Mobile Positioning
in a Natural Disaster Environment

IWISSI 2012, Tokyo

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Providing Geolocation Information

- Mobility Management
  - Location management, paging, handoff management, call roaming, billing
  - LA – location area, HLR – home location register, VLR – visiting location register, Cell ID
- FCC Enhanced Wireless 911 Services
  - E-911 Phase 1: phone number and cell phone tower must be reported to a public safety answering point (PSAP) within 6 minutes of a request
  - E-911 Phase 2: latitude and longitude of callers within 300 meters must be reported to the PSAP within 6 minutes of a request (extended deadline)
- Location Based Services (LBS)
  - Provide appropriate services based on user's current location (map, place/service/event guide, ads, network resource allocation, etc.)

Issues for Considerations

- Methods
  - Network-based/Handset-based/others
- Accuracy/Cost/Latency
  - FCC Location accuracy (phase II location accuracy & reliability)
    - Network-based: 100m for 67% of calls, 300m for 95% of calls
    - Handset-based: 50m for 67% of calls, 150m for 95% of calls
- Environments
  - Indoor/Outdoor (Line-of-sight/Non-Line-of-Sight)
- Obligation
  - Mandatory/Optional

Location Positioning Techniques

- Network-based method
  - Without affecting the handset
    - Cell id
    - Triangulation
    - Measurement: RSS (Received Signal Strength), RTT (Round Trip Time), TOA (Time of Arrival), TDOA (Time Difference of Arrival), AOA (Angle of Arrival)
    - Forward link timing
    - Accuracy vs. high concentration of BSs
    - Database Correlation, fingerprinting

Location Positioning Techniques

- Handset-based method
  - Still require some measurement
    - Enhanced-Observed Time Different (E-OTD)
    - Need user's equipment software installation
    - Different user's equipments from different makers
  - GPS/Assisted GPS
    - Mobile Station Assisted (MSA) – A-GPS device calculates its location
    - Mobile Station Based (MSB) – A server calculates the location by some snapshot information from the A-GPS device
- Hybrid method
- Social Positioning
  - User approach ➪ user checks in at a specific place (social network)
  - System approach ➪ mobile nodes in a proximity act as sensors (especially indoor)
  - Privacy? Security?

Location Positioning Techniques (cont.)

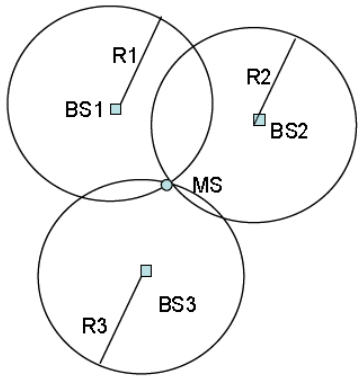
- Received Signal Strength
  - RSS + Cell id
  - RSS is the only common information available, no need for additional hardware/synchronization
  - Okumura-Hata model is widely used for prediction

$$PL = 69.55 + 26.16\log_{10} f_c - 13.82\log_{10} h_b - a(h_m) + (44.9 - 6.55\log_{10} h_b)\log_{10} R$$

  - Urban/suburban environments
  - Shadowing and multi-path fading

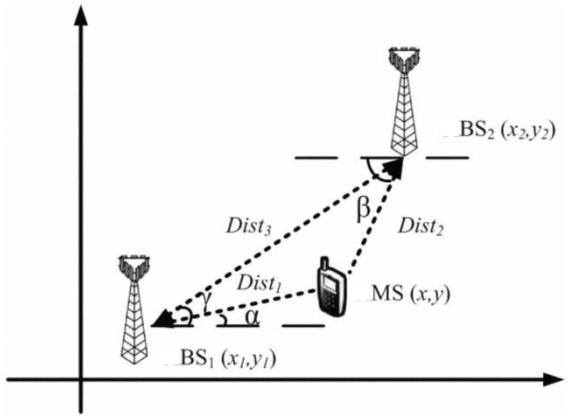
- Triangulation

$$R_1^2 = (x - x_{BS1})^2 + (y - y_{BS1})^2$$
$$R_2^2 = (x - x_{BS2})^2 + (y - y_{BS2})^2$$
$$R_3^2 = (x - x_{BS3})^2 + (y - y_{BS3})^2$$



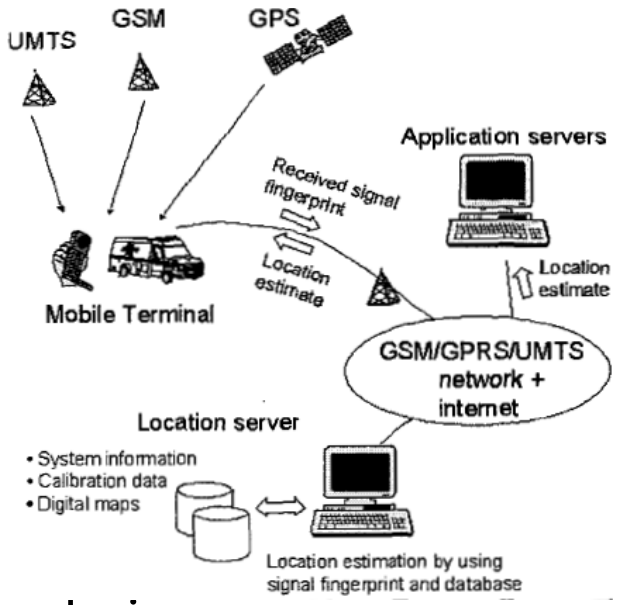
Location Positioning Techniques (cont.)

- Time of Arrival (TOA)/Time Difference of Arrival (TDOA) /Round Trip Time (RTT)
  - Estimate distance from BS by using signal propagation time
    - Preamble (OFDMA), Pilot arrival (CDMA), Timing Advance (GSM)
  - Require
    - Accurate time synchronization between BSs and MS
    - At least 3 BSs for triangulation
    - Location Management Units (LMU) installation at BS
- Angle of Arrival (AOA)
  - Require
    - Sophisticated antenna system/antenna arrays
    - 2 BSs for more accuracy
    - Locating the MS at the point where the lines along the angles from each tower intersects.



Location Positioning Techniques (cont.)

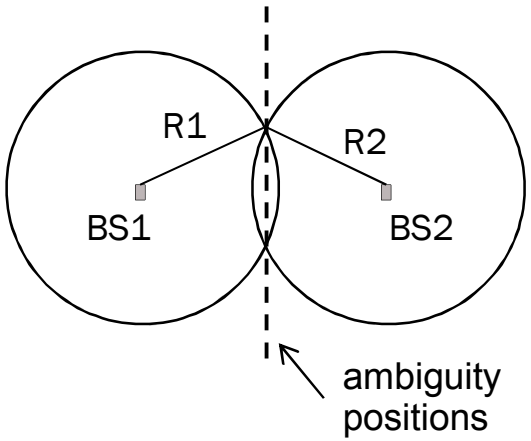
- Increase accuracy
  - NLOS mitigation
  - Specified network topology
  - Indoor environment
- Hybrid method
  - Hybrid TDOA/AOA
  - Hybrid RSS/TOA
  - Hybrid TOA/AOA
  - Hybrid TDOA/TOA
- Database Correlation/Fingerprinting technique
  - Received signal patterns from different locations (of each cell) are stored for future comparison with the RSS in query



Natural Disaster Environment

- Change in terrain
- Change in network infrastructure/topology
  - Limited resources
    - Information
    - Energy
- Proposed method
  - RSS
  - Standard handset
  - Plain/flat terrain
  - Simple network topology

Proposed Method



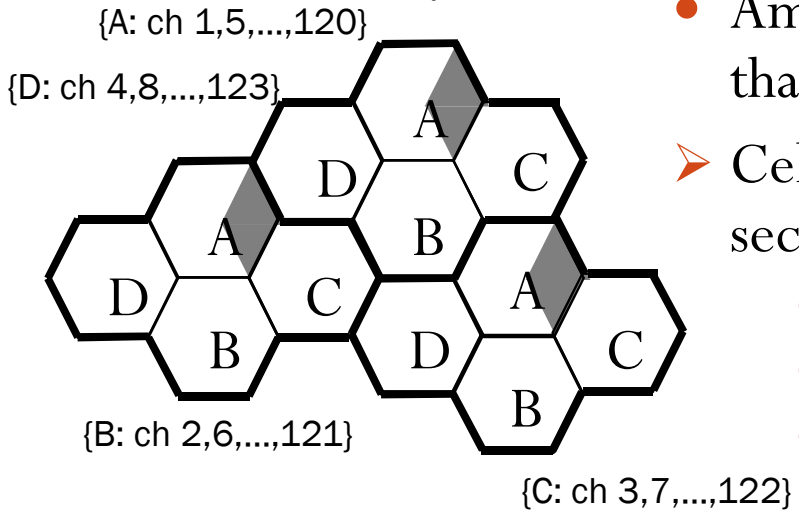
- RSS based on two-ray model for modeling land mobile radio

$$P_r = P_t G_t G_r \frac{h_b^{\,2} h_m^{\,2}}{R^4}$$

$$R_1^{\,2} = (x - x_{BS1})^2 + (y - y_{BS1})^2$$

$$R_2^{\,2} = (x - x_{BS2})^2 + (y - y_{BS2})^2$$

- Ambiguity positions are on the straight line that connects intersected points of 2 circles

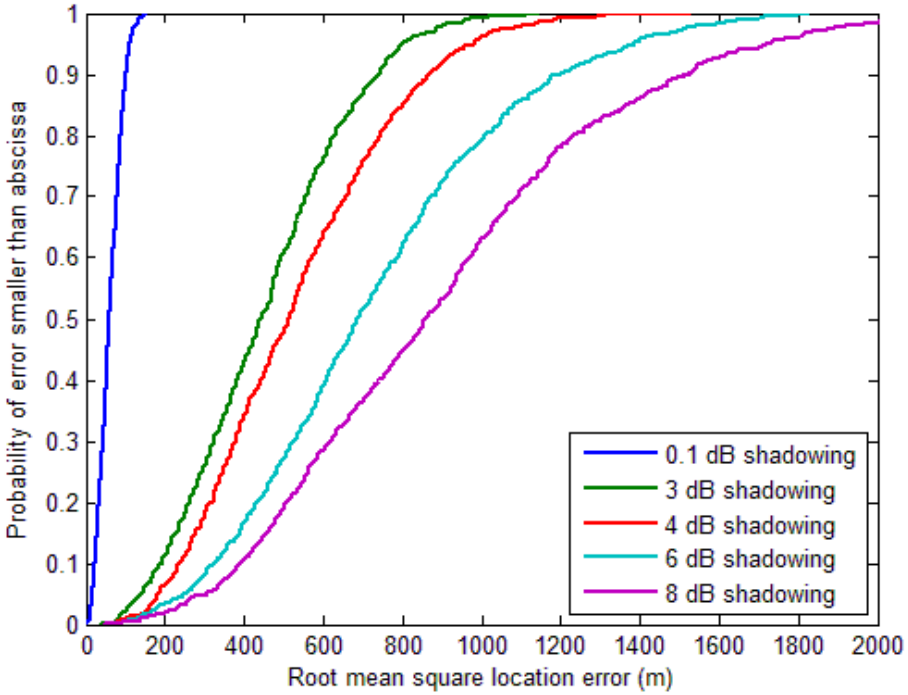


- Cell clustering, frequency reuse, and cell sectorization
  - 3 (120°) or 6 (60°) sectored antennas
  - Each cell has its own set of frequency channels
  - No connected cell uses the same set of frequency

Simulation & Results

- 2D plane
- 2 BSs (2 km apart) locating a fixed MS
  - Maximum cell coverage can be ~30km
- Propagation model: two-ray model
- BS and MS antenna gain 3 dBi
- Transmitted power: 0.8 W
- The number of MSs are equally distributed among cells
  - MSs (with their channel numbers) are uniformed distributed
- 1,000 independent simulation runs

Preliminary Simulation



Shadowing (dB)	Location error standard deviation (m)
0.1	28.82
3	195.18
4	239.64
6	348.72
8	429.78

Ongoing & Future Work

- Investigation/Simulation/Measurement on
  - Various types of RSS error
    - Multi-path fading
    - Line-of-sight (Rician fading)
    - Non-Line-of-Sight (Rayleigh fading)
  - Estimate response time
  - Coverage
    - Terrain profile and frequency/capacity planning
- Integration with DB correlation/fingerprinting techniques
    - Terrain profile and frequency/capacity planning

Problems

- No cell sectorization in rural areas
- Terrain changes completely
- No network infrastructure!!
  - Resilient system design
    - Ad hoc sensor network
    - Each device forms an ad hoc network
    - Each device acts as a sensor, i.e. reports nearby devices

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