Synchronization in LBS

Leon Goldin

Cisco Systems

Topics covered in the presentation

1. Location use cases
2. Localization basics.
3. Some ways of localizing an object
4. Emergency response: E911, LTE

Location use cases

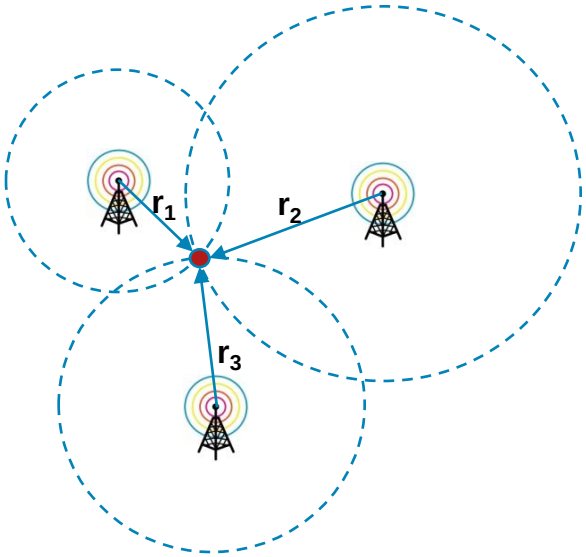
- Finding friend in a building, gate in an airport, product on a shelf and such applications are getting more and more popular. The accuracy of such use cases varies from several tens centimeters to several meters.
- Precise agriculture, construction, warehouses, mining, connected vehicle, etc. require centimeter level of accuracy.

Location basics

Some ways of identifying 3D location

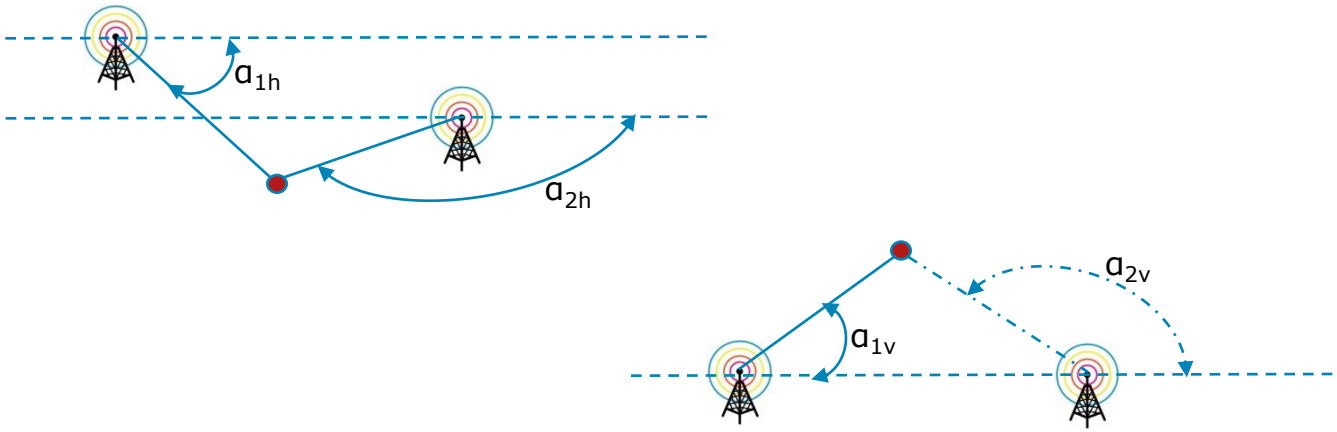
1. Distance from 4 reference points
2. Vertical and horizontal directions from 2 reference points
3. Vertical and horizontal directions and distance from a single reference point

Distance only



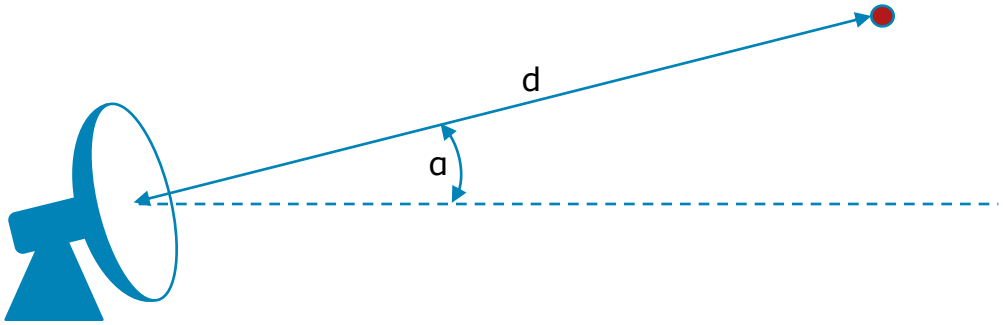
The location of the object can be identified by knowing its distance from three anchor points on a flat surface or from four anchor points in three dimensions

Direction only



The location of the object can be identified by knowing its vertical and horizontal angles from two reference points.

Distance and direction



The location of the object can be identified by knowing its vertical and horizontal angles and distance from an anchor point.

How to find distance

- By measuring signal strength.
  - Signal strength attenuates in reverse proportion to the square of the distance without obstacles.
  - In theory signal can be anything: magnetic, gravitational, acoustical, optical, radio signal.
  - Received signal strength indication (RSSI) is widely used.
  - The accuracy depends on the stability of the environment and accurate fingerprinting of the covered area.
  - No time synchronization is required between stations.

How to find distance (continue)

- By measuring propagation time knowing distribution speed.
  - Used in optical, acoustic, electromagnetic devices.
  - By measuring round trip delay. No time synchronization is needed between transmitter and receiver. Time of Arrival (ToA) may use such technique.
  - By receiving signal at the client from transmitters with a known location and tight time synchronization. This is another option for ToA.
  - By receiving signal from a client at the receivers with tight time synchronization. For example, used in mobile network and called Time Difference of Arrival (TDoA)

How to find angle

- Mechanically or electronically move the main narrow antenna beam and wait for the signal. Used in radars.

- By using Angle of Arrival (AoA) method
- AoA his effectively the same TDoA executed on different elements of antenna array. By knowing distance between elements and measuring the phase difference of the signal at these elements it is possible to identify the angle.

How tight should be time synchronization?

- Radio signal travels about 1ft (0.3m) each nanosecond

- By using direct GNSS signal it is hard to get centimeter level accuracy due to change in the speed of radio signal caused by non ideal satellite sync, altitude, weather, etc.

GNSS augmentation

- A stations with a known accurate position can provide correction information which would take in account environmental conditions.
- The correction is gathered from ground based stations and transmitted via geo stationary satellites or ground based stations.
  - Geo stationary satellites provide Satellite Based Augmentation System (SBAS) for wide area correction. European EGNOS, Japanese MSAS, Canadian CDGPS, US WAAS.
  - Ground based augmentation systems (GBAS) use ground based receivers to transmit correction and cover smaller area

Differential GNSS

- Augmented GNSS achieves sub-meter accuracy and high integrity of the service by eliminating majority of ionosphere and troposphere effects.
- Augmented GNSS covers rather large areas and such does not correct for all ionosphere irregularities between sensor station and the client
- Differential GNSS (DGNSS) use correction from closer located well surveyed stations to the client and covers smaller areas
- Real Time Kinematics (RTK) is DGNSS which uses the carrier phase which allows centimeter level of accuracy from the reference station. The time synchronization of the satellites is an essence here
- In order to correctly estimate the number of carrier wavelengths at the reference and remote receivers, they must be close enough to insure that the ionospheric delay difference is less than a carrier wavelength. This usually means that carrier-phase GPS measurements must be taken with a remote and reference station within about 30 kilometers of each other.

Issue with GNSS

- Political. Each GNSS belongs to a country and may be turned of at any time by that country.
- Jamming. GNSS signal is very low in power and can be easily jammed.
- Indoor issue. Due to weak signal GNSS can not be used indoor.

Mitigation of weak signal indoor

- GNSS repeater can be installed close to indoor location and retransmit the satellite signal.
  - The problem with the repeaters that they work like jammers for other locations
- Low orbit satellites
  - Not widely deployed
- Ground based pseudolites. Effectively is GNSS transmitters but installed on the ground.
  - Requires expensive installations and tight time sync between them

Cell Identity

- The technique can be used with the cell phones which do not have built in GPS.
- The basestations may identify where the phone is located based on the signal strength. The result is very crude
- TDoA allows better positioning of the cell phone. However the accuracy is limited by the time synchronization between basestations.

E911

- THE WIRELESS E911 LOCATION ACCURACY REQUIREMENTS *
  - **For terminal-based and terminal-assisted positioning**:
    - within 50m for 67% of all calls measured at country level
    - within 150m for 95% of all calls measured at county level
  - **For network-based positioning**:
    - within 100m for 67% of all calls measured at county level
    - within 300m for 90% of all calls measured at county level
- E911 uses Assisted GPS A-GPS or TDoA in LTE stations.
  - A-GPS is used outdoor with the GPS enabled phones
  - TDOA may be used indoor
- The time synchronization between stations is one of major parameter in identifying location of the client.

*Wireless E911 Location Accuracy Requirements, Second Report and Order, FCC, September 2010

WiFi based location

- WiFi becomes a very important tool in location service due to wide use of it.
- RSSI is largely utilized in WiFi areas.
- AoA utilization is picking up although requires complex multi element antenna
- TDoA is also may be used in WiFi but the level of synchronization between access points (APs) needs to be brought to sub-nanosecond level
- PTP may be used on a wired side to sync the APs to the required level (hopefully)