CS 528 Mobile and Ubiquitous Computing

Lecture 5b: Mobile and Location-Aware Computing

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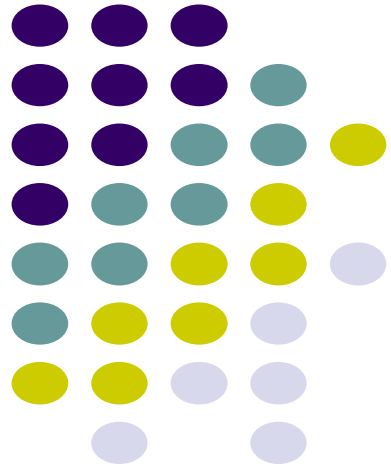
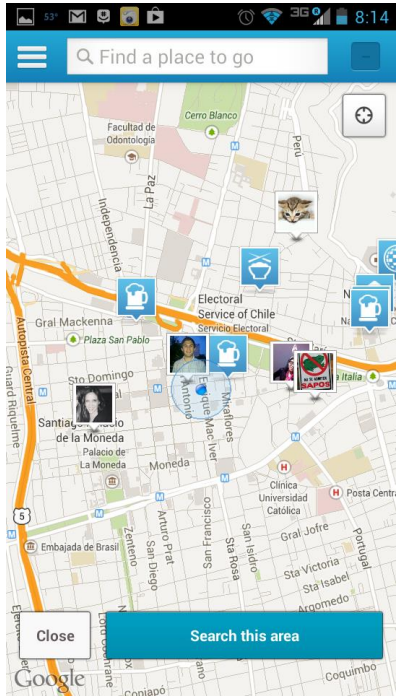


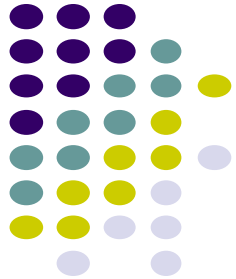
Location-Aware Computing

- **Definition:** Location-aware applications generate outputs/behaviors that depend on a user's location

- Examples:
  - Map of user's "current location"
  - Print to "closest" printer
  - Apps that find user's friends "closeby"
  - Reviews of "closeby" restaurants

- Apps above require first determining user's location

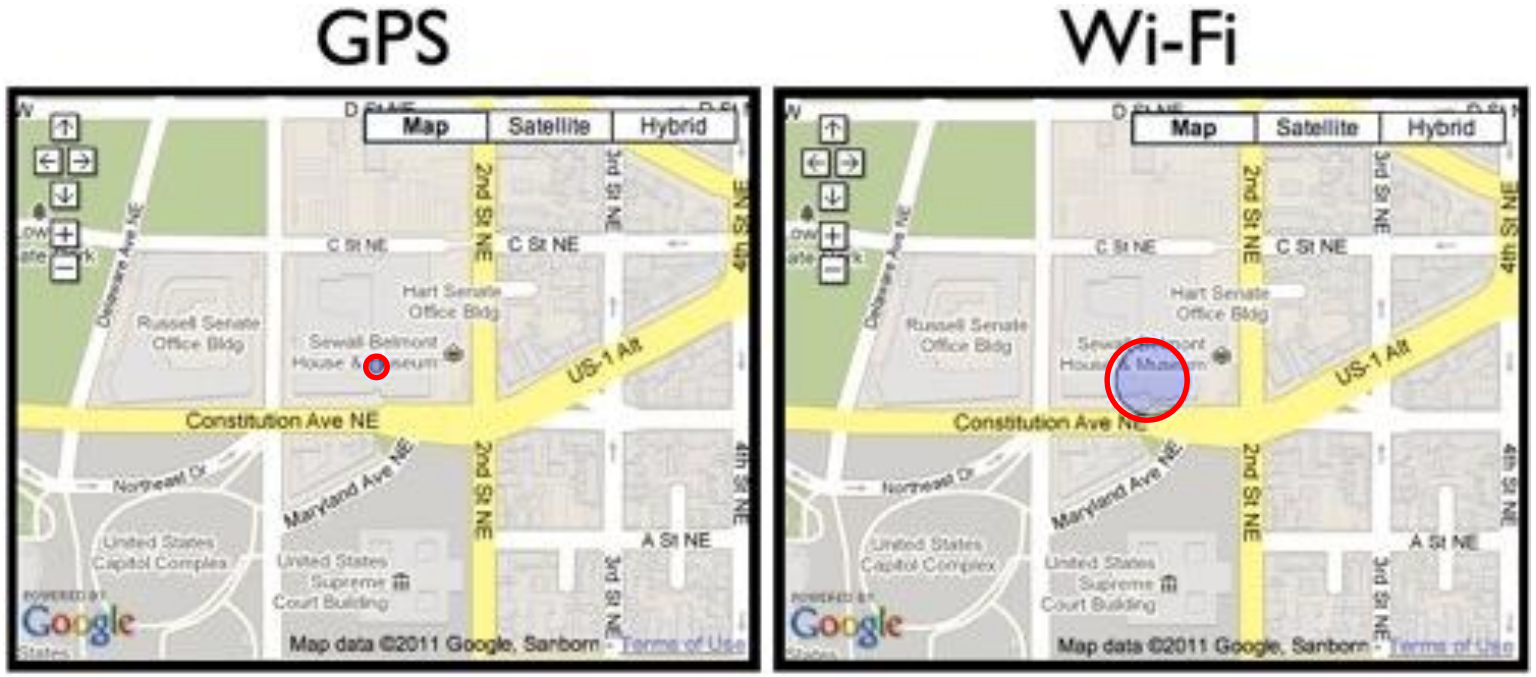




Determining User Location on Smartphones

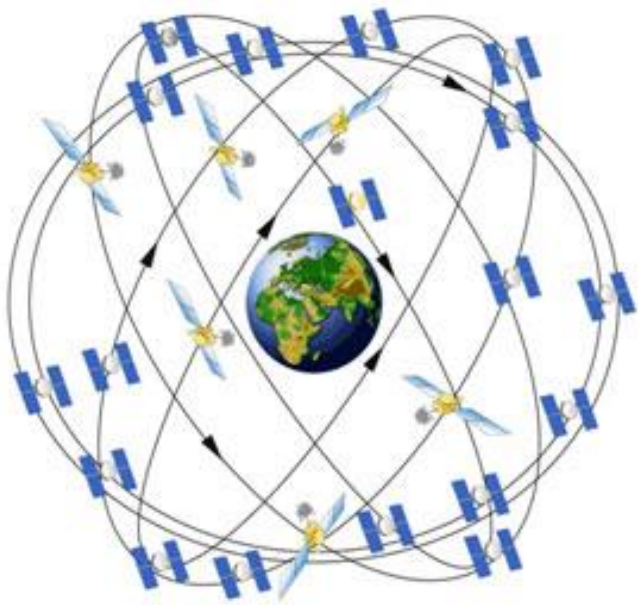
Location Tracking on Smartphones

- **Outdoors:** Uses GPS (More accurate)
- **Indoors:** WiFi or cell tower signals (Location fingerprinting, less accurate)



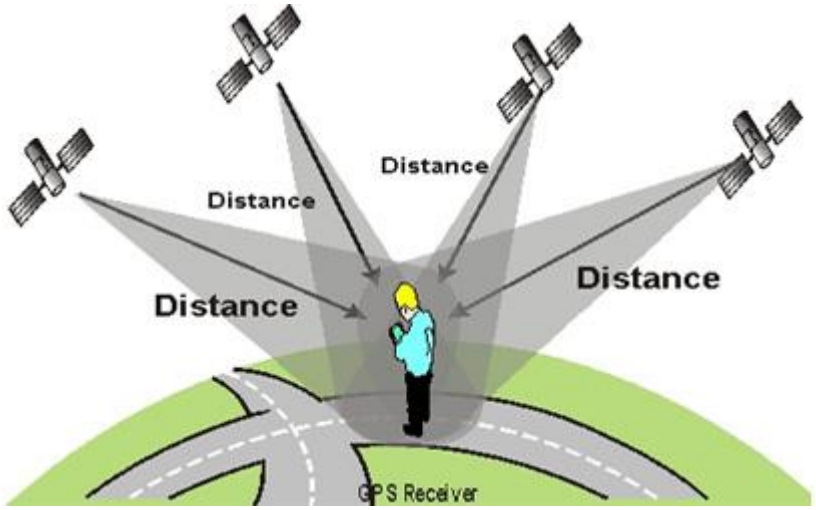
Global Positioning System (GPS)

- 27 satellites orbiting earth
- **20,000 km above earth** (Medium earth orbit)
- 6 orbital planes with 4 satellites each
- 4 satellites visible from any spot on earth
- Location of any location on earth specified as <longitude,latitude>
- E.g. Worcester MA has **Latitude:** 42.2625,
  Longitude: -71.8027778



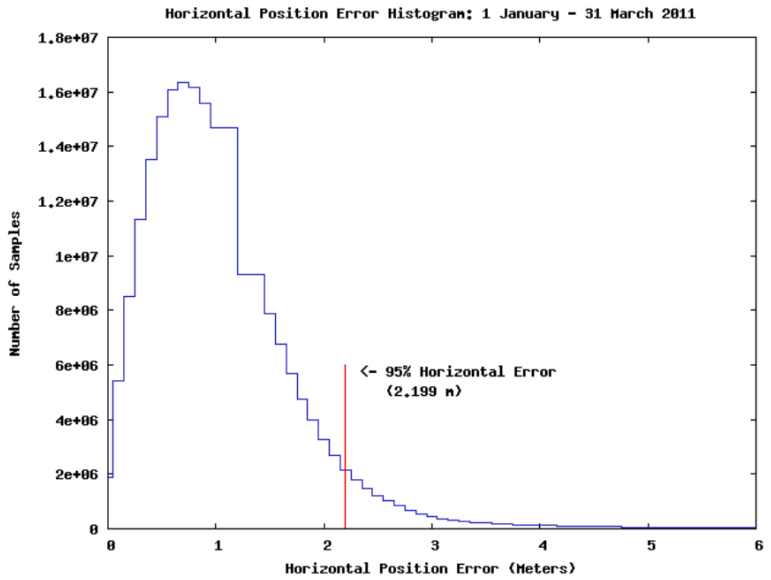
GPS User Segment

- **Triangulation:** GPS receiver calculates user's position by comparing delay of signals from multiple satellites at known positions



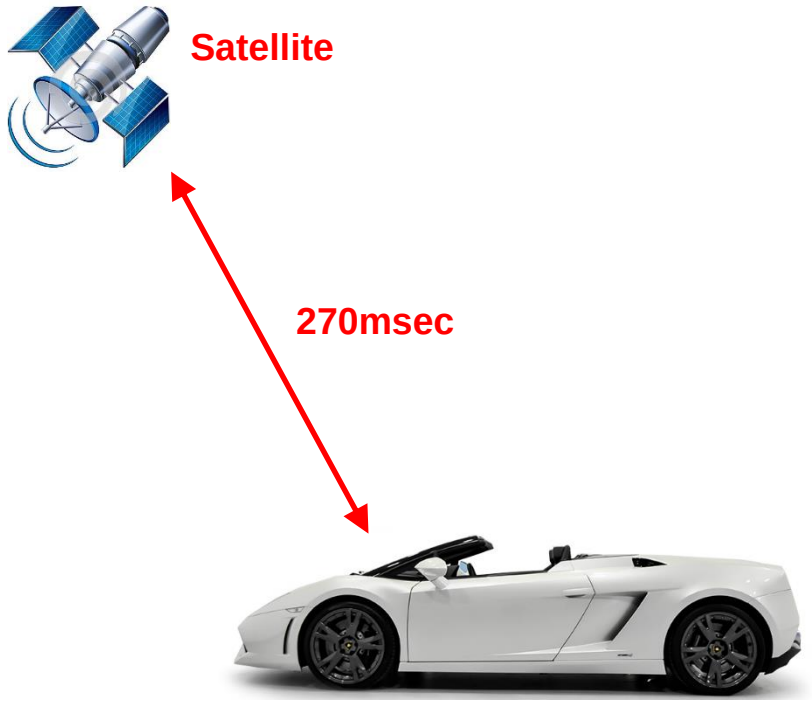
http://adamswalk.com/gpx-2/

- Accuracy within 5 - 10 meters (16-32 feet)



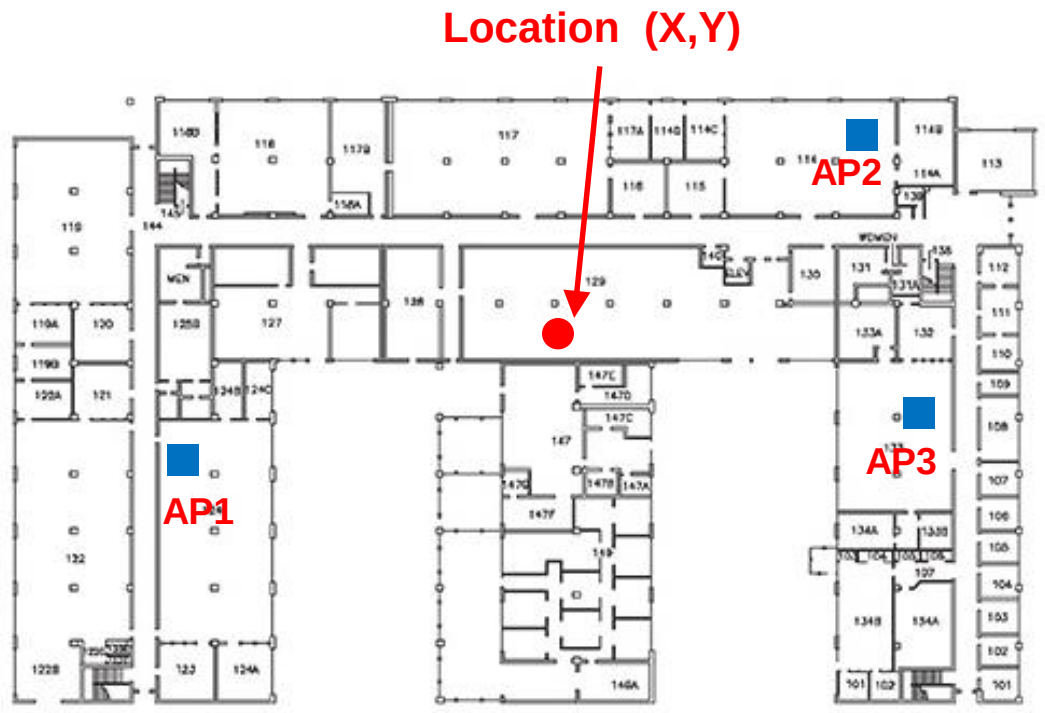
Determining User Location

- GPS reasonably accurate but
  - Requires line-of-sight between satellite and car receiver
  - Only works OUTDOORS (signals don't penetrate buildings)
  - **Lag/delay** in acquiring satellites (~270 msec) or re- acquiring if lost
  - Drains battery power
- **Alternative:** Use Wi-Fi location sensing indoors

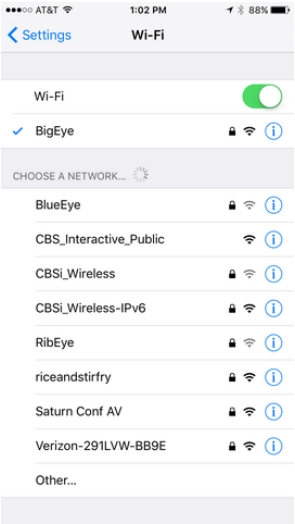


WiFi Location Fingerprinting

- **Key insight:** At each (X,Y) location, WiFi APs observed + their signal strengths, is unique



OBSERVED AP SIGNAL STRENGTH			
	AP1	AP2	AP3
(X,Y)	24	36	45



- **WiFi Location fingerprinting:** Infer device's location based on combination of Wi-Fi access points seen + Signal Strengths

Location Estimation using Wi-Fi Fingerprinting

PRE-RECORDED TUPLES					
LOCATION		SIGNAL STRENGTH			
X	Y	AP1	AP2	AP3	AP4
:::	:::	:::	:::	:::	:::
80	145	32	28	12	8
40	145	36	20	10	6
:::	:::	:::	:::	:::	:::
220	355	-	25	36	44
260	355	4	21	39	42
:::	:::	:::	:::	:::	:::
350	210	16	-	28	36
:::	:::	:::	:::	:::	:::
380	145	22	12	-	44
:::	:::	:::	:::	:::	:::

OBSERVED SIGNAL STRENGTH			
AP1	AP2	AP3	AP4
-	24	36	45

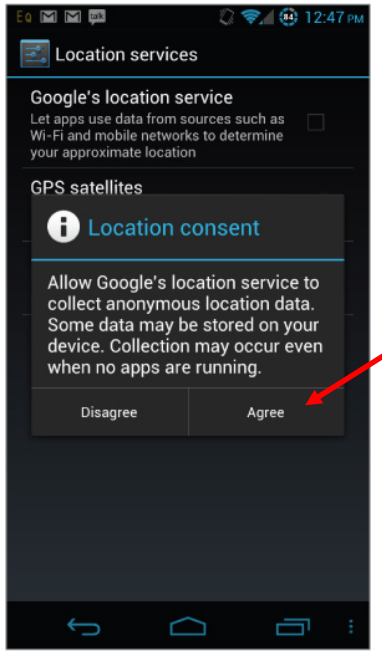
Location (X,Y)??

- Inference Algorithms
  - Min. Threshold
  - Euclidean Dist.
  - Joint Probability
  - Bayesian Filters

Google builds and stores this database (APs + Signal Strength) at each X,Y location)

How to Build table of APs observed at (X,Y) Locations?

- Devices (e.g. smartphone) with GPS and WiFi turned on simultaneously build table
- Send data to third party repositories (e.g. Wigle.net) or Google
- Also called **war driving**
- Can record cell tower signal strength instead of AP

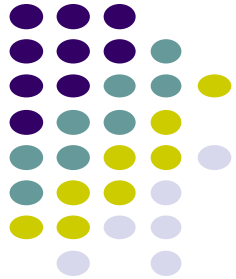


Google gathers Location, AP seen Data if you consent

PRE-RECORDED TUPLES					
LOCATION		SIGNAL STRENGTH			
X	Y	AP1	AP2	AP3	AP4
:::	:::	:::	:::	:::	:::
80	145	32	28	12	8
40	145	36	20	10	6
:::	:::	:::	:::	:::	:::
220	355	-	25	36	44
260	355	4	21	39	42

GPS gathers Location (X,Y)

WiFi card gathers APs seen + Signal Strengths

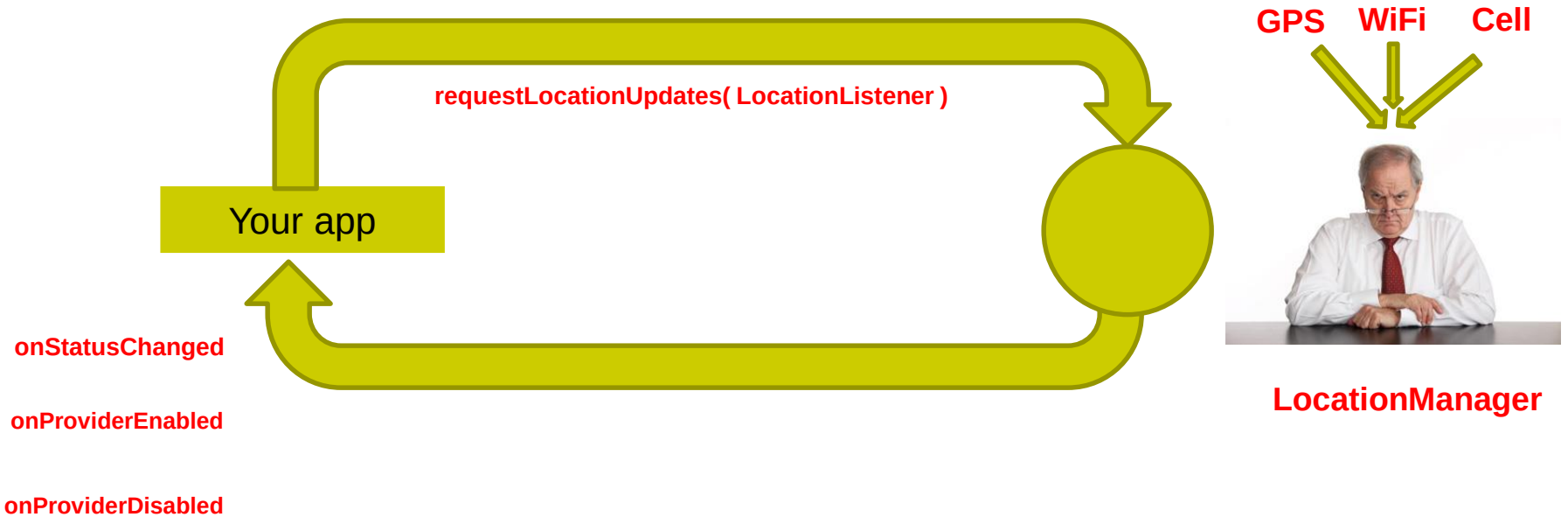


Location Sensing in Android Apps

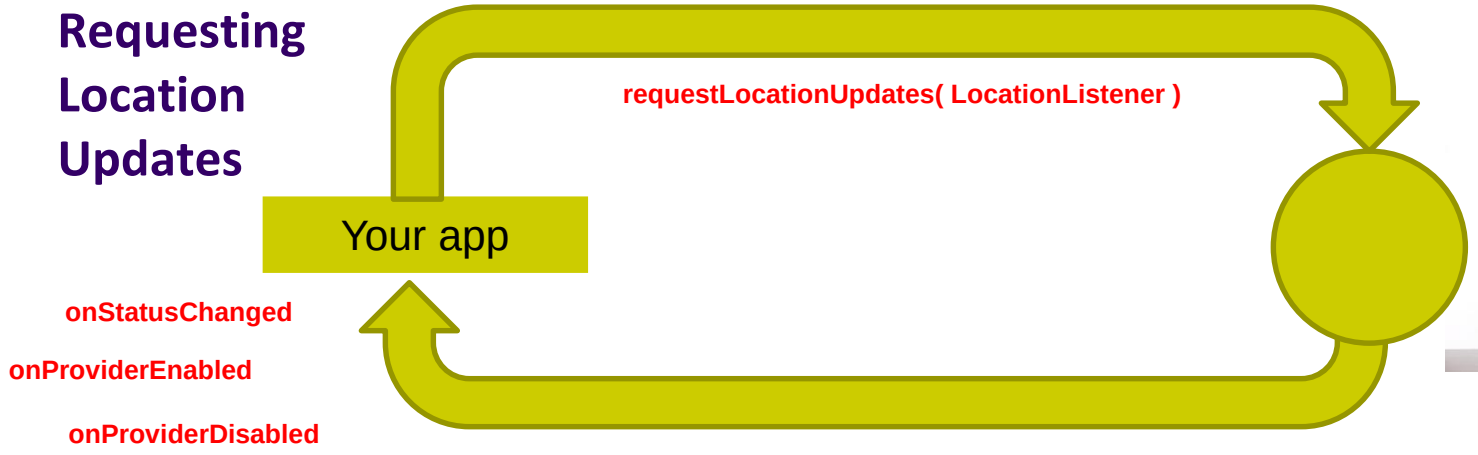
Google Location APIs

https://developer.android.com/guide/topics/location/strategies.html

- Android now has 2 location APIs (older vs newer)
- Newer nocation API is now part of Google Play Services
- Older Android framework location APIs (**android.location**)
  - Used by most books, online sources. We will use that
  - http://developer.android.com/guide/topics/location/strategies.html
- **LocationManager:**
  - Android module receives location updates from GPS, WiFi, etc
  - App registers/requests location updates from LocationManager



Requesting Location Updates



LocationManager

```
// Acquire a reference to the system Location Manager
LocationManager locationManager = (LocationManager) this.getSystemService(Context.LOCATION_SERVICE);

// Define a listener that responds to location updates
LocationListener locationListener = new LocationListener() {
    public void onLocationChanged(Location location) {
      // Called when a new location is found by the network location provider.
      makeUseOfNewLocation(location);
    }

    public void onStatusChanged(String provider, int status, Bundle extras) {}

    public void onProviderEnabled(String provider) {}

    public void onProviderDisabled(String provider) {}
  };

// Register the listener with the Location Manager to receive location updates
locationManager.requestLocationUpdates(LocationManager.NETWORK_PROVIDER, 0, 0, locationListener);
```

Create listener for Location info

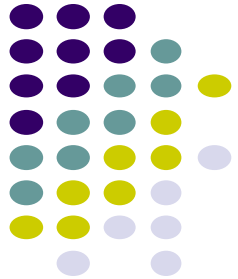
Callback methods called by Location manager (e.g. when location changes))

Type of location Provider (e.g. cell tower and Wi-Fi based)

Listener that receives callbacks

Requesting User Permissions

https://developer.android.com/guide/topics/location/strategies.html



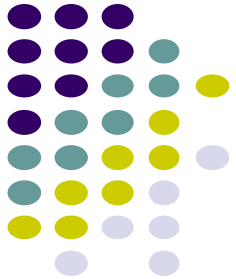
- Need smartphone owner's permission to use their GPS

```
<manifest ... >
    <uses-permission android:name="android.permission.ACCESS_FINE_LOCATION" />
    ...
    <!-- Needed only if your app targets Android 5.0 (API level 21) or higher. -->
    <uses-feature android:name="android.hardware.location.gps" />
    ...
</manifest>
```

- **ACCESS_FINE_LOCATION:** GPS
- **ACCESS_COARSE_LOCATION:** WiFi or cell towers

Getting Cached Copy of Location (Fast)

https://developer.android.com/guide/topics/location/strategies.html



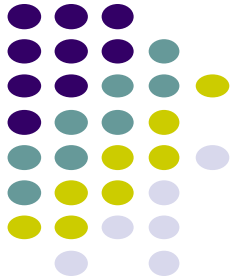
- Getting current location may take a while
- Can choose to use location cached (possibly stale) from Location Manager

```
String locationProvider = LocationManager.NETWORK_PROVIDER;
// Or use LocationManager.GPS_PROVIDER

Location lastKnownLocation = locationManager.getLastKnownLocation(locationProvider);
```

Stopping Listening for Location Updates

https://developer.android.com/guide/topics/location/strategies.html



- Location updates consume battery power
- Stop listening for location updates whenever you no longer need

```
// Remove the listener you previously added
locationManager.removeUpdates(locationListener);
```

Location Representation

Semantic Location

- GPS represents location as <longitude,latitude>
- **Semantic location** is better for reasoning about locations
- **E.g.** Street address (140 Park Avenue, Worcester, MA) or (building, floor, room)
- **Android supports:**
  - **Geocoding:** Convert addresses into longitude/latitude coordinates
  - **Reverse geocoding:** convert longitude/latitude coordinates into human readable address

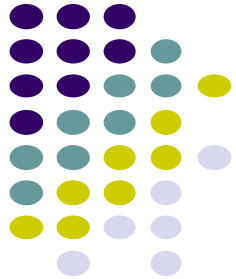
- **Android Geocoding API:** access to **geocoding** and **reverse geocoding** services using HTTP requests

Google Places API Overview

- Access **high-quality photos** of a place
- Users can also add place information to the database
  - E.g. business owners can add their business as a place in Places database
  - Other apps can then retrieve info after moderation

- **On-device caching:** Can cache places data locally on device to avoid roundtrip delays on future requests

Google Places



- **Place:** physical space that has a name (e.g. local businesses, points of interest, geographic locations)
  - E.g Logan airport, place type is **airport**
- **API:** Provides Contextual information about places near device.
- **E.g:** name of place, address, geographical location, place ID, phone number, place type, website URL, etc.
- Compliments geographic-based services offered by Android location services

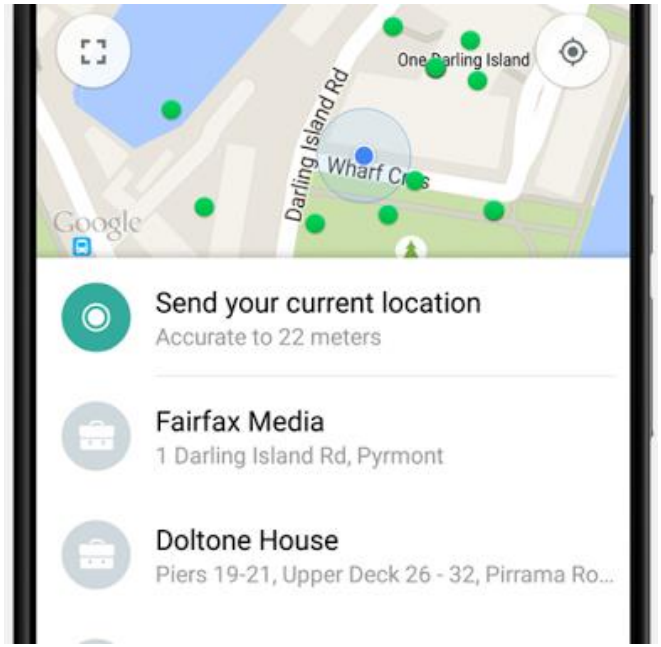
Sample Place Types

- accounting
- airport
- amusement_park
- aquarium
- art_gallery
- atm
- bakery
- bank
- bar
- beauty_salon
- bicycle_store
- book_store
- bowling_alley
- bus_station
- cafe
- campground
- car_dealer
- car_rental
- car_repair
- car_wash
- hospital
- insurance_agency
- jewelry_store
- laundry
- lawyer
- library
- liquor_store
- local_government_office
- locksmith
- lodging
- meal_delivery
- meal_takeaway
- mosque
- movie_rental
- movie_theater
- moving_company
- museum
- night_club
- painter
- park
- city_hall
- clothing_store
- convenience_store
- courthouse
- dentist
- department_store
- doctor
- electrician
- electronics_store
- embassy
- establishment (deprecated)
- finance (deprecated)
- fire_station
- florist
- food (deprecated)
- funeral_home
- furniture_store
- gas_station
- general_contractor (deprecated)
- grocery_or_supermarket
- gym
- hair_care
- hardware_store
- health (deprecated)
- hindu_temple
- home_goods_store
- physiotherapist
- place_of_worship (deprecated)
- plumber
- police
- post_office
- real_estate_agency
- restaurant
- roofing_contractor
- rv_park
- school
- shoe_store
- shopping_mall
- spa
- stadium
- storage
- store
- subway_station
- synagogue
- taxi_stand
- train_station
- transit_station
- travel_agency
- university
- veterinary_care
- zoo

Google Places API Overview

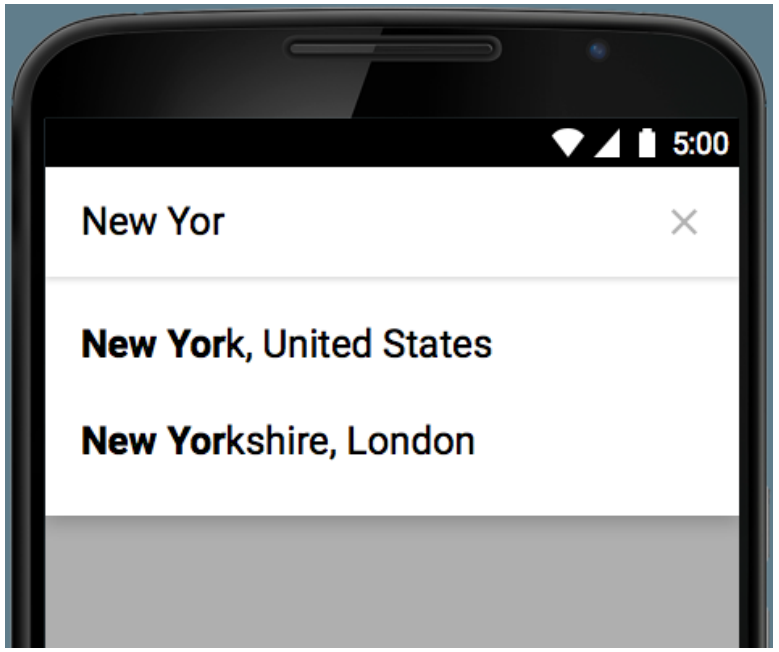
- **Use Place picker UI:** allows users select place from “possible place” on a map

- **Get current place:** place where device is last known to be located
  - Returns **list** of likely places + likelihood device is in that place

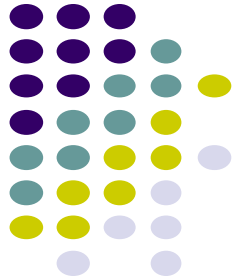


Google Places API Overview

- **Autocomplete:** queries the location database as users type, suggests nearby places matching letters typed in



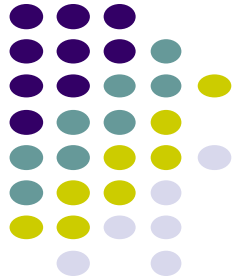
Learning Google Places API



- Official Google Places website is “decent”, up to date:
  - https://developers.google.com/places/android-sdk/intro

- Two great references:
  a) Getting started with Google Places API
     https://developers.google.com/places/android-sdk/start

  b) Tutorial by Paul Trebilcox-Ruiz may be more readable:
     - http://code.tutsplus.com/articles/google-play-services-using-the-places-api--cms-23715



Other Useful Google Maps/Location APIs

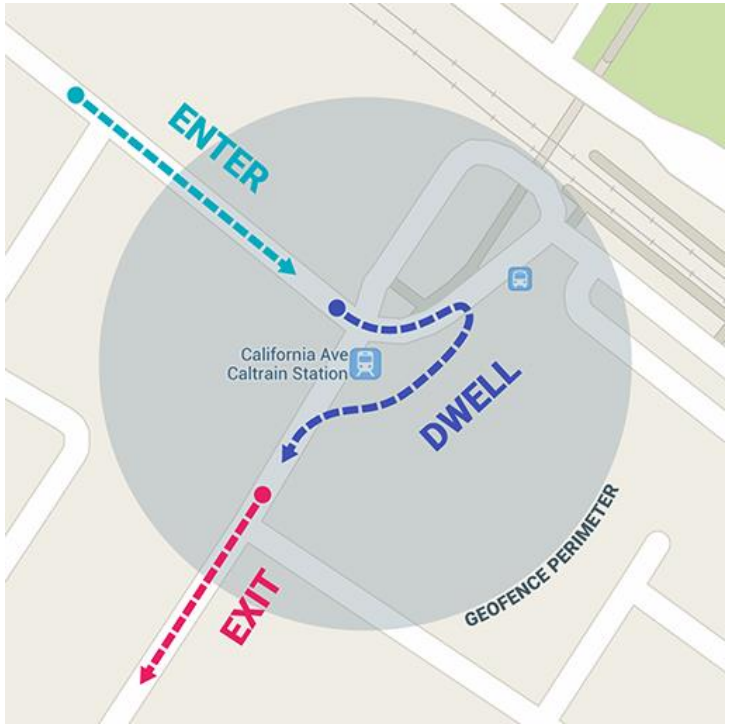
GeoFencing

https://developer.android.com/training/location/geofencing.html

- **Geofence:** Sends alerts when user is within a certain radius to a location of interest

- Can be configured to send:
  - **ENTER** event when user enters circle
  - **EXIT** event when user exits circle

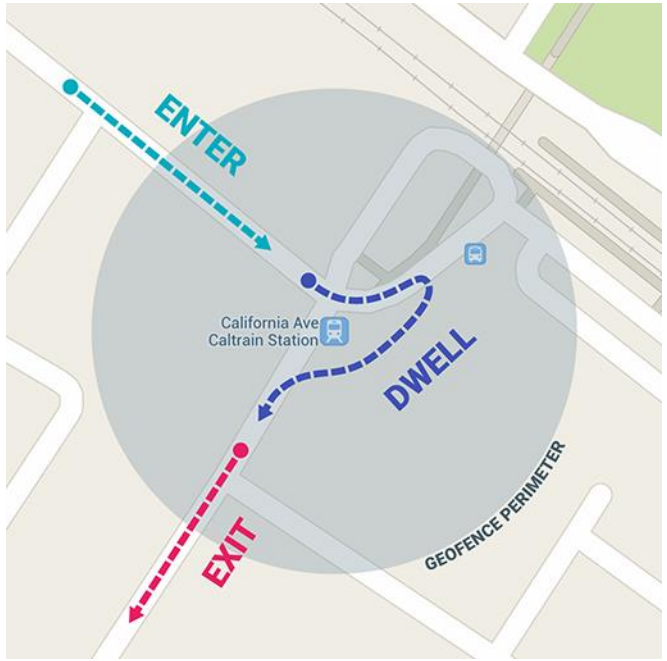
- Can also specify a duration or **DWELL** user must be in circle before triggering event



GeoFencing

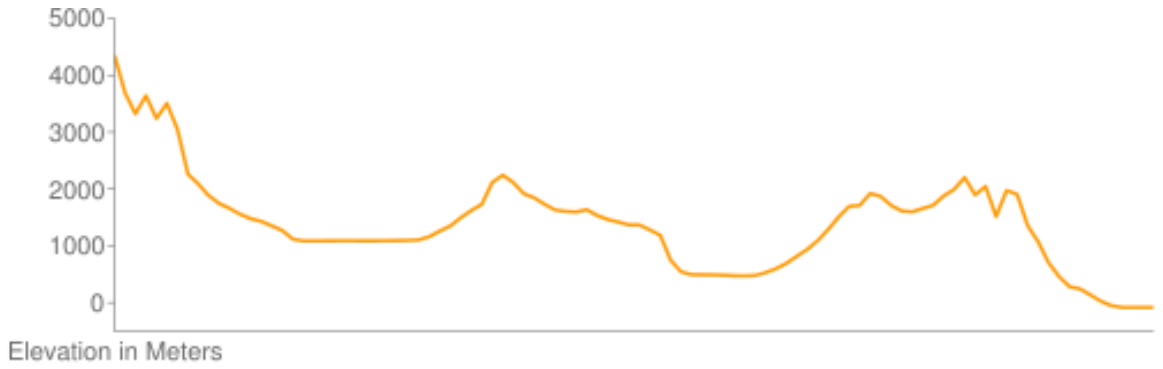
https://developer.android.com/training/location/geofencing.html

- **Great reference:**
  - How to work with GeoFences on Android by Tin Megali
    https://code.tutsplus.com/tutorials/how-to-work-with-geofences-on-android--cms-26639

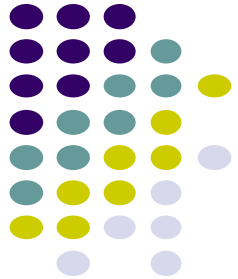


Other Maps/Useful Location APIs

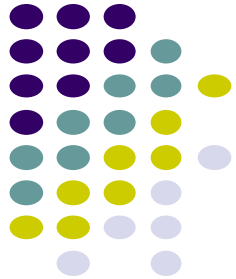
- **Maps Directions API:** calculates directions between locations (walking, driving) as well as public transport directions
- **Distance Matrix API:** Calculate travel time and distance for multiple destinations
- **Elevation API:** Query locations on earth for elevation information, calculate elevation changes along routes



Other Useful Maps/Location APIs



- **Roads API:**
  - snaps set of GPS coordinates to road user was likely travelling on (best fit)
  - Returns posted speed limits for any road segment (premium plan)
- **Time Zone API:** request time zone for location on earth



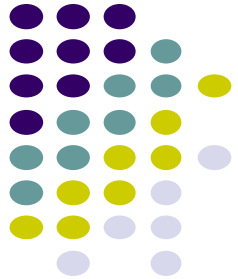
GPS Clustering & Analytics

Determining Points of Interest from GPS Location Sequences

- **Points of Interest:** Places where a person spends lots of time (e.g. home, work, café, etc)
- **Given a sequence GPS <longitude, latitude>** points, how to infer points of interest
- **General steps:**
  - **Pre-process sequence of GPS points** (remove outliers, etc)
  - **Cluster points**
  - **Convert to semantic location**

LATITUDE	LONGITUDE
35.33032098	80.42152478
35.29244028	80.42382271
35.33021993	80.45339956
35.35529007	80.45222096

Step 1: Pre-Processing GPS Points (Remove Noise and Outliers)



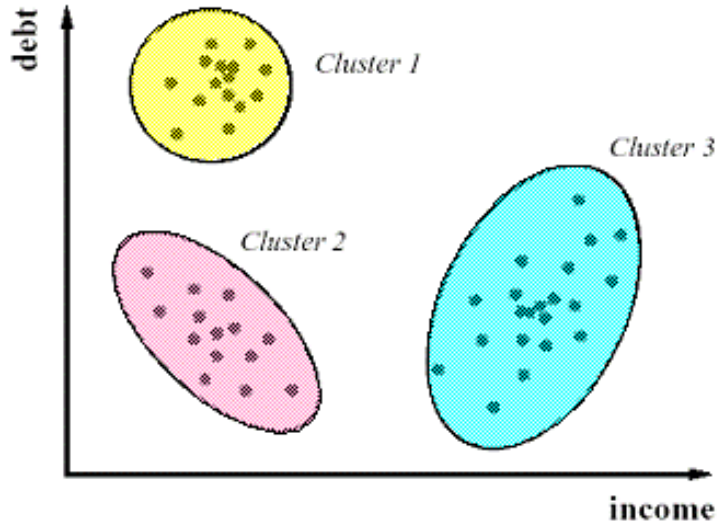
- **Remove low density points (few neighbors):**
  - i.e. places where little time was spent
  - E.g. radius of 20 meters, keep only clusters with at least 50 points
  - If GPS coordinates retrieved every minute, only considering places where you spent at least 50 minutes

- **Remove points with movement:**
  - GPS returns speed as well as <longitude, latitude> coordinates
  - If speed user is moving, discard that GPS point

- **Reduce data for stationary locations:**
  - When user is stationary at same location for long time, too many points generated (e.g. sitting at at chair)
  - Remove some points to speed up processing

Step 2: Cluster GPS Points

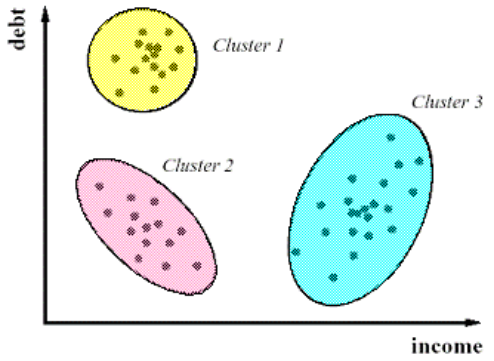
- **Cluster Analysis:** Group points



- Two main clustering approaches
  - K-means clustering
  - DBSCAN

K-Means Clustering

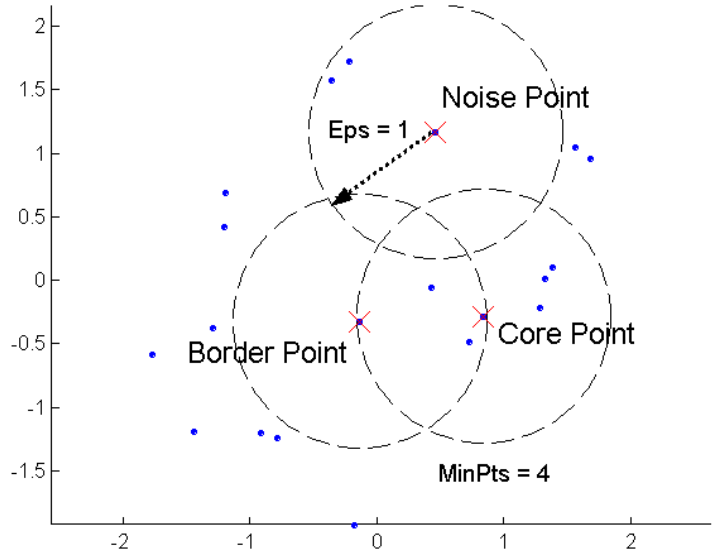
- Each cluster has a center point (centroid)
- Each point associated to cluster with closest centroid
- Number of clusters, *K*, must be specified
- Algorithm:



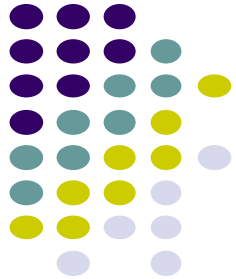
1: Select K points as the initial centroids.
2: **repeat**
3: Form K clusters by assigning all points to the closest centroid.
4: Recompute the centroid of each cluster.
5: **until** The centroids don't change

DBSCAN Clustering

- Density-based clustering
- **Density:** Number of points within specified radius (Eps)
- **Core points:** has > minPoints density
- **Border point:** has < minPoints density but within neighborhood of core point
- **Noise point:** not core point or border point



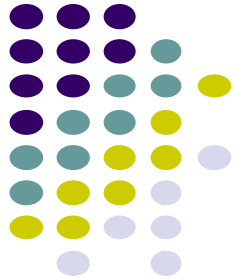
DBSCAN Algorithm



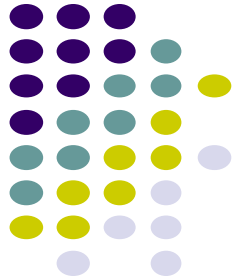
- Eliminate noise points
- **Cluster remaining points**

```
current_cluster_label ← 1
for all core points do
  if the core point has no cluster label then
    current_cluster_label ← current_cluster_label + 1
    Label the current core point with cluster label current_cluster_label
  end if
  for all points in the Eps-neighborhood, except i^th the point itself do
    if the point does not have a cluster label then
      Label the point with cluster label current_cluster_label
    end if
  end for
end for
```

Converting Clusters to Semantic Locations



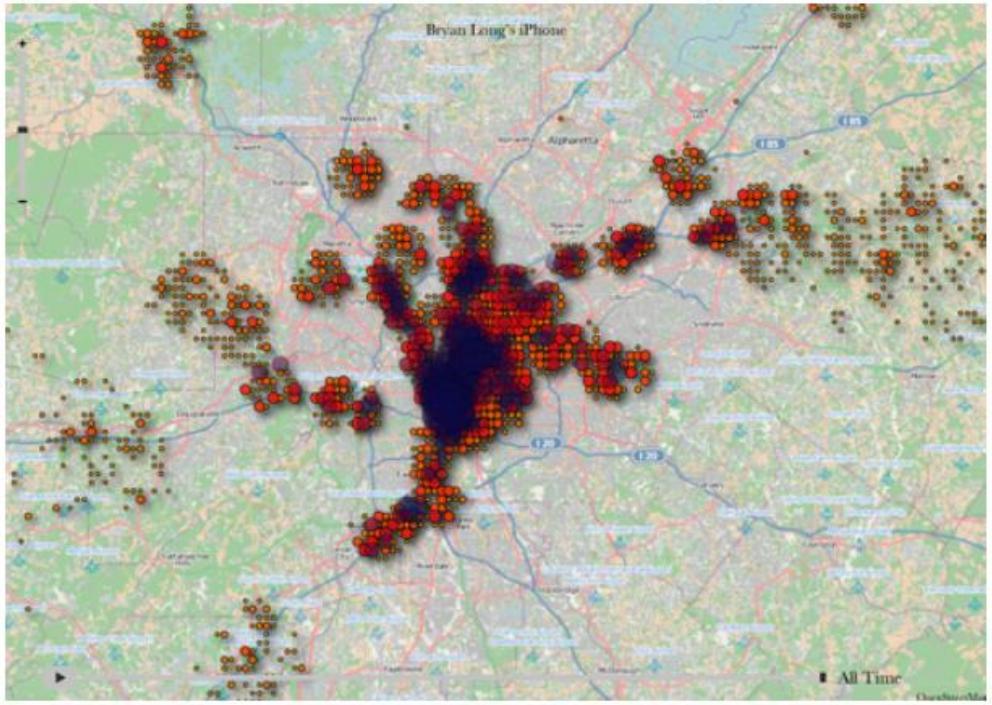
- Can simply call reverse geocoding or Google Places on the centroid of the clusters
- Determining work? Cluster where user spends longest time most time (9-5pm)
- Determining home? Cluster where user spends most time 6pm – 6am



Visualizing Points of Interests visited

Visualizing Points of Interest

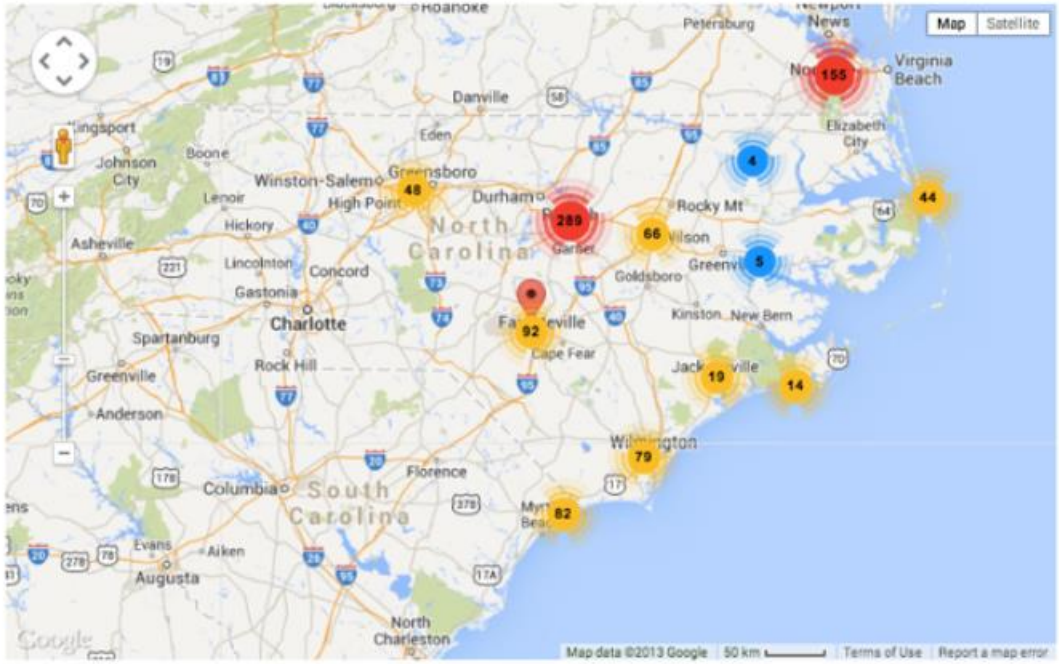
- Option 1:
  - Show a point for each location you visited?



Credit: Deepak Ganesan

Visualizing Points of Interest

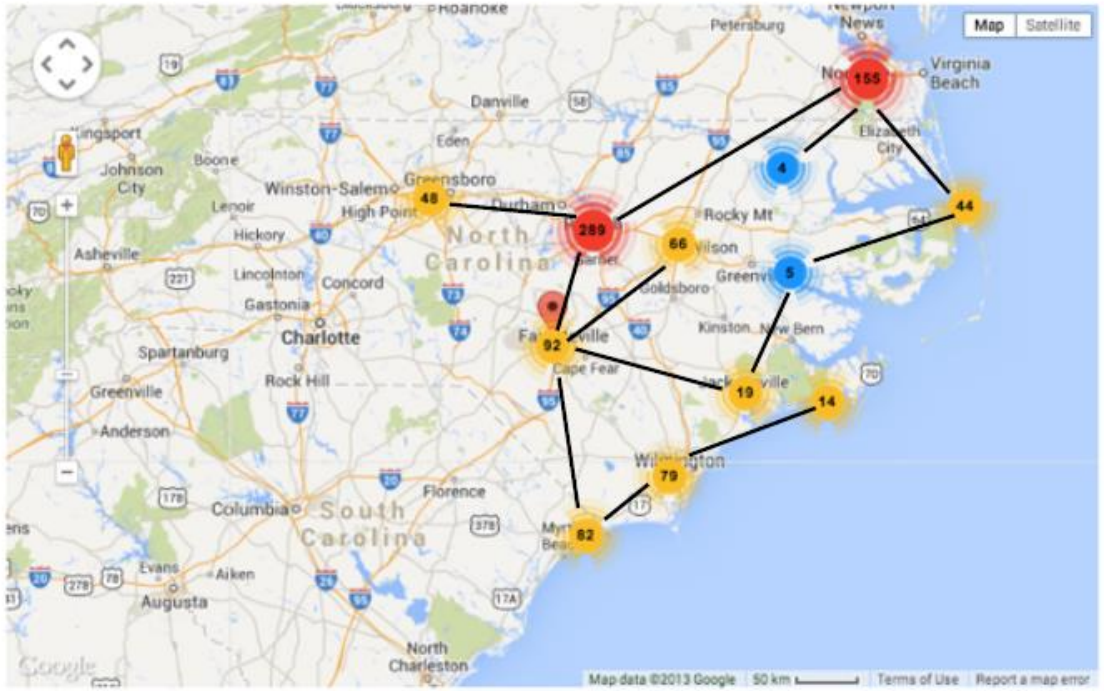
- Option 2:
  - Show a cluster for significant locations.



Credit: Deepak Ganesan

Visualizing Points of Interest

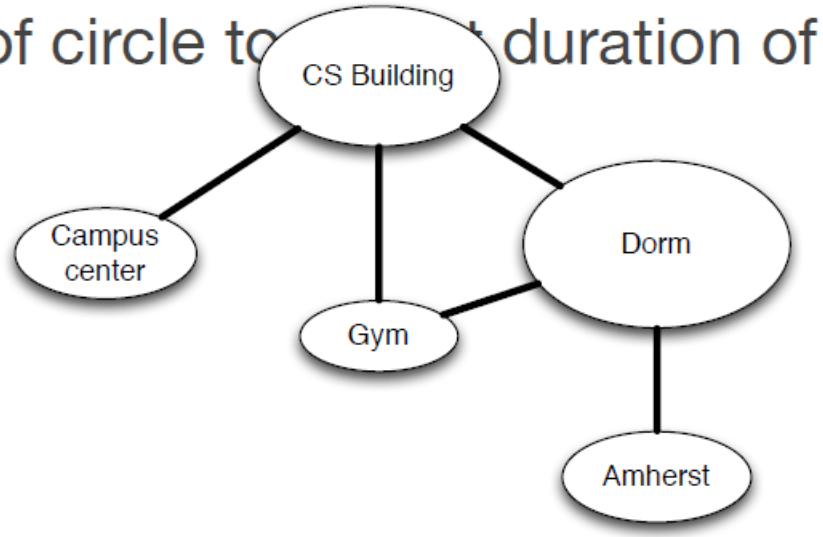
- Option 3:
  - Connect the clusters with lines



Credit: Deepak Ganesan

Visualizing Points of Interest

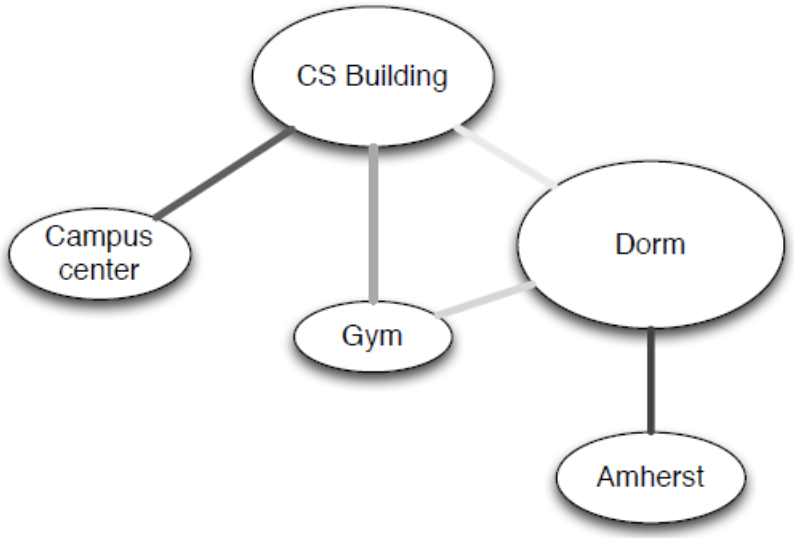
- Option 4
  - Show “semantic locations” instead of co-ordinates
  - Use size of circle to [illegible] duration of stay



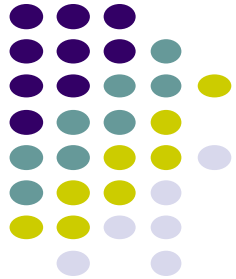
Credit: Deepak Ganesan

Visualizing Points of Interest

- Option 5
  - Show semantic locations with time-of-day encoded in line opacity/saturation.



Credit: Deepak Ganesan



Distance Travelled Updates using Services
Example from Head First Android

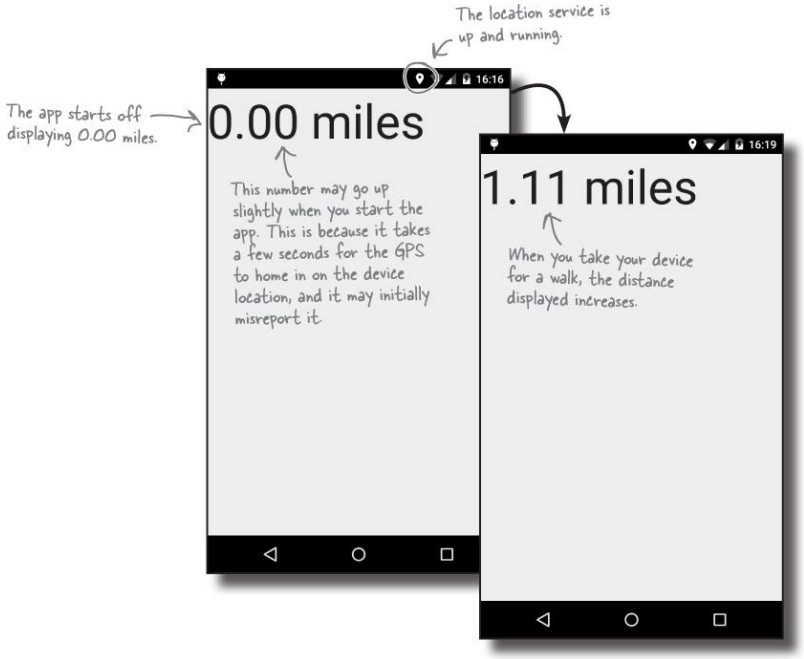
Example: Odometer (Distance Travelled) updates as a Services

(Ref: Head First Android pg 541)

- **Services:** long running background processes, no UI

- May want background service (a module in our app) to continuously retrieve location updates from LocationManager, forward updates to our Activity

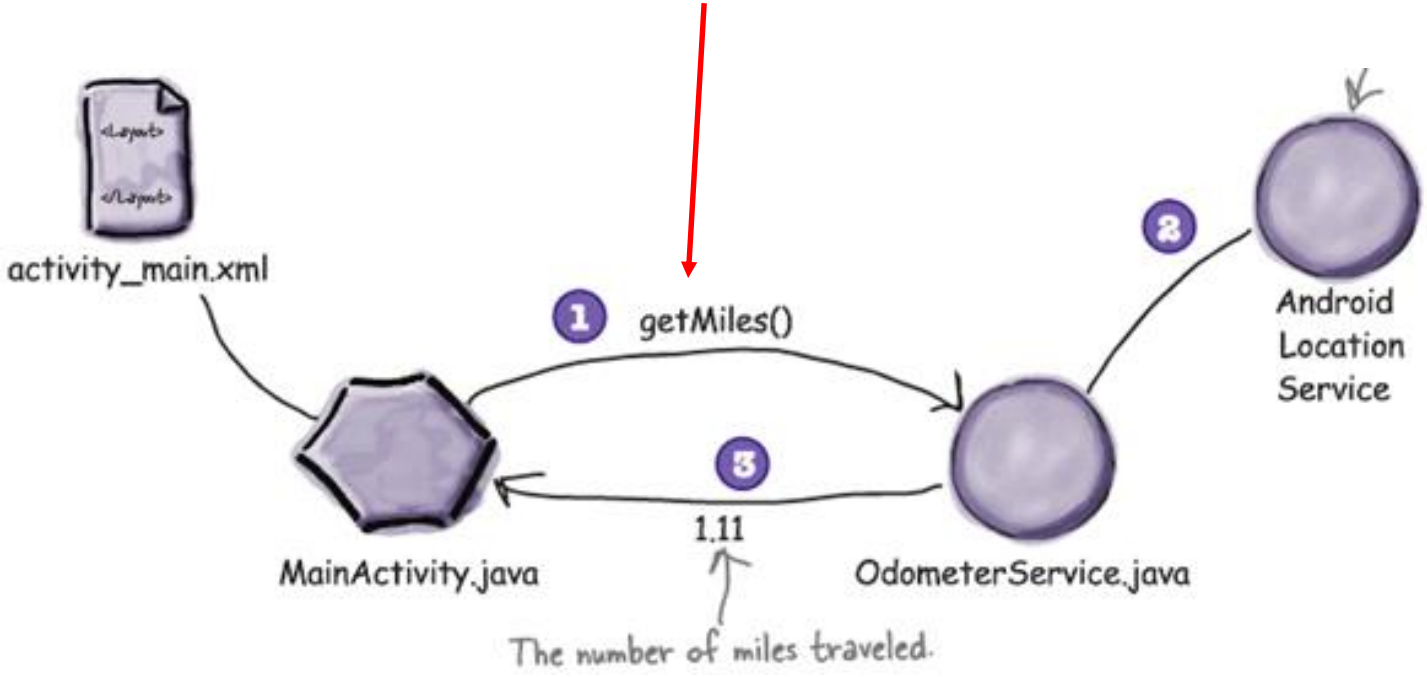
- Ref: Head First Android pg 541
  - Example of using a Service
  - Nice Example app using Odometer Service
  - Tracks distance travelled
  - Gets, displays distance travelled every 10 secs



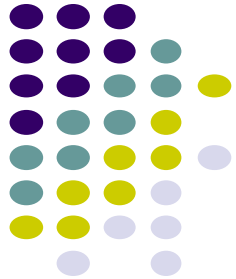
Example: Odometer (Distance Travelled) updates as a Services

(Ref: Head First Android pg 541)

- Example odometer app that tracks distance travelled
- getMiles( ), displays distance travelled every 10 seconds



Study this example!!!



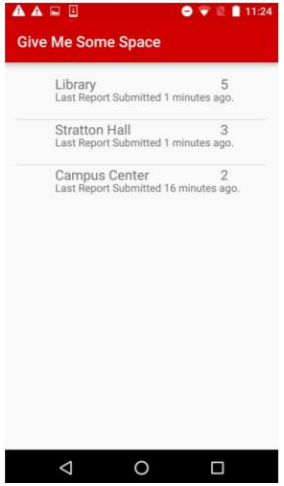
Location-Aware Apps from CS 4518

Location-Aware Final Projects from CS 4518 (Undergraduate offering)

- **Ground rules:**
  - Apps must use mobile, location or sensors
  - Try to solve problems of benefit to WPI community

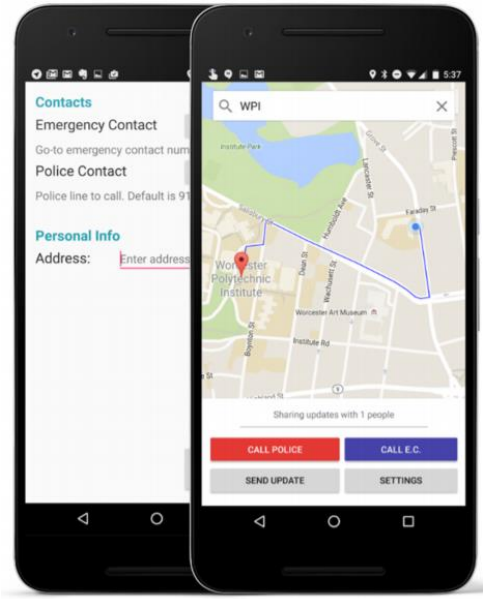
- More than half of apps used location.

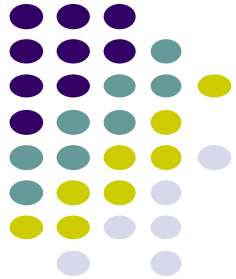
- **Give me some space:** Bianchi, Chow, Martinez ’16
  - Find available study spaces on campus during exam week
  - Set up geoFences at study locations, count users in/out



Location-Aware Ideas from Previous Offerings

- **HomeSafe:** Nickerson, Feeley, Faust ’16
  - Safety app
  - Automatically sends message to users’ subscribers when they get home safely



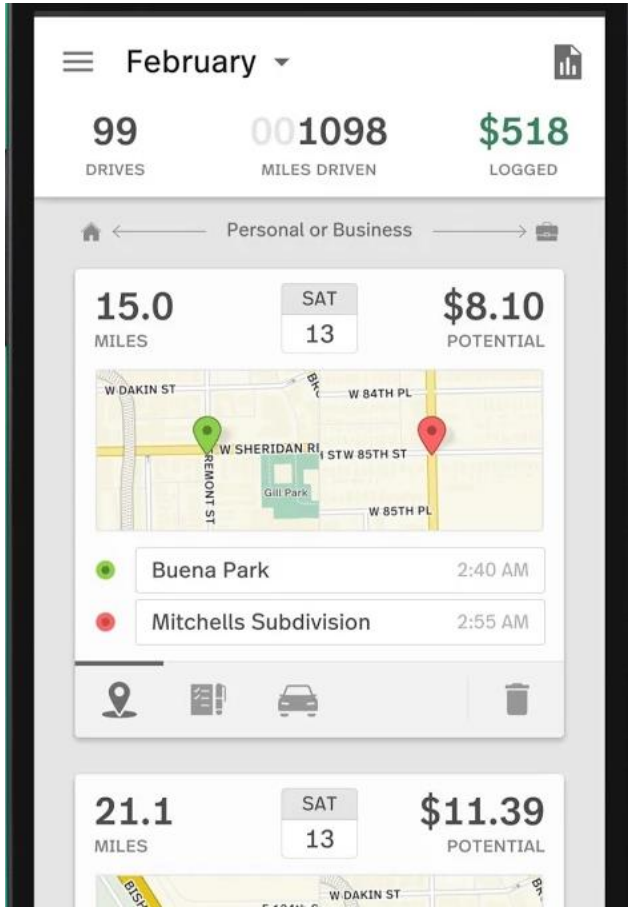


Some Interesting Location-Aware Apps

MileIQ

- **The Problem:** Mileage tracking is useful but a burden.
  - IRS deductions on taxes
  - Some companies reimburse employees for mileage,
- Passively, automatically tracks business mileage, IRS compliant
- Swipe right after drive to indicate it was a business trip
- Project idea? Implement some of this functionality

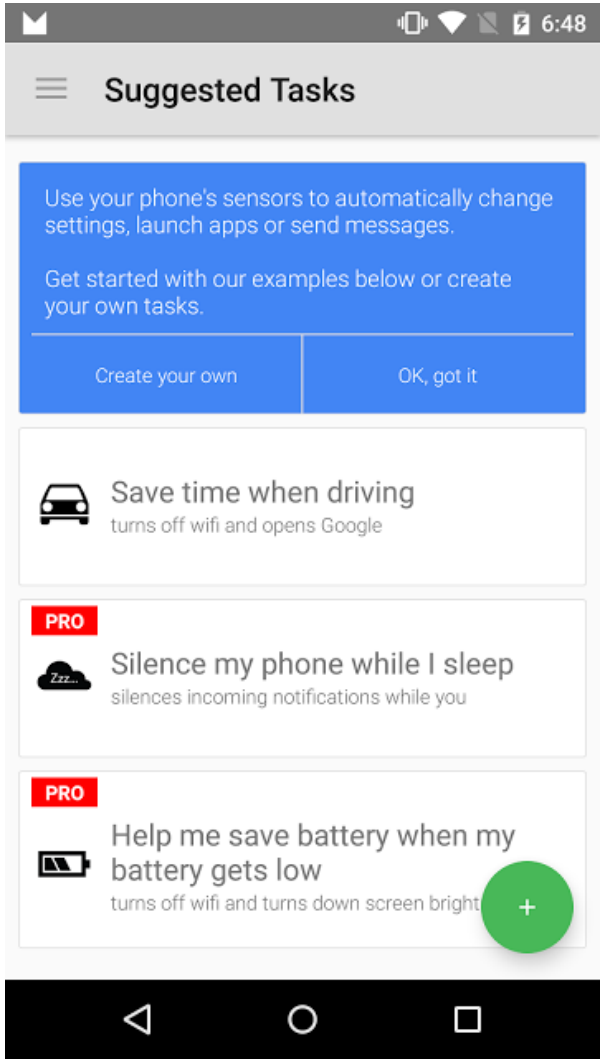
- **How Android modules? For what?**
- **What stats to decide if this is tackling important problem?**



Trigger

- Use geofences, NFC, bluetooth, WiFi connections, etc to set auto-behaviors
  - Battery low -> turn off bluetooth + auto sync
  - Silence phone every morning when you get to work
  - Turn off mobile data when you connect to your home WiFi
  - Silence phone and set alarm once I get into bed
  - Use geofence for automatic foursquare checkin
  - Launch maps when you connect to your car's bluetooth network
- Project idea? Implement subset of these features

- **What triggers would be useful for a WPI student?**



References

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- Liane Cassavoy, 21 Awesome GPS and Location-Aware Apps for Android,
- Head First Android
- Android Nerd Ranch, 2nd edition
- Busy Coder's guide to Android version 6.3
- CS 65/165 slides, Dartmouth College, Spring 2014
- CS 371M slides, U of Texas Austin, Spring 2014