Location Based Services and Technology

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Slides 14

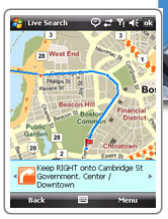
Location Aware Services

• 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

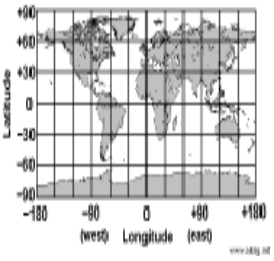
- Technology originally driven by E-911 mandate in U.S. – goal was to develop systems to locate emergency cell phone calls
- Now many applications envisioned
  - Emergency Services
  - Navigation
    - Directions
    - Traffic management
  - Information
    - Entertainment, shopping info, advertisements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



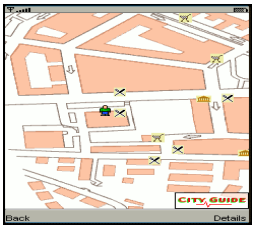
- Systems currently in use – in USA largely restricted to service provider offerings – outside of US more 3rd party applications
  - AT&T Live Contacts buddy finder – identifies contacts in neighboring cells
  - Verizon Chaperone – allows one to track child's phone location
  - 3 proximity dating service – 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.

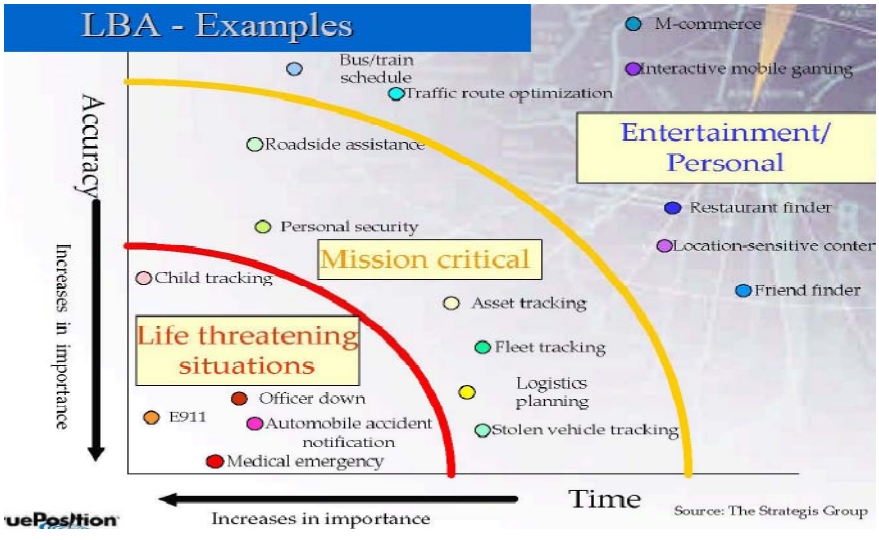


Location Accuracy

- 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

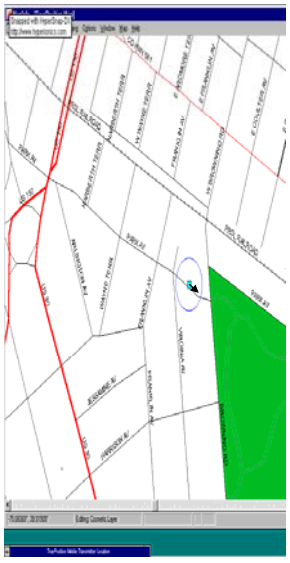
Location Services Examples



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

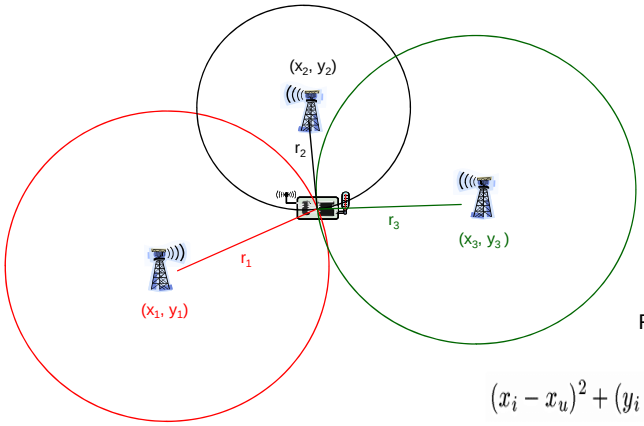


- FCC Requirements for Location Accuracy
- For network-based solutions
  - 100 meters for 67% of 911 calls, and
  - 300 meters for 95% of 911 calls
- For handset-based solutions
  - 50 meters for 67% of 911 calls, and
  - 150 meters for 95% of 911 calls
- Both approaches require the use of wireless location 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

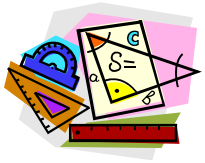


From geometry have

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

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)

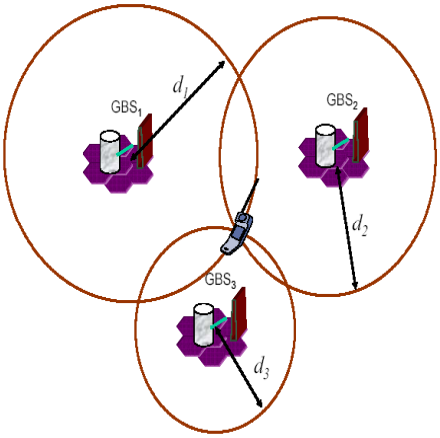
Network: Time Difference of Arrival (O-TDOA)

- 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.

  $d_i = c \times t_i$

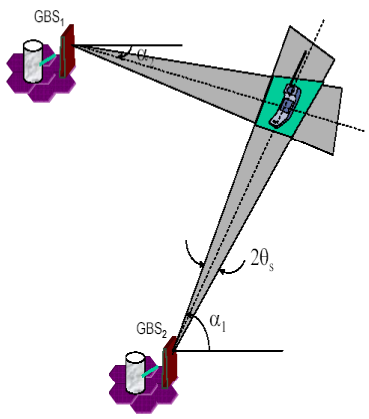
  where c is speed of light and t_i = time between transmission and reception

- 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.



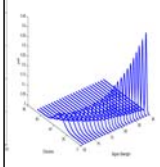
Network: Angle of Arrival

- 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



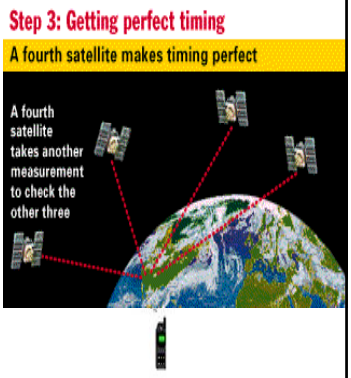
Network: Multipath or Scene Analysis

- 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



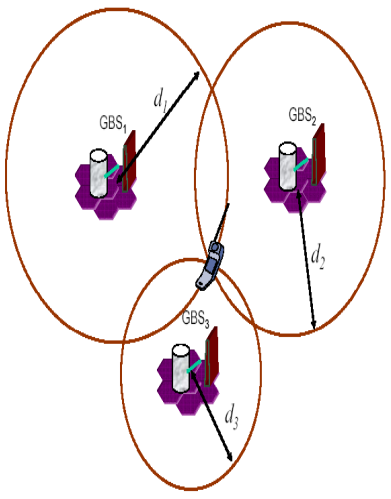
Handset: Global Positioning System

- 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



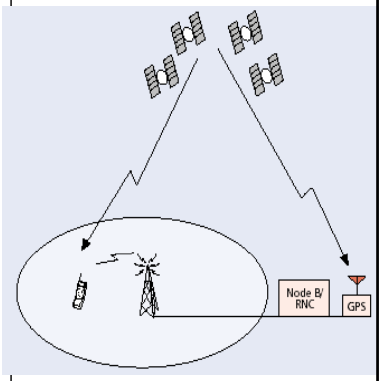
Handset: Advanced Forward Link Trilateration

- 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



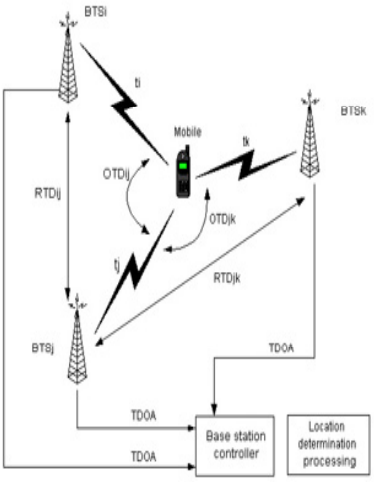
Hybrid : Assisted Global Positioning System (A-GPS)

- 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

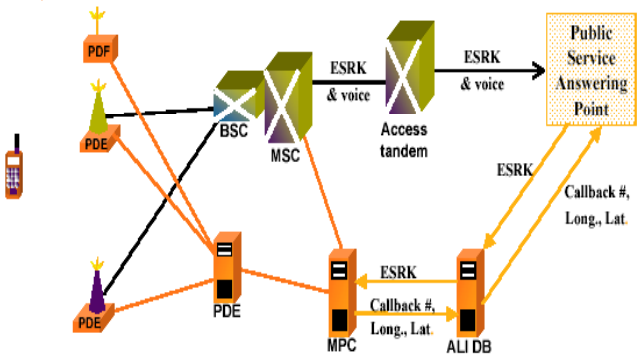


Accuracy

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



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

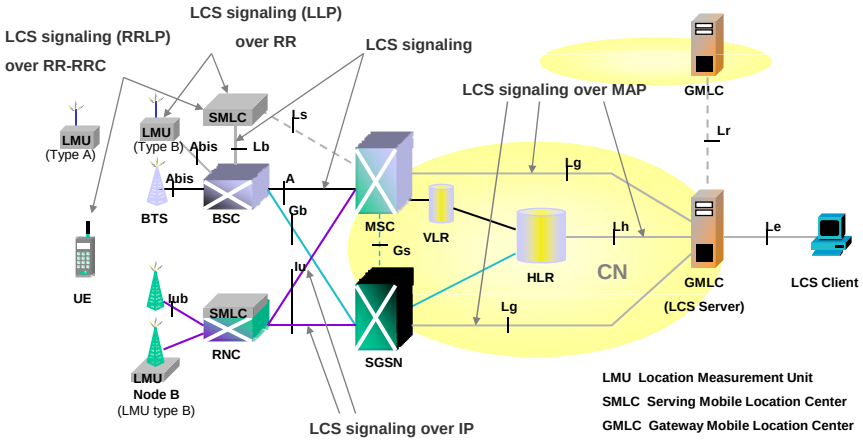
OMA LCS Architecture

Gateway Mobile Location Center

Serving Mobile Location Center

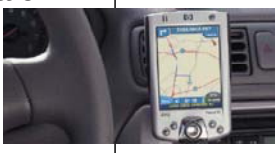
- Two Key Components in backhaul
- Gateway Mobile Location Center
  - Application interface for location services
  - Application Authentication
  - Privacy checking
  - Interrogates HLR to find visited MSC/SGSN
    - Roaming user can be located
  - Called Mobile Positioning Center (MPC) in IS-95/3GPP2
  - 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



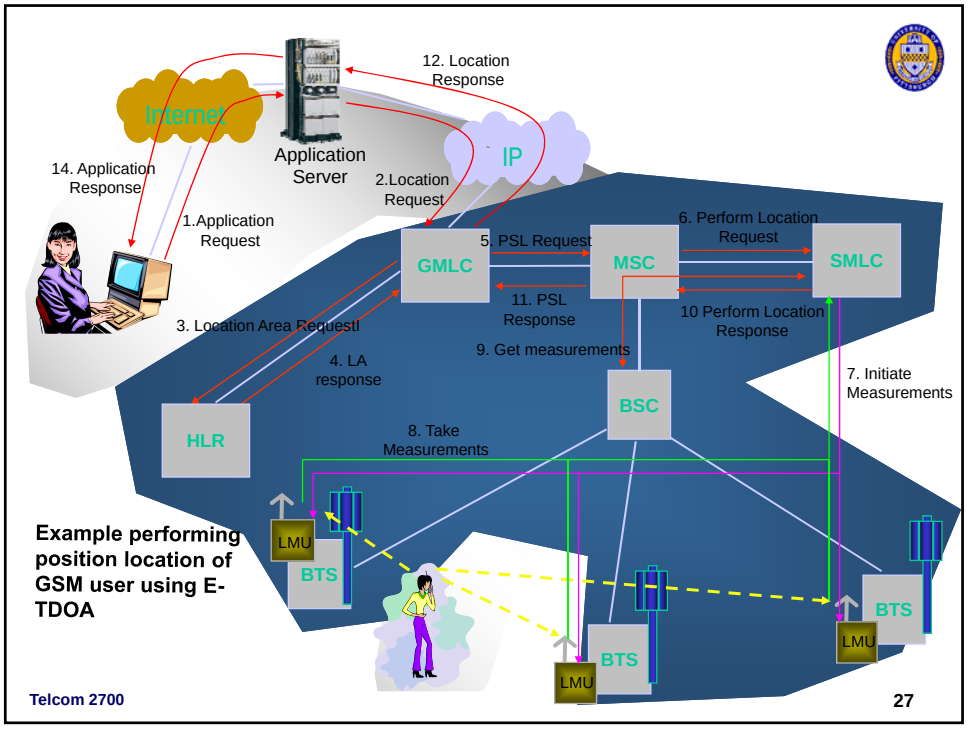
Location Requests

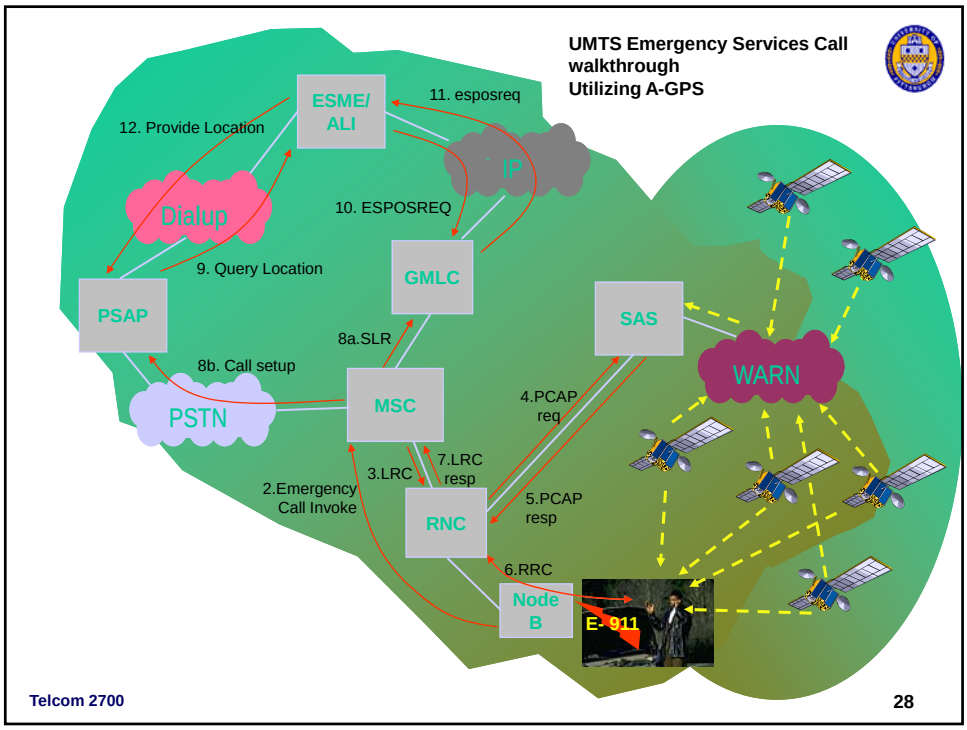
- MLP – Mobile Location Protocol
  - from Location Interopability Forum (LIF) -> now part of Open Mobile Alliance
  - based on HTTP/SSL/XML
  - allows Internet clients to request location services
  - Response includes *quality* of the location estimate
  - GMLC is the Location Server
  - UE can be idle, 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)


Internet
Application Server
12. Location Response
IP
14. Application Response
1.Application Request
2.Location Request
GMLC
5. PSL Request
MSC
6. Perform Location Request
SMLC
11. PSL Response
10 Perform Location Response
3. Location Area Request
4. LA response
9. Get measurements
7. Initiate Measurements
BSC
HLR
8. Take Measurements
Example performing position location of GSM user using E-TDOA
LMU
BTS
BTS
LMU
BTS
LMU
Telcom 2700
27


UMTS Emergency Services Call walkthrough
Utilizing A-GPS
ESME/ ALI
11. esposreq
12. Provide Location
IP
Dialup
10. ESPOSREQ
9. Query Location
GMLC
PSAP
SAS
8a.SLR
8b. Call setup
WARN
PSTN
MSC
4.PCAP req
7.LRC resp
3.LRC
2.Emergency Call Invoke
5.PCAP resp
RNC
6.RRC
Node B
E- 911
Telcom 2700
28

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