Location-Tracking Technologies

Location-Tracking

- How it’s done
- How it’s shared
- How it’s used

Criteria

- Accuracy
- How current the data is
- Historical data
- Individual versus “who was where, when?”
- With or without user consent or knowledge
- Devices to which it is applicable

Common Technologies

- GPS, in a phone or dedicated device
- Cell tower
- WiFi signal
- Bluetooth signal
- IP geolocation
- Voluntary disclosure

GPS: Global Positioning System

- Satellite-based
  - (There are other satellite “constellations” planned or operated by other countries)
- The satellites continuously broadcast the time of day and their precise location
- Receivers use this data from several satellites to find their location
  - N.B. Receivers *receive*; they do not emit tracking signals
- **Accuracy:** About **4.9m**
  - Accuracy affected by trees, multipath reception, indoor use—and the satellite signal is weak

CS@CU

GPS Devices

- GPS receivers are built into most phones
- They can also be standalone devices that either keep a track log or use a cellular connection to relay data
  - Many commercial vehicles have trackers, to aid in logistics and scheduling
- *Not* the primary way that phones do location
  - GPS location is slow and power-hungry, and doesn't work well indoors
  - But: other location technologies are used to "prime" the GPS algorithm; it's iterative and works best with a moderately accurate starting point

Cell Tower Location

- Especially in urban areas, phones typically hear multiple cell phone towers
  - Towers are at known locations
  - They typically broadcast to three *sectors* using different antennas
  - Signal strength used depends on the range
- By hearing multiple towers, it's possible to construct a Venn diagram to locate a phone
- With more towers heard and/or small cells—and both are increasingly common—location can be determined reasonably accurately
- **Accuracy:** Varies; much better in urban areas, often poor (~2 km² area) in rural areas

Tower Dumps

- A cell tower knows all phones that have connected to it during a given period
- It is possible to ask “who connected to Sector X on Tower Y during such-and-such an interval?”—a *tower dump*
- Tower dumps and the Fourth Amendment
  - Is a tower dump a search?
  - Is it reasonable?
  - Is it particularized?

Signaling System 7

- The phone network needs to know where your cell phone is, to route calls appropriately
- Telephone company “switches” use a protocol known as SS7 to talk to other switches; among other things, cell phone roaming data is exchanged as needed
- Since you can roam anywhere in the world, any phone company in the world can ask your phone company where your phone is
- It’s actually very easy to set up a small “phone company” and join the SS7 network, and hence learn where anyone is
- Or: you can hack a telco or bribe one of its employees

Historical Location Information

- Unlike other types of location-tracking, cell tower data is routinely archived by phone companies
  - Use for billing, engineering, etc.
- This provides a time machine—where was this person, when?

WiFi/Bluetooth Location Information

- WiFi base stations have a range of about 100m; Bluetooth, about 10m
- *If* you know where the base stations are, you can calculate location the same way you do with cell towers—but because the signal range is much shorter (cell towers can have a ~1.5 km radius), the location is much more precise
- The trick is building up the database of base station locations—but companies have done it
  - Google StreetView vans also map WiFi base stations

Privacy Issues

- This scheme requires the device to query someone else's database
- *You can't rationally download the list of every WiFi base station in the world*
- Also: when a phone learns its location, it can record it internally; this information can be recovered by forensic analysis.

> 20. During a subsequent search of [redacted] Apple iPhone on or about January 12, 2021, agents were unable to recover data for photos, videos, chats, or messages from approximately January 4 through January 7, 2021. Agents also were unable to recover device location data for January 6, 2021, from 5:40AM to 4:17PM. At the same time, agents were able to recover device location data for January 6, 2021, at 4:23PM. This data indicated that the device was utilizing a WiFi system located at GPS coordinates (38.892002, -77.006646). According to Google Maps, these coordinates correspond to a location just northeast of the U.S. Capitol building.

WiFi Hotspots

- The operator of a hotspot can log the MAC addresses of devices that connect
- It can also monitor what websites they connect to
- MAC addresses are not PII—personally identifiable information—but they're reasonably constant over time, and can be used to track return visitors
- Some sites require registration

Nordstrom tracking customer movement via smartphones' WiFi sniffing

IP Geolocation

- Much like (landline) phone numbers, IP addresses are allocated in blocks, and hierarchically
- This implies geographic allocation; location is often embedded in infrastructure hostnames
- Conclusion: anyone you talk to on the Internet knows your (approximate) location
- You can’t (easily) do anything about it
- **Accuracy:** City

154.54.12.22	sprint.**jfk**10.atlas.cogentco.com
144.232.18.7	sl-crs2-**chi**-be2.sprintlink.net
206.82.104.100	net2ez-**ewr**.netarch.akamai.com
199.109.11.34	i2-**clev**-**buf**-9208.nysernet.net

There are Errors!

- There are some IP addresses for which the mapping companies don't have a decent location
- Some IP geolocation companies assigned a default <longitude,latitude> value
- Some of those were actual residences—and the people who live there have been harassed

Voluntary Location Disclosure

- Many apps *need* to know where you are
  - Mapping applications—obvious
  - Weather apps—obvious
  - Tinder et al.—who is nearby?
- What happens to this information?
- *Many services share—or sell—the data*

Location-Tracking Summary

Type	Who	Historical	Devices	Consent	Accuracy (Radius)
GPS	User	No	Phone, standalone	Yes	4.9 meters
Cell Tower	User, network	Yes	Phone	Maybe	1.5 km (plus sector)
WiFi/Bluetooth	User*	Maybe	Phone, computer, IoT	Maybe	A few meters
IP Address	Network	Maybe	All	No	City
Voluntary	User	Maybe	All	Yes	Varies

The Value of Location Data

Selling Location Data

- Location data is very valuable for marketing
- Sometimes, all that's needed is aggregate data
- Other times, though, you want to market location-dependent products to people

> The Notify Nearby is a proximity marketing start-up whose platform allows retailers to send promotions through the Notify Nearby app. The technology is based on iBeacons (provided by Estimote) which are installed and customised by Notify Nearby in cooperation with retailers. Retailers have an online platform to easily

Users Don’t Know

From the New York Times:

- “At least 75 companies receive anonymous, precise location data from apps whose users enable location services to get local news and weather or other information, The Times found. Several of those businesses claim to track up to 200 million mobile devices in the United States”
- “Tell All Digital, a Long Island advertising firm that is a client of a location company, says it runs ad campaigns for personal injury lawyers targeting people anonymously in emergency rooms.”
- “Even industry insiders acknowledge that many people either don’t read those policies or may not fully understand their opaque language.”

Insufficient Checks

- Cell phone companies often sell location data to other companies
- Some of them sell to law enforcement, bounty hunters, etc.

Private Movements

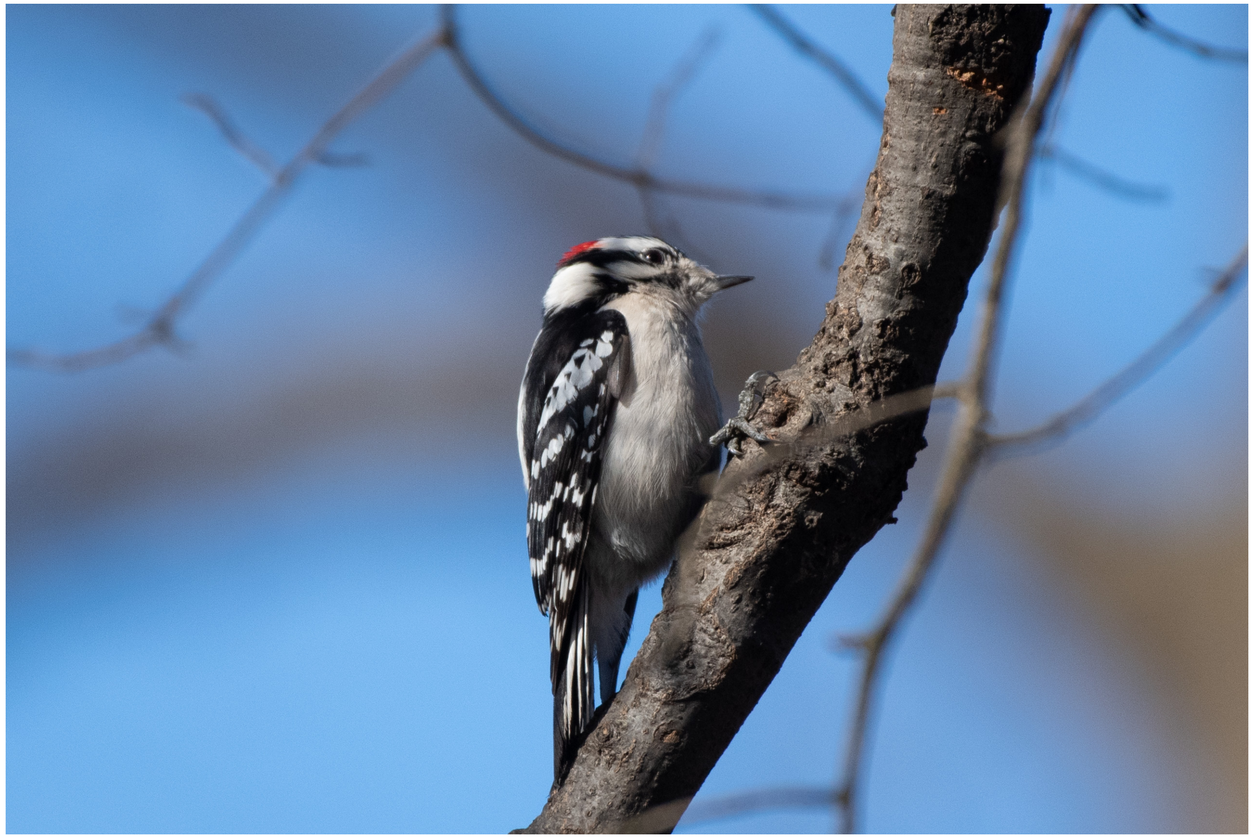
- “Disclosed in [GPS] data . . . will be trips the indisputably private nature of which takes little imagination to conjure: trips to the psychiatrist, the plastic surgeon, the abortion clinic, the AIDS treatment center, the strip club, the criminal defense attorney, the by-the-hour motel, the union meeting, the mosque, synagogue or church, the gay bar and on and on” (Sotomayor’s concurrence in *Jones*)

- “One path tracks someone from a home outside Newark to a nearby Planned Parenthood, remaining there for more than an hour.” (*New York Times*, reporting on actual collected data)

Patterns of Movement

- Few people have the same movement pattern
- Using cell tower location granularity, “four spatio-temporal points are enough to uniquely identify 95% of the individuals” (de Montjoye et al.)
- The “uniqueness of mobility traces decays approximately as the 1/10 power of their resolution. Hence, even coarse datasets provide little anonymity.”
- No “significant changes in user regularity over the weekends compared with their weekday mobility, which suggested that regularity is not imposed by the work schedule, but potentially is intrinsic to human activities.” (Song et al.)

Questions?



(Downy woodpecker, Central Park, March 1, 2020—this bird doesn't migrate…)