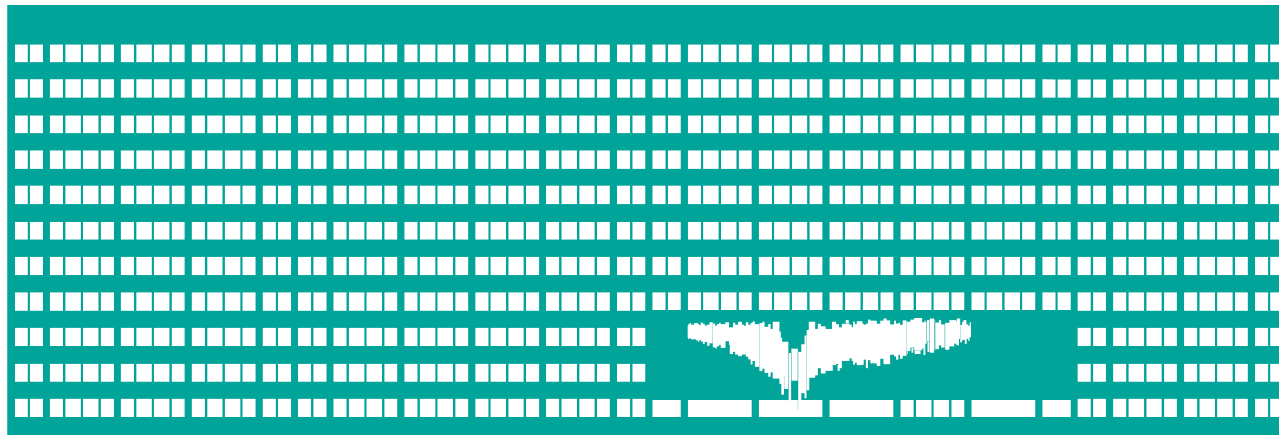# Location Management

MS (Mobile Computing)
Lecture 7

Location methods

- Cellular infrastructure
  - GSM networks
  - WLANs
- Global navigation satellite system - GNSS
  - GPS
    - DGPS, WAAS/EGNOS, ...
  - GLONASS
  - Galileo
  - Beidou
- Special technologies – laser beams, ultrasound, ...

Localization methods

- Cell of origin (COO, CGI)
- Received signal strength indication (RSSI)
- Timing advance (TA)
- Time of arrival (ToA) = Time of flight (ToF)
- Angle of arrival (AoA)
- Multilateration techniques
  - Time difference of arrival (TDoA)
  - Enhanced observed time difference (E-OTD)
- Symmetrical double sided – Two way ranging

Cell of origin

- Basic approach – the location of cell is the location of user
- Variable and imprecise locator: depending on the number of base stations in the search area, accuracy may be within one hundred meters of the target (urban area) → thirty kilometers away from the target (base stations are less densely concentrated)
- Quickly identifies given location (~ 3s).
- Phase 1 in 911 systems in US.
- The only positioning technique widely used in wireless networks

Received signal strength indication

- Measurement of the power present in a received radio signal
- Combined with the known topology of network, signal strengths of different cells may be used for better localization than in COO
  - In GSM networks, phones constantly measure the signal strength from the closest 6 base stations and optimize based on lowest power consumption
  - 'enhanced' COO

Timing advance

- In GSM cellular networks – length of time a signal takes to reach the base station from a mobile device
- Precise arrival-time within the slot can be used by the base station to determine the distance to the mobile phone.
  - Original purpose of TA: time at which the phone is allowed to transmit a burst of traffic within a timeslot must be adjusted accordingly to prevent collisions with adjacent users. Maximum distance from BTS: 35km
  - With 1ms precision, the distance precision is ~100-150m
- Usually used in combination with other methods

Time of arrival/flight

- Travel time of a radio signal from a single transmitter to a remote single receiver. Speed of light (electromagnetic wave) propagation in medium (on carrier frequency) + carrier frequency. Trilateration
- Absolute time, precise synchronization → determination of position from 3+ base stations. Synchronization:
 - Exact synchronous clocks on all stations
  - Difference of two signals with different wavelengths
  - Reference points
  - Without direct synchronization, with compensation of clock phase differences

Multilateration

- Hyperbolic positioning, process of locating an object by accurately computing the time difference of arrival (TDOA) of a signal emitted from that object to three or more receivers or locating a receiver by measuring the TDOA of a signal transmitted from three or more synchronized transmitters.
- N receivers/transmitters provide N − 1 hyperboloids, in ideal case 3 intersecting hyperboloids could provide 3D localization.
  - In fact surfaces rarely intersect (errors, multipath), because of various errors → optimization problem: least squares method or extended Kalman filter.
- Phase difference of arrival, frequency differ. of arrival

Time difference of arrival

- Emitted signal will arrive at different times on geographically separate receiver sites
- Signals emitted at the same time from multiple locations will arrive at slightly different times at receiver.

TDOA Geometry
Image Source: http://en.wikipedia.org/wiki/File:TDOA_Geometry.png
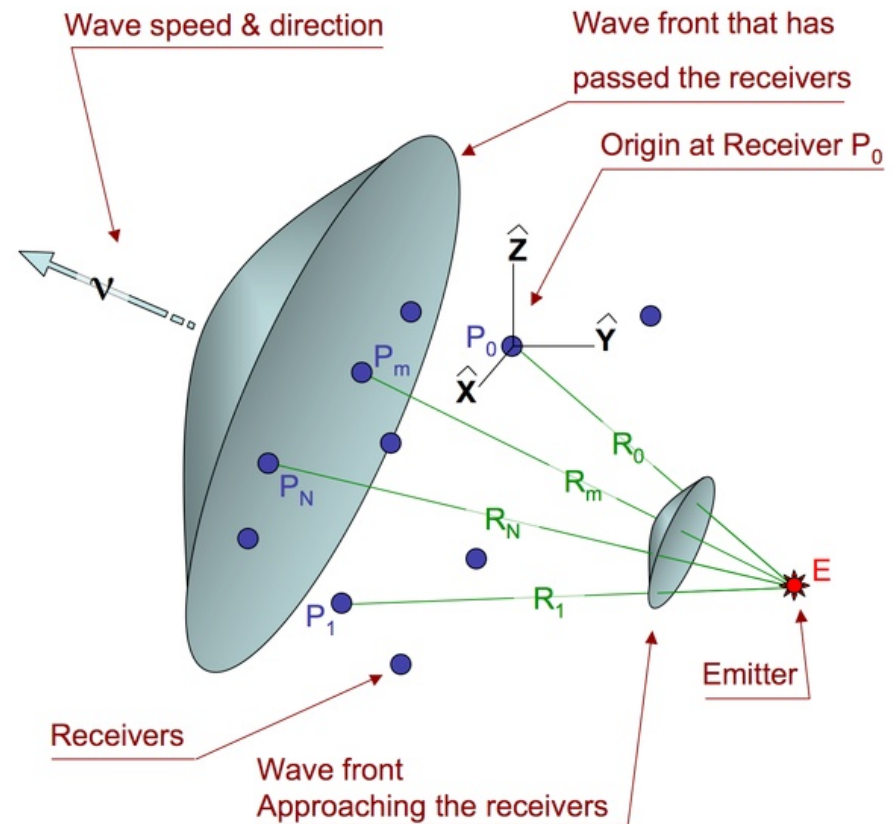
Angle of arrival

- Direction of propagation of a radio-frequency wave incident on an antenna array. Calculated by measuring TDOA at individual elements of the array.
- Triangulation is used to determine the position of mobile device
- Proposed to use for emergency calls to localize the caller. Not really used as an actual singular method
- Used to localize the sender – illegal transmissions, detection of military transmitters

Enhanced observed time difference

- Standard for the location of mobile phones – GSM, 3G, WCDMA, … Modification of phone FW, ~30-300 m
- TDOA from one or more tuples of base stations on mobile device – observer time differences (OTD). Pseudo-synchronization of the network $\rightarrow$ Geometric Time difference (GTD): GTD = OTD – RTD
  - Location measurement unit (LMU) estimates the transmission time offset between tuples base stations. Placed in position which allows determining real-time difference (RTD) of different base stations. LMUs are expensive to operate and must be at suitable places
  - LMU-less approach with enough OTDs to estimate RTDs

Positioning in LTE

Besides normal techniques (e-CID) we have following other methods:

- Downlink observed TDOA – measured by mobile node
- Uplink TDOA – network based
- RF fingerprinting – not really used yet

Symmetrical double sided Two way ranging

- Range determination only between two stations
- Two natural delays between 2 stations:
  - Signal propagation delay
  - Propagation delay of acknowledgment
- Symmetrical: ABA = BAB
- ACK sent back to Station A includes in its header two delay values – signal propagation delay (A → B) and processing delay (on B). After reception on A, we obtain second signal propagation delay (B → A).