18-452/18-750
Wireless Networks and Applications
Survey 7:
Localization
Tyler Goulding
Spring Semester 2017

Outline
• Review of last lecture
  ➢ GPS
  ➢ CAESAR
• Importance of Localization
• More Hybrid Systems
  ➢ SAR
  ➢ UnLoc

GPS:
• Outdoors:
  – It provides good accuracy (2–3 m).
  – It has become almost ubiquitous in today’s society
• Indoors/Concrete Jungle:
  – High attenuation of the RF signals from the GPS satellites through buildings.
  – Shadowing and multi-path disrupt signals resulting in low resolution.

How do we deal with indoors?
• Current technologies used to solve indoor location:
  – Ultrasonic
  – IR
  – UWB
  – WiFi
  – Bluetooth
  – Non-wireless approaches
Time-based location estimation

• TOF defined as the time that the signal takes to travel from Node A to Node B
  \[ T_{\text{flight}} = T_{\text{arrival}} - T_{\text{transmit}} \] (ex. GPS)
• More often, Round trip time is used than single direction time of flight, thus:
  \[ T_{\text{flight}} = (T_{\text{round}} - T_{\text{processing}})(1/2) \] (ex. CAESAR)
  \[ \text{Distance} = c \cdot T_{\text{flight}} \]

Et tu Brute?

• CAESAR:
  – Average errors of less than 1 m are obtained in 8 links out of 10.
  – A lower accuracy is obtained in links with severe multipath obstruction.
  – The error drops below 2 m after fewer than 25 samples in 9 links out of 10.
  – It is stable across different frame rates at the L-STA.
  – WLAN interference has a limit impact on the estimate, when 3 other stations send a high traffic rate.
  – It can track the distance to a WLAN smartphone at pedestrian speeds both outdoors and indoors.

Why the need for Hybrid?

• Unlike, outdoors, Indoor localization usually needs higher level granularity.
  – 2-3m would be the same street outdoors, but different aisle/store indoors
• Achievable with wifi alone, but requires super high density of nodes and requires exact calibration
• Non-wifi wireless solutions exist at the cost of new infrastructure

Outline

• Review of last lecture
  » GPS
  » CAESAR

• Hybrid Options
  » Ubicarse
    » Antenna Array
    » SAR
  » UnLoc
    » Dead Reckoning
    » Fingerprinting on Sensor data
**Antenna Array**

- Antenna Arrays can be used to detect with great precision the physical direction of the transmitter
- Not suitable for phone
  - As shown →

**Synthetic Aperture Radar (SAR)**

- SAR is a technique of using a single antenna to emulate an antenna array.
- Traditional SAR techniques are used to get millimeter accuracy.
- Requires precise knowledge of how the antenna is located in space

\[ P(x) = \left| \frac{1}{n} \sum_{i=1}^{n} h_i e^{\frac{-j2\pi rd}{\lambda} \sin(\alpha - \delta)} \right|^2 \]

**UbiCarse: SAR for a phablet**

- Translation Independence:
  - Traditional SAR requires mm accuracy for position of antenna. Easy on radar systems. Impossible on phones
  - UbiCarse uses a two antenna device to detect and compute the direction of source
- **Assumptions:**
  - During SAR computation, the source is at a far distance compared to the movement of the tablet.

**UbiCarse: Does it work?**

- Rays from Distant Transmitter at (0,0)
- \( \delta \): \( \delta \)
- \( \alpha \): \( \alpha \)
- \( r \): \( r \)
Ubicarse: Multipath

- median error of 39 cm in full three dimensional space.

Unsupervised localization?

- All of the previous solutions require some form of war-driving.
- Can we do it autonomously?

Unloc: Fingerprinting landmarks

- Fingerprinting Sensor data in conjunction with Dead-reckoning to localize users
- Landmark based localization generates broad estimations based on smartphone sensor data.
- Several modern infrastructure exhibit unique magnetic/RF/accelerometer reading
- Issues:
  - Drift error from Accelerometer
  - Fingerprinting is susceptible to small changes in environment

Unloc: Landmarks

- Seed Landmarks (SLM):
  - Unloc relies on pre-existing data on a building’s layout to identify landmarks that are known to exhibit predictable user interaction:
    - Stairs (pressure/accelerometer data)
    - Elevators (magnetometer/accelerometer)
    - Entrances (significant drop in GPS signal)
    - Escalators (magnetometer/accelerometer)
- Organic Landmarks (OLM):
  - Several locations in an indoor system will exhibit unique ambient signatures (fingerprinting).
  - Clusters user’s sensor data along with dead-reckoning to estimate location of organic landmark.
    - Wifi strength,
Dead-reckoning

- Using the accelerometer readings of the mobile phone, count steps a person has walked, and therefrom derive the displacement of the person.
- Direction is dictated by either compass or gyroscope.

Unloc: Concerns

- Heterogeneous Hardware – will the clustering algorithm work on different sensor hardware?
- Phone Orientation Effect – Sensor data differ on orientation?

Landmark accuracy?

But what about drift?

- IMUs are all susceptible to drift.
  - Can be estimated as an unknown but linear shift in direction
  - Ubicarse
    - Linear drift leads to constant shift in SAR multipath
    - Estimating shift in multipath profiles is used to actively correct for gyro drift
  - Unloc
    - Magnetic features of infrastructure lead to using the gyro
    - Landmarking zero’s out error with
Questions