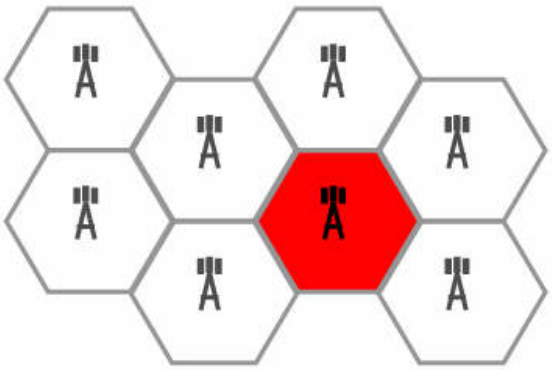
MOBILE COMPUTING

CSE 40814/60814
Spring 2021

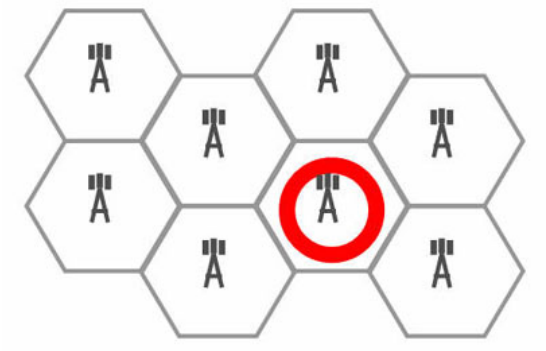
Cellular Positioning: Cell ID



Open-source database of cell IDs: opencellid.org

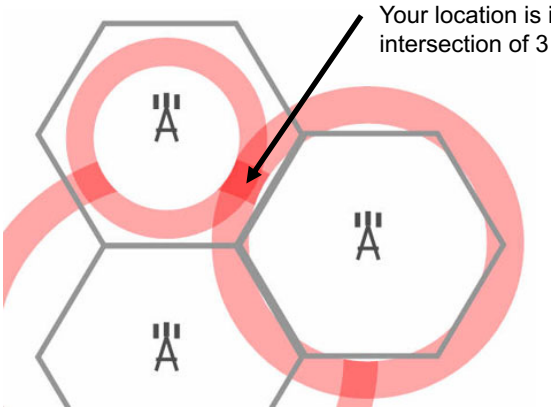
Cellular Positioning - Cell ID with TA

TA: Timing Advance (time a signal takes to travel from mobile device to cell tower)



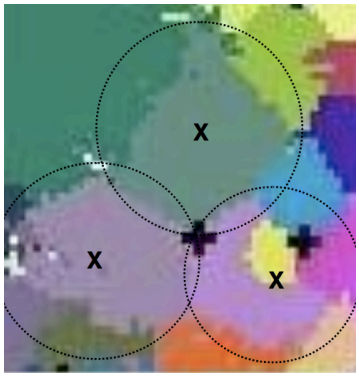
Cellular Positioning - EOTD

EOTD: Enhanced-Observed Time Difference



Cellular Positioning Performance

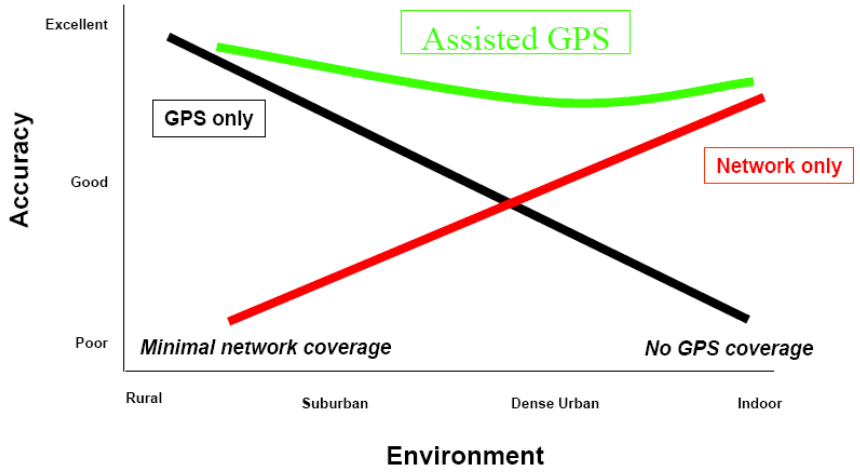
- Maps of the area served by individual cell towers are complex
- GSM signal reception
  - Attenuated by barriers
  - Change with call volume
- Cells size varies 100m- 30Km
- Resulting positioning is inconsistent and unreliable
- Sufficient for some applications



Cellular Based Location

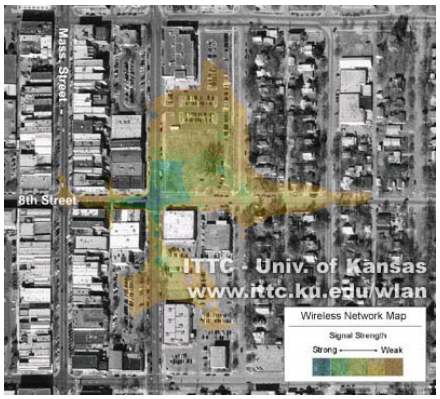
- Development of location systems based on mobile phase was driven by US Federal Communication Commission (FCC)
- The main purpose was to locate mobile phones to assist phones to deliver emergency services
- Later it was also used for
  - Location Based services
  - Advertisement
  - Recommendation systems
  - Gaming

Comparing Cellular and GPS Positioning



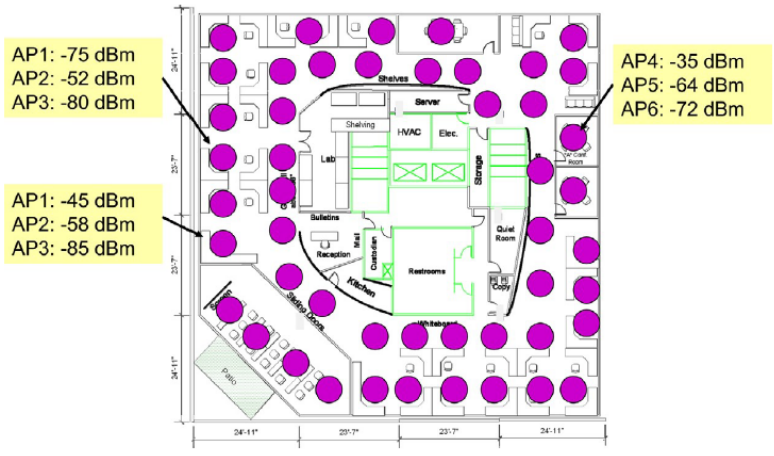
Wi-Fi Positioning Systems

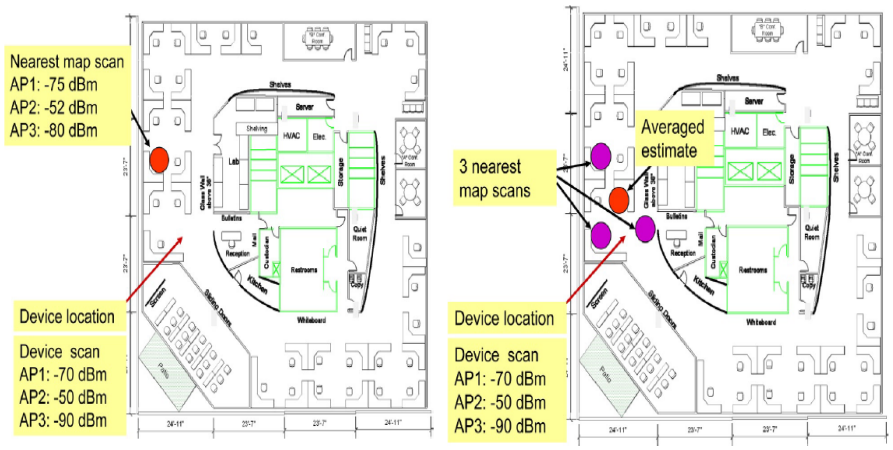
- Wi-Fi access points (hotspots) broadcast signals up to 100m
- Wi-Fi chips in devices detect the name of the access point, signal strength, and (sometimes) angle of arrival
- Client devices can detect access points in two ways
  - Passively listening on 802.11 channels for beacon frames
  - Initiate scan by sending requests which access points reply



Location based on 802.11

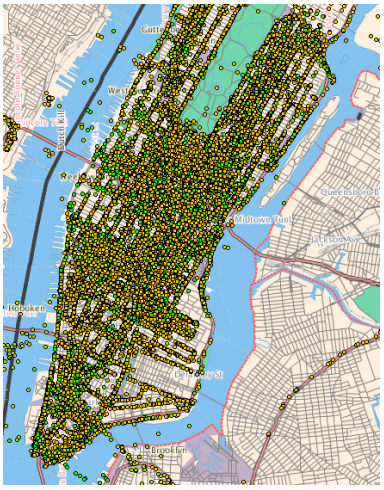
- 802.11 takes advantages of two properties observed by clients
  - Spatial variability: signal strength depends on distance & location
  - Temporal consistency: good chance this will be true in days/weeks/months/...
- Map of “radio fingerprints” can be established





Wi-Fi Localization

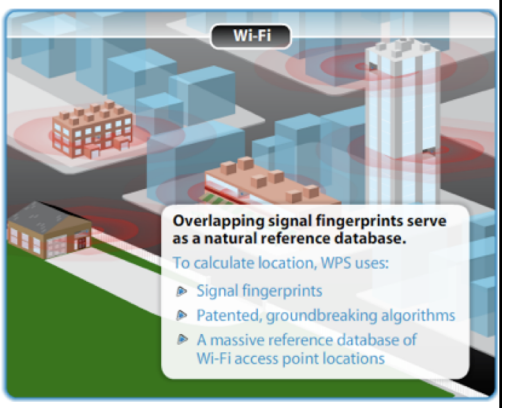
- Wi-Fi is everywhere now
  - No new infrastructure
  - Low cost
  - APs broadcast beacons
  - "War drivers" build AP maps
    - Calibrated using GPS
    - Constantly updated
- Position using Wi-Fi
  - Indoor Wi-Fi positioning gives 2-3m accuracy
  - But requires high calibration overhead: 10+ hours per building
  - Changes over time (adding/removing/relocating APs) impact accuracy



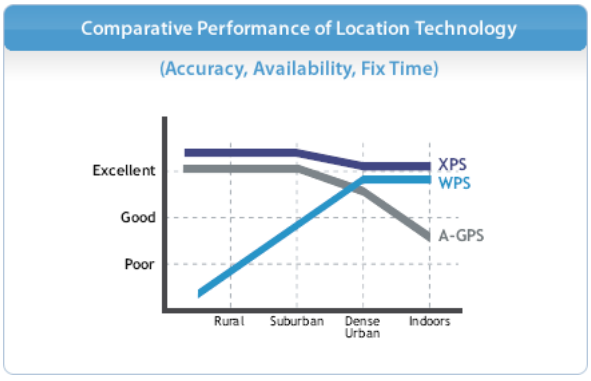
Manhattan (Courtesy of Wigle.net)

Access to Wireless Positioning

- **Skyhook** provides wireless positioning solution (XPS) based on fusion of GPS, Wi-Fi, and cellular
- **Ekahau** offers a commercial solution using fingerprinting mainly for internal building positioning

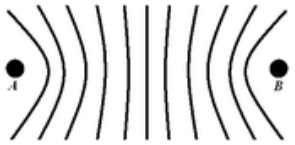


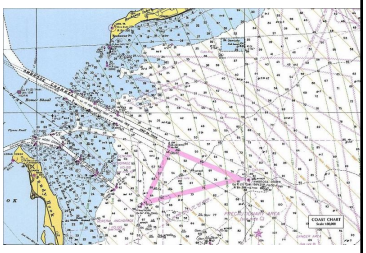
Hybrid Positioning System (XPS)



Radio-Navigation (LORAN)

- Synchronized signals are broadcast from coastal stations over large geographic areas
- Difference in the time of reception of the signals is constant along hyperbolic curves
- Position calculated by intersecting curves from 2 sets of stations
- Was seen as an ideal backup for GPS in case of jamming/outages
- Terminated in US/Canada in 2010



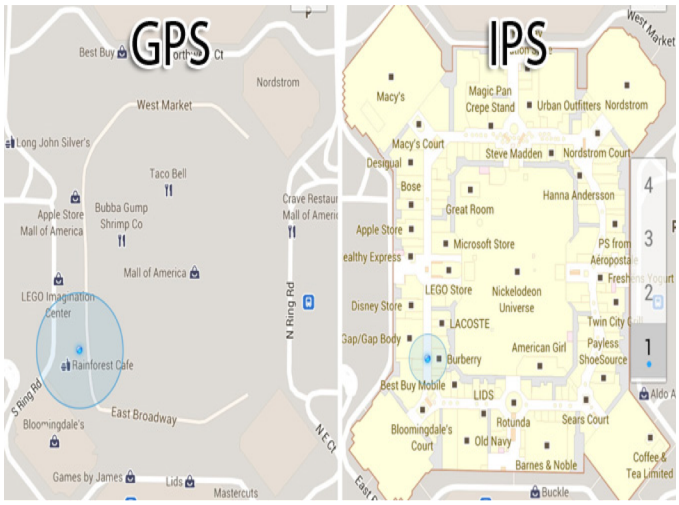


Other Indoor Positioning Options

- Bluetooth positioning
  - Used to send local messages about location/ services
- RFID chips embedded in the environment
  - RFID scanners can check location/ services available
- UWB
  - High precision industrial positioning of tags on items
- TMSI
  - Temporary ID of GSM phones can be tracked for short period within small areas (e.g., shopping centers)
- IP positioning
  - Using structure of Internet to situate IP address geographically

Indoor Positioning System (IPS)

GPS vs. IPS



IPS

- Beaconing: Wi-Fi, Bluetooth, ...
- RFID tags (later lecture)
- Magnetic or other sensor data

Positioning Accuracy

Technique	Range / accuracy	Remarks
(A)GPS	Accuracy: 6.0 m - 10.0 m	+ Low barrier entry - Slow computation and processing time Very susceptible to reflectance and multi-paths
GSM / UMTS	Range: ≈ 35.0 km	+ Globally available - Cell-based accuracy
Bluetooth	Range: ≈ 100 m Accuracy:10 m – 20 m	+ High speed data transfer - Positioning via triangulation (no objects into account),Explicit links between devices required
IR	Range: 0.7 m – 2.5 m	- Short range of detection limits infrastructure, No penetration of materials / multipath, Line of sight, Signal can be disturbed easily
IEEE 802.11 (Wi-Fi)	Range: ≈ 32 m (indoor) ≈ 95 m (outdoor) Accuracy: 1 m – 5 m	+ Large scale available over the world .Economical viable - High power consumption, Slightly multipath susceptible

iBeacon (Apple, BLE-based)

iBeacon

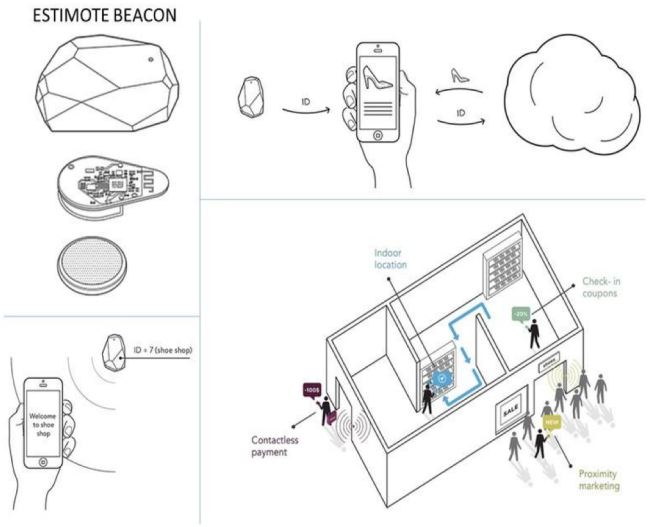
- iBeacon is the Apple Trademark for an indoor positioning system that Apple Inc. calls “a new class of low-powered, low-cost transmitters that can notify nearby iOS devices of their presence.”
- The iBeacon works on Bluetooth Low Energy (BLE), also known as Bluetooth Smart. BLE can also be found on Bluetooth 4.0 devices that support dual mode.

iBeacon

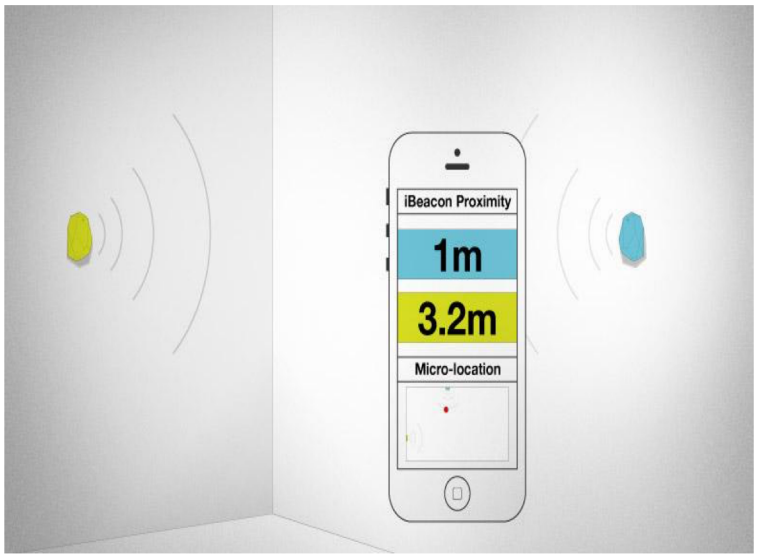
Estimote iBeacon

- An Estimote Beacon is a small wireless device. When placed in a physical space, it broadcasts tiny radio signals to smart devices
- Smartphones that are in range are able to 'hear' these signals and estimate their location very precisely, as well as to communicate with the beacon to exchange data and information

iBeacon



iBeacon



iBeacon

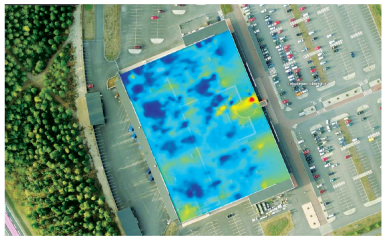
- Video: http://www.youtube.com/watch?v=sUlqfjpInxY
- Video: http://www.youtube.com/watch?v=SrsHBjzt2E8

iBeacon: Advantages

- Accuracy (Bluetooth, low-range)
- Privacy (beacon DO NOT track users)
- Integration (Apple, Android, ...)
- Affordability (low-cost beacons, other devices can be configured as beacons)
- Usability (BLE -> low energy); simple to use (built into OS/platform)

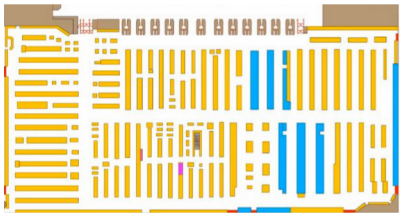
Magnetic Positioning

- Magnetometer + data connection
- Evaluates building's distortion of Earth's magnetic field or "magnetic fingerprint"
- Correlates to reference data
- More steel improves accuracy (1-2 meters)

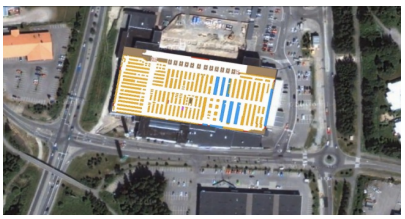


Magnetic Positioning

Step 1: Adding floor plans

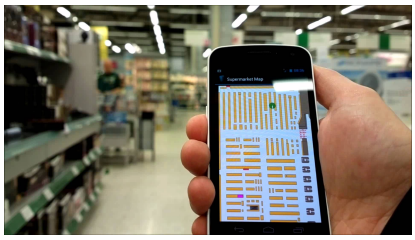


Step 2: Mapping buildings

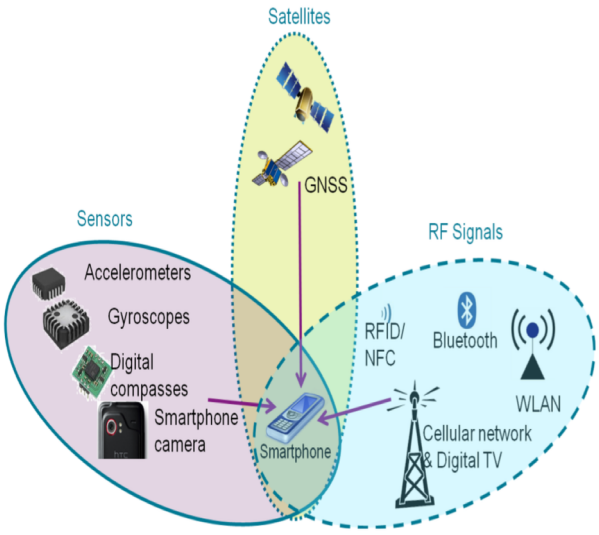


IndoorAtlas

Step 3: Creating applications



Smartphone Positioning



Future for Positioning

- Combination/fusion of multiple positioning techniques is now norm
- Focus on energy efficiency
- Focus on indoor localization
- Dead reckoning (accelerometer/gyroscope) when no GPS
- "Snapping" of location ("natural" boundaries)
- Cooperative localization
- Applications:
  - Asset tracking: RFID
  - Geo-fencing: alerts
  - Emergency response
  - Social networking
  - Health/Wellness

Positioning in Flutter

- Tutorials:
  - https://morioh.com/p/832f968ed090
  - http://flutterintern.blogspot.com/2018/11/how-do-i-access-gps-sensor-part-one.html
  - https://pub.dev/packages/location
- Packages:
  - https://pub.dev/packages/flutter_background_geolocation
  - https://pub.dev/packages/location
  - https://pub.dev/packages/google_maps_flutter
  - https://morioh.com/p/1eb6dcd4a19a