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

Your location is in the zone at the intersection of 3 cell circular bands
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 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
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)

![Comparative Performance of Location Technology](chart.png)
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

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

• Video: [http://www.youtube.com/watch?v=sUlqfpInxY](http://www.youtube.com/watch?v=sUlqfpInxY)
• Video: [http://www.youtube.com/watch?v=SrsHBjzt2E8](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
Step 3: Creating applications

Smartphone Positioning

Sensors
Accelerometers
Gyrosopes
Digital compasses
Smartphone camera

GNSS
Satellites

RF Signals
Bluetooth
WLAN
Cellular network
RFID/NFC
Digital TV
**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

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**Positioning in Flutter**

- **Tutorials:**
  - [https://morioh.com/p/832f968ed090](https://morioh.com/p/832f968ed090)
  - [https://pub.dev/packages/location](https://pub.dev/packages/location)

- **Packages:**
  - [https://pub.dev/packages/flutter_background_geolocation](https://pub.dev/packages/flutter_background_geolocation)
  - [https://pub.dev/packages/location](https://pub.dev/packages/location)
  - [https://pub.dev/packages/google_maps_flutter](https://pub.dev/packages/google_maps_flutter)
  - [https://morioh.com/p/1eb6dcd4a19a](https://morioh.com/p/1eb6dcd4a19a)