Location Based Services and Technology

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Slides 14

Location Aware Services

• Location services marketplace generated over $40 billion in revenues worldwide in 2006

- Location Based Applications (LBA)
  - Applications capable of finding the geographical location of an object and providing services based on the location information
  - *Not only in mobile systems* (911)
  - Examples for mobile systems
    - Traffic updates
    - Next bus
    - Friend finder
    - Direction to nearest *X* (X – is hospital, store, bar, etc.)

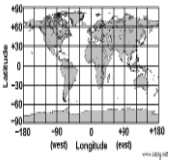
Location Aware Services

- Technology originally driven by E-911 mandate in U.S. – goal was to develop systems to locate emergency cell phone calls
- Now many applications envisioned
  - Emergency Services
  - Navigation
    - Directions
    - Traffic management
  - Information
    - Entertainment, shopping info, advertisements
  - Tracking
    - Vehicle tracking, people tracking
  - Billing
    - Location sensitive billing

- Systems currently in use – in USA largely restricted to service provider offerings – outside of US more 3rd party applications
  - AT&T Live Contacts buddy finder – identifies contacts in neighboring cells
  - Verizon Chaperone – allows one to track child's phone location
  - 3 proximity dating service – alerts user when someone with profile match is at same location (e.g., party, club)
  - Windows – Livesearch mobile for Blackberry with Windows mobile

Taxonomy of Location

- Absolute and Relative Location
  - Absolute uses a reference grid (Longitude, Latitude)
  - Relative depends on its own frame of reference
    - Nearest hospital to car accident
- Physical and Symbolic Location
  - Physical Location
    - Uniquely identifies a point on 2D or 3D map of the earth
  - Symbolic location
    - Coarsely identifies a physical location
      - School, work, home, etc.

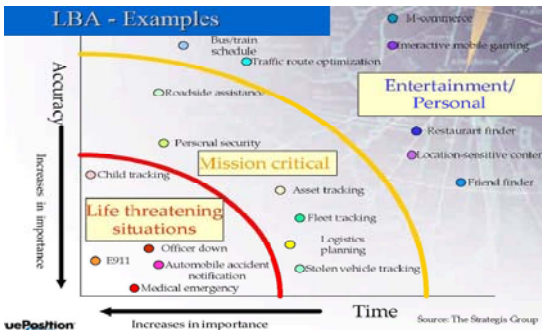


Location Accuracy

- Accuracy needed depends on application

Service	Example	Accuracy
Emergency	911 call	Medium-high
Navigation	directions	High
Information	Mobile Yellow Pages, Advertisement	Medium
Tracking	Vehicle Tracking	Low
Billing	Location based billing	Low to medium

Location Services Examples



Enhanced 911

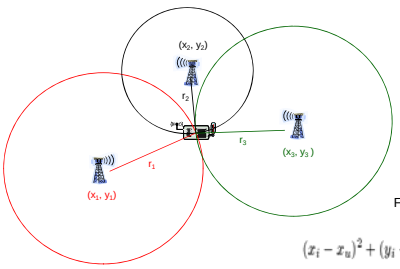
- Location data accompanied with 911 call, expedites emergency response time – can save lifes
- FCC mandate (94-102) driving demand for location capability
  - Phase I
    - Wireless carriers to supply cell site, sector, and call-back number for 911 calls.
  - Phase II - By December 31, 2004,
    - Undertake reasonable efforts to achieve 100% penetration of Assisted Location Information (ALI) -capable handsets in its total subscriber base.
- Requires public safety answering point (PSAP) capable of displaying position data

FCC 94-102 Phase II
Location Accuracy Requirements

- FCC Requirements for Location Accuracy
- For network-based solutions
  - 100 meters for 67% of 911 calls, and
  - 300 meters for 95% of 911 calls
- For handset-based solutions
  - 50 meters for 67% of 911 calls, and
  - 150 meters for 95% of 911 calls
- Both approaches require the use of wireless location technology
  - Equipment and algorithms added to network to find user position
  - Location technology options are similar regardless of wireless technology
    (GSM, IS-95, cdma2000, UMTS, WLAN, etc.)

Triangulation of Position

- Basis of most techniques for location position is triangulating position from known reference points called anchor points.
- (x_i,y_i) : coordinates of ***anchor point*** *i*, r_i distance to anchor *i*
- (x_u, y_u) : unknown coordinates of node



From geometry have

$$(x_i - x_u)^2 + (y_i - y_u)^2 = r_i^2 \text{ for } i = 1, \ldots, 3$$

Triangulation of Position

- Assuming can estimate/measure r_i exactly need three measurements to determine position
  - Solve for (x_u, y_u) from

$$(x_i - x_u)^2 + (y_i - y_u)^2 = r_i^2 \text{ for } i = 1, \ldots, 3$$

  - Usually rewrite by subtracting equation 3 from 1 and 2 and rearranging terms get

$$2\begin{bmatrix} x_3 - x_1 & y_3 - y_1 \\ x_3 - x_2 & y_3 - y_2 \end{bmatrix}\begin{bmatrix} x_u \\ y_u \end{bmatrix} = \begin{bmatrix} (r_1^2 - r_3^2) - (x_1^2 - x_3^2) - (y_1^2 - y_3^2) \\ (r_2^2 - r_2^2) - (x_2^2 - x_3^2) - (y_2^2 - y_3^2) \end{bmatrix}$$

  - Have two equation and two unknowns to solve for

    Example: $(x_1, y_1) = (2,1)$, $(x_2, y_2) = (5,4)$, $(x_3, y_3) = (8,2)$, $r_1 = 3.1623$, $r_2 = 2$, $r_3 = 3$

$$2\begin{bmatrix} 6 & 1 \\ 3 & -2 \end{bmatrix}\begin{bmatrix} x_u \\ y_u \end{bmatrix} = \begin{bmatrix} 64 \\ 22 \end{bmatrix}$$

    Which results in $(x_u, y_u) = (5,2)$

Location Technology

- Network-Based Approaches
  - add equipment to network to locate mobile
    - Time Difference of Arrival (TDOA)
    - Angle of Arrival (AOA)
    - Multipath Analysis (MPA)
- Handset-Based Approaches
  - Handset determines location and reports it to the network
    - Global Positioning System GPS
    - Advanced Forward Link Trilateration
- Hybrid (Network+ user assisted approach)
  - Combine handset and network based techniques
    - Assisted GPS (A-GPS)
    - Enhanced Observed Time Difference (EOTD)

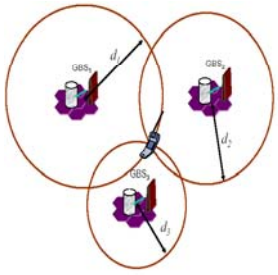
Network: Time Difference of Arrival (O-TDOA)

- Use existing cell towers and infrastructure to triangulate user's location
- Determine the difference in time in which *uplink* radio signal from user reaches different cell sites.

  $d_i = c \times t_i$

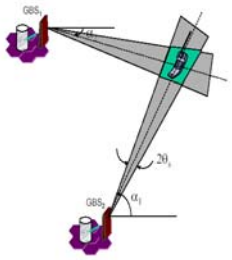
  where c is speed of light and t_i = time between transmission and reception

- Difference in time is resolved to determine position, velocity, and heading.
- Can use the same idea with received signal strength (RSSI) but not accurate enough due to obstructions, multipath, etc.
- Need synchronization of cell sites.



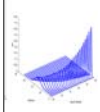
Network: Angle of Arrival

- Requires specialized listening receivers to be placed at the base station
- Requires construction of directional uplink antenna array onto existing cell towers (similar to spot beams)
- Measures the direction of signal received at multiple towers with respect to antennas of known position to determine mobile position
- Requires 2 or more basestations or sectors to receive the signal
- Sometimes called triangulation



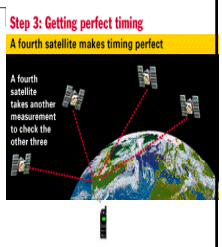
Network: Multipath or Scene Analysis

- Constructed a database of the received uplink multipath signal on a location grid for a specific service area
- Uses existing cell towers and infrastructure, may require additional specialized receivers to placed at the base station to improve accuracy
- Uses the multipath database to match the transmitter's signal characteristics to determine a point on the location grid
- Also called *fingerprinting* of locations
- Can be very accurate – time consuming



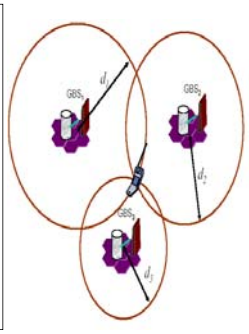
Handset: Global Positioning System

- Requires GPS receiver and GPS antenna to be imbedded into the mobile phone
- Requires traffic or control channel resources for handset to transmit location data
- Employs signal timing techniques from three or more satellites from a constellation of 24 to determine position
- Can require a significant time to acquire signal and compute position.
- GPS signal hard to pick up indoors or dense urban environment



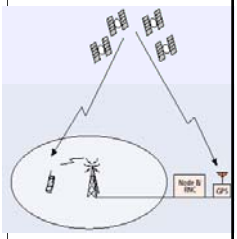
Handset: Advanced Forward Link Trilateration

- Time Difference of Arrival technique using the handset's receiver and the downlink radio signal
- MS needs to receive 3 or more BS signals at sufficient signal strength to triangulate it's position
- Requires phones with precise timing.
- Needs systemwide Base Station Synchronization
- Requires traffic/control channel resources to transmit location data from handset



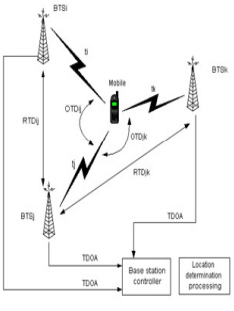
Hybrid : Assisted Global Positioning System (A-GPS)

- Requires GPS receiver and GPS antenna to be imbedded into the mobile phone
- Requires special GPS servers to be placed throughout the area of coverage to *ASSIST* mobile receivers with acquiring GPS signals or reradiating GPS signal to indoor/shadowed areas
- Mobile GPS receivers communicate with stationary GPS servers to assist in position determination – helps speed up calculation and indoor acquisition
- Requires traffic/control channel resources to transmit assistance and location data



Hybrid: Enhanced Observed Time Difference of Arrival (E-OTDA)

- Time Difference of Arrival technique using the handset's receiver and specialized reference receivers to triangulate position
- Use Forward and Reverse Link measurement
- Requires phones with precise timing.
- Requires addition of new uplink receivers throughout the network
- Requires traffic/control channel resources to transmit assistance messages and location data

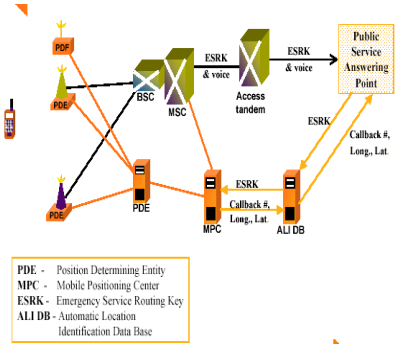


Accuracy

Technique	Handset Impact	Resolution
TDOA	NO	300-500m
AOA	NO	300-500m
MPA	NO	1-5M (depends on grid size)
GPS	Yes	3-5 M
AFLT	Yes	50-200M
EOTD	Yes	50-200M
AGPS	Yes	3-30M

Basic Cellular Architecture for IS95/CDMA 2000

- Basic architecture common to all approaches
- Requires network to overlay/retrofit new equipment



PDE - Position Determining Entity
MPC - Mobile Positioning Center
ESRK - Emergency Service Routing Key
ALI DB - Automatic Location Identification Data Base

Evolving Standards for Location Tracking

- CTIA
  - TR 45.5
    - geolocation network support for AMPS, NA-TDMA, IS-95
    - E-OTDA, A-GPS options for each technology
- 3GPP
  - GSM, GPRS, EDGE, UMTS
  - E-OTDA, A-GPS options for each technology
- 3GPP2
  - cdma 2000 (UWC-136B) network assisted A-GPS
- USA Service Provider Techniques Adopted
  - Verizon, Sprint: A-GPS,
  - AT&T, T-Mobile: E-OTDA
- Open Mobile Alliance

OMA Location Architecture

- Open Mobile Alliance (OMA)
  - http://www.openmobilealliance.org
  - Location working group - absorbed earlier work by Location Interoperability Forum (LIF)
- LoCation Services (LCS) Architecture
  - Leverages normal infrastructure for transport and resource management - independent of wireless location technology used
- LCS Architecture Components
  - UE (User Entity)
    - may assist in position calculation
  - LMU (Location Measurement Unit)
    - Maybe required or not depending on location technology approach adopted – if used is distributed among the cells
  - SMLC (Serving Mobile Location Center)
    - Coordinates measurements to determine location
  - GMLC (Gateway Mobile Location Center)
    - Location server for outside queries

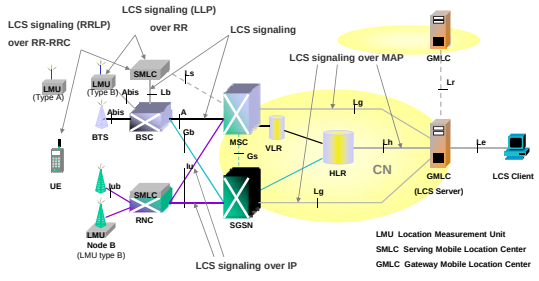
OMA LCS Architecture

Gateway Mobile Location Center

Serving Mobile Location Center

- Two Key Components in backhaul
- Gateway Mobile Location Center
  - Application interface for location services
  - Application Authentication
  - Privacy checking
  - Interrogates HLR to find visited MSC/SGSN
    - Roaming user can be located
  - Called Mobile Positioning Center (MPC) in IS-95/3GPP2
  - Standalone equipment or integrated into GMSC
- Serving Mobile Location Center
  - Determines the location
  - Talks to access network and user device
  - Standalone equipment or integrated into BSC/RNC or MSC/3GMSC
  - Called Position Determining Entity (PDE) in IS-95/3GPP2

OMA Location Architecture for UMTS/GSM

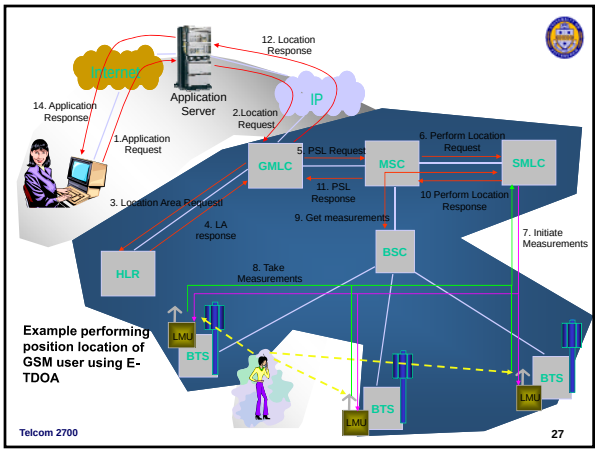


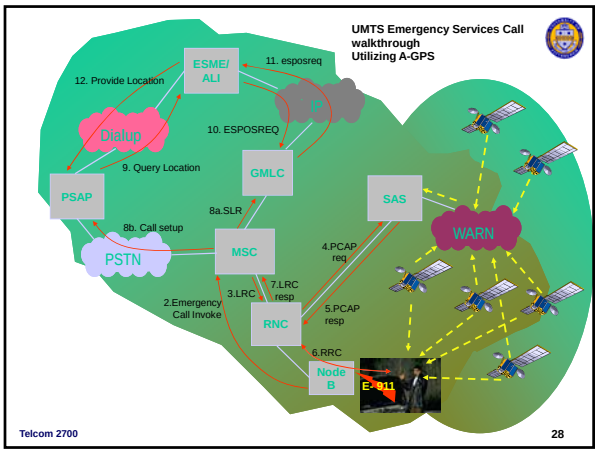
Location Requests

- MLP – Mobile Location Protocol
  - from Location Interopability Forum (LIF) -> now part of Open Mobile Alliance
  - based on HTTP/SSL/XML
  - allows Internet clients to request location services
  - Response includes *quality* of the location estimate
  - GMLC is the Location Server
  - UE can be idle, but not off !
  - Immediate or deferred result, can request periodic updates

MLP Services

- Standard Location Immediate Service (SLIS)
  - Provide location of mobile user to an LCS client based on LCS client's request
- Standard Location Reporting Service (SLRS)
  - Provide location of mobile user to an LCS client based on user's request
- Triggered Location Reporting Service (SLRS)
  - Provide location of mobile user to an LCS client based on preset events (e.g., time of day)
- Emergency Location Immediate Service (ELIS)
  - Provide location of mobile user to an LCS client based on emergency LCS client's request (e.g., police)
- Emergency Location Reporting Service (SLRS)
  - Provide location of mobile user to an LCS client when an emergency call is placed (e.g., 911)





Location Based/Aware Services

- Originally developed for E-911 calls
  - 296,000 E-911 calls in US per DAY in July, 2008 (CTIA.org)
- Handset and Network Based Technology Options
- Standards forming
- Growing demand and new applications possible
- Privacy and openness a big issue for service providers

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