Location Based Services for Mobiles :Technologies and Standards

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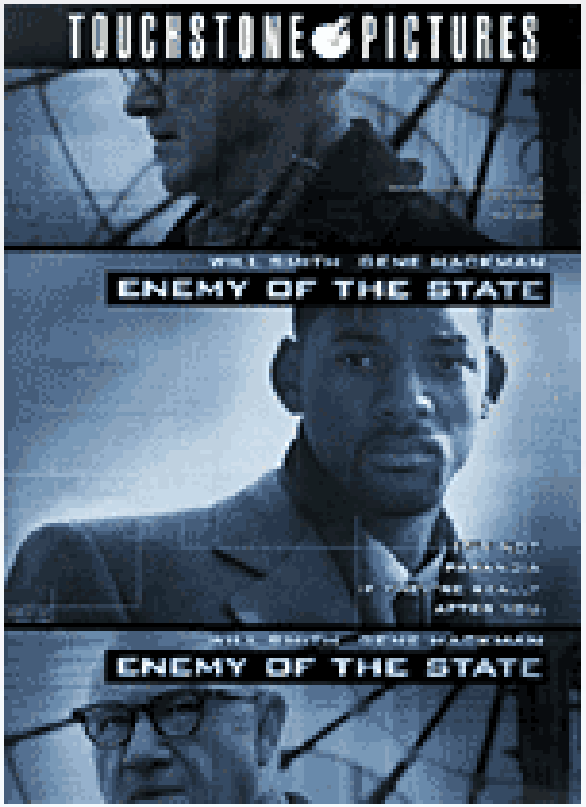
Outline

- **Section I: Introduction**
  - **View of the wireless business domain above 30,000 feet**
  - **Historic overview**
  - **LBS concept**
  - **LBS applications and market**
  - **LBS in mobile standards**
- **Section II: Wireless Positioning Technologies**
  - Basic positioning methods
  - Satellite positioning systems
  - Positioning in mobile networks
- **Section III: Location Services in Mobile Networks**
  - LCS design considerations
  - Location management in mobile networks
  - LCS architecture: control plane and user plane
  - LCS procedure in mobile standards
- **Section IV: Challenges for Mobile Location Based Services**
  - New mobile technologies
  - Interoperability
  - Security design

Enemy of The State



"In God we trust. The rest we monitor."

Location, Location, Location

YOUR PHONE KNOWS WHERE YOU ARE

With E911, your cellphone's location can be tracked within seconds. Sounds great for emergencies, but is there a dark side?

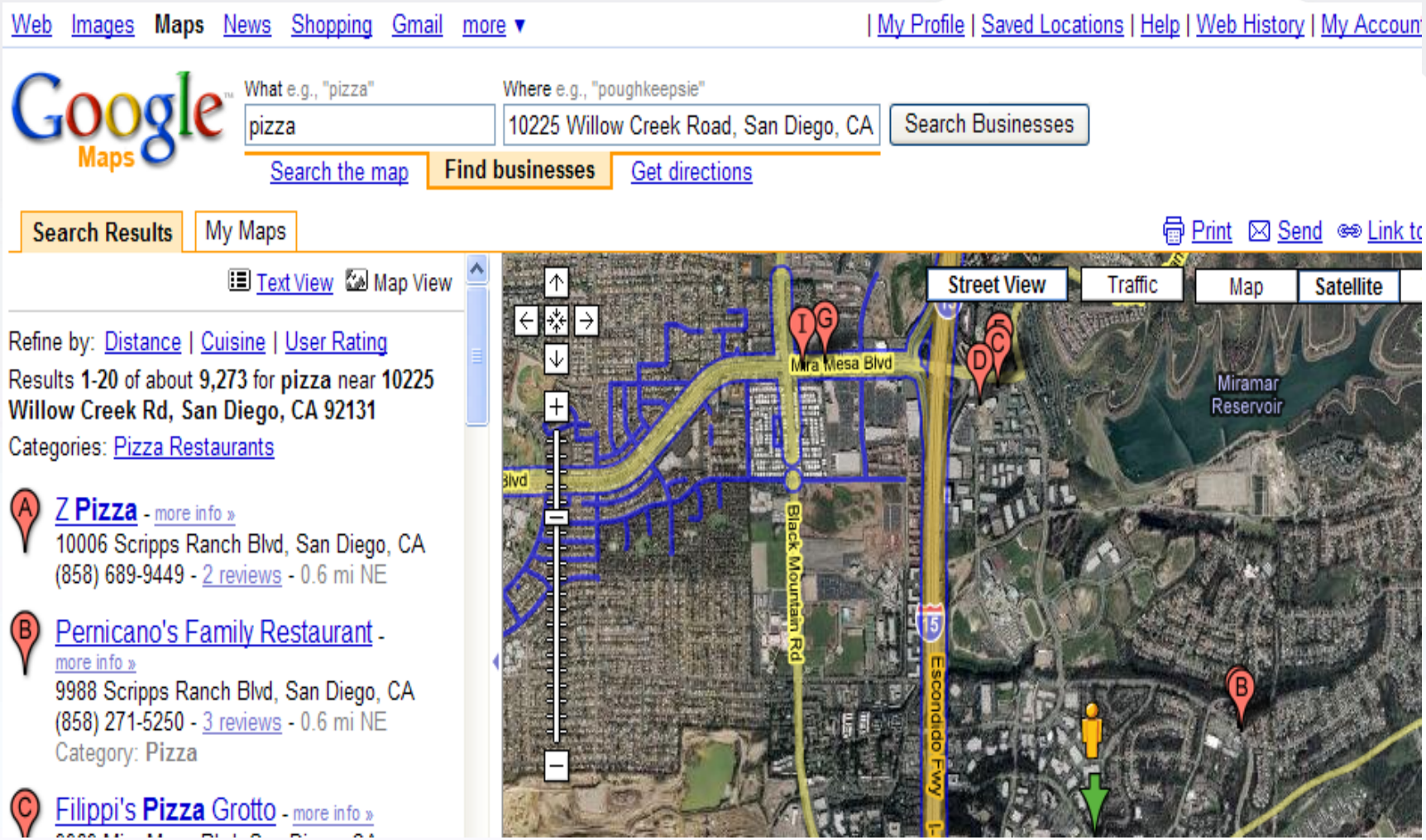
1 | 2

In February 2001, while driving on the state turnpike to her home in Miramar, Florida, 32-year-old Karla Gutierrez lost control of her BMW 328i and skidded into a canal. She dialed 911 on a cellphone and explained her predicament as the vehicle slowly sank. But since Gutierrez couldn't describe her precise location—"I'm not sure where I am," she told the operator—Miami-Dade County rescue units didn't know where to go to save her. By the time a passing patrolman noticed a busted fence by the accident site and found Gutierrez, she was dead.

Cases like this give emergency workers the shivers. If Gutierrez had called 911 from her home, the dispatcher would have instantly seen her exact location on a computer terminal, because landlines are matched to household addresses in emergency-services databases. But mobile phones are untethered to any network and provide no clue about where an SOS is coming from.

With more than 200,000 emergency calls coming from cellphones daily, the Federal Communications Commission is eager to remedy this defect. In 1997, the agency ordered wireless

Mobile.LBS.Google.Com?



LBS: A Historic View

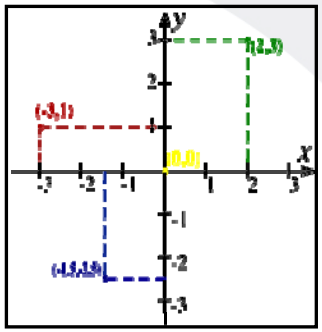
The Weather Channel

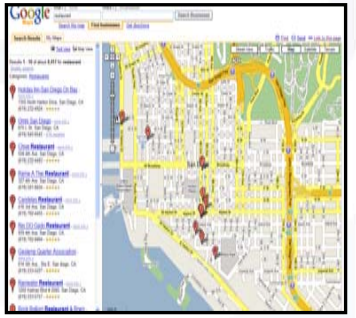
weather.com

- **Emergency medical services (EMS)**
  - In 1487, the first recorded use of ambulance was by the Spanish army, Queen Isabella of Spain.
- **Yellow Pages** (A more than $136B world wide market)
  - In 1886, Reuben H. Donnelly produced the first Yellow Pages.
  - In 1909, St. Louis produced the first Yellow Pages directory with coupons.
- **Local weather and traffic broadcast in radio and TV**
  - Since 1960s, radio traffic report has been very popular in US.
  - On May 2, 1982, the weather channel (TWC) went on the air.
- **Emergency phone services**
  - In 1968, AT&T and FCC come out with this nationwide emergency phone number – 911. (It is 1-1-2 across the European Union and 999 in UK).
  - In 2000, FCC issued a mandate of E911 to wireless carriers.

Concepts in LBS

- **Position**
  - *"32° 49' 49.7964"-116° 49' 9.9228""*
  - Position appears to developers in the form of spatial coordinates.
  - It can be represented as a single point in the Cartesian coordinate.
- **Location**
  - *"San Diego downtown gas lamp quarter"*
  - Location is associated with a certain place in the real world.
  - If positioning delivers a spatial location, it will be mapped onto a descriptive location in order to be interpretable by the LBS user.
- **LoCation Service (LCS)**
  - *"Where am I?"*
  - LCS should be distinguished from LBS as it exclusively deals with the localization of target, and also makes the resulting location data available to external actors.
  - It is responsible for the generation and delivery of location data.
- **Location Based Service (LBS)**
  - *"How can I go to the gas lamp quarter from here?"*
  - LBS is the service that adds value to target locations provided by LCS. It uses knowledge of a mobile device's location to offer value to the mobile subscriber or to a third party.





LBS Applications

- Emergency Services
  - E-911
  - Roadside Assistance
- Tracking
  - Commercial: workforce, fleet management
  - Family locator
  - Personal asset tracking
- Navigation
  - Direction
  - Planning
  - Assistance
- Billing
  - Road tolling
  - parking
- LBS Alert
  - Promotion alert
  - advertising
- Social Networking
  - Friend-finder
  - Instant messaging.

- Network Operator Applications
  - Location sensitive billing
  - Cellular fraudulent detection and prevention
  - Wireless network optimization
  - Cellular inter-network border negotiation.
- Service Provider Application
  - Fleet navigation and management
  - Wireless M2M
  - Remote access/management – mobile data/television
  - Auto insurance
  - Promotion and advertising
- End-User Application
  - Tons of it.

LBS Services in Market

Sprint-Nextel Sprint Navigation

- Sprint Navigation provides voice-guided and on-screen turn-by-turn driving directions, along with 3D moving maps.
- It comes with business listings, and real-time intelligent traffic alerts with one-click rerouting.

- Verizon Chaperone uses a child phone's A-GPS to help pinpoint the location.
- It makes the location information available online or on the parent phone.

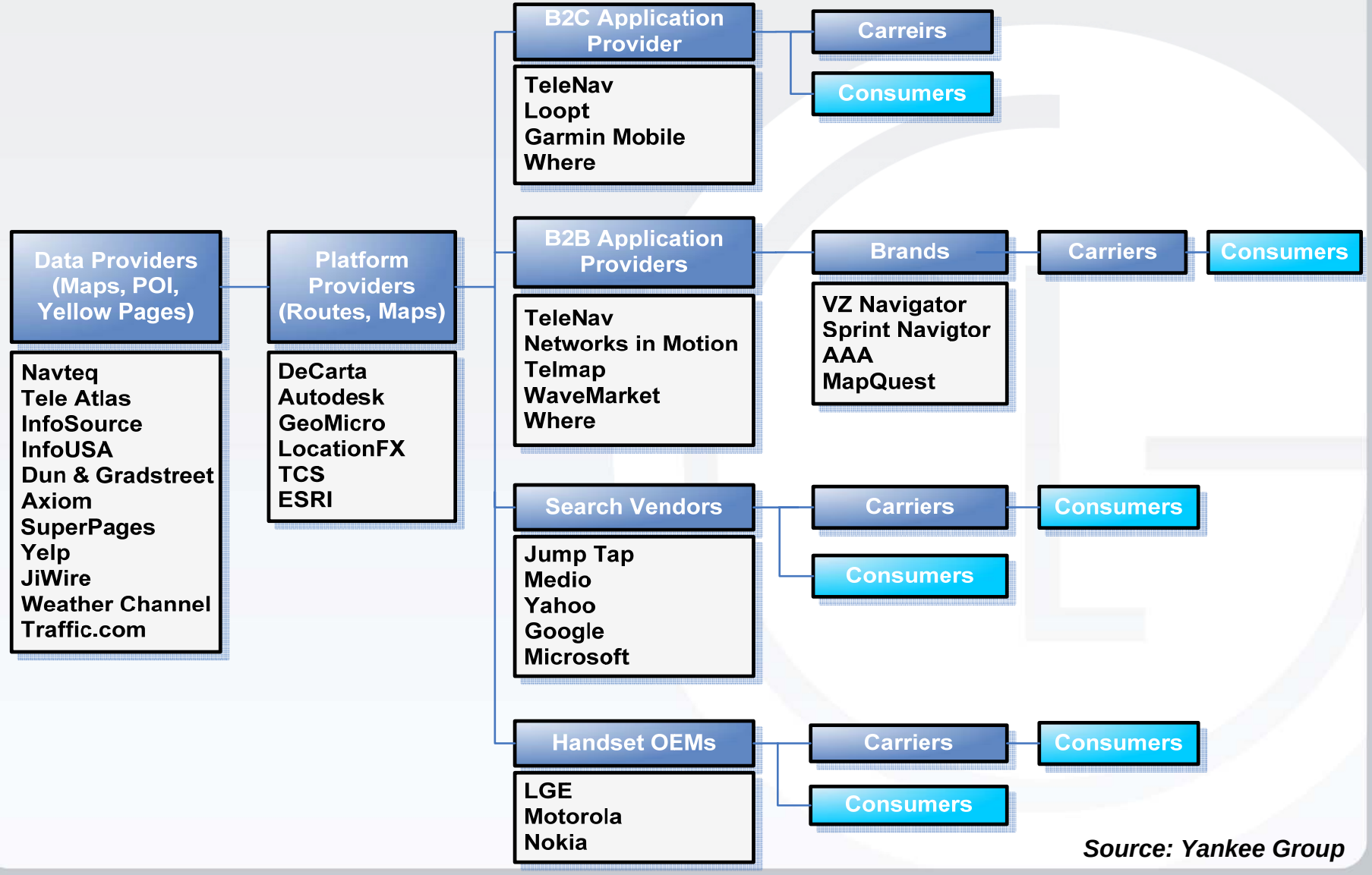
Verizon Chaperone

NTT DoCoMo i-Area

- NTT DoCoMo i-Area provides location-based services for corporate FOMA users.
- It offers services such as security alert.
- It aims to improve logistical efficiency for business.

LBS Companies

LBS Explosion Ahead



Source: Yankee Group

Key Factors to LBS Success

- **Compelling applications**
  - Valuable to consumers or businesses
  - Easy and intuitive to use
  - Good return on the investment
- **Handset availability**
  - Wide range of LBS-capable handsets
- **Internet-friendly**
  - IP-based user plane standards
- **Good business model**
  - Customer segmentation is important.
  - Adopt applications from 3rd parties.
  - Help operators increase revenue.
- **User awareness and promotion**
  - Security and privacy concerns

Major Design Challenges

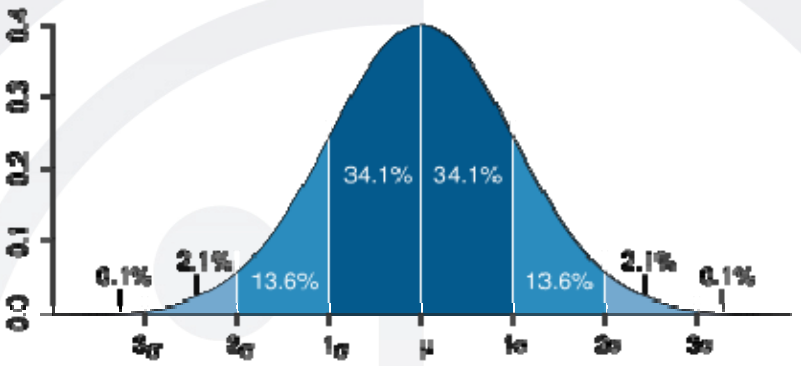
- **Positioning technologies**
  - Different levels of accuracy required for various services
  - Multiple mobile positioning techniques with varying accuracy
  - Quality of position: horizontal accuracy, response time, etc.
- **Privacy**
  - “Right to be let alone”
  - Users care about their privacy and are concerned with any intrusions.
  - Dilemma: LBS may be highly beneficial while it can do harm to the user’s privacy.
- **Interoperability**
  - Key for LBS to expand from a niche service to a mass market service
  - Standards help LBS providers deliver products and services while reducing cost and business risks.
- **Emergency services**
  - Timely delivery of accurate emergency call locations to the close emergency station
  - Demanding emergency service mandates in the US and the EU

FCC Enhanced 911

- **Phase I**
  - Within six months of a request by a Public Safety Answer Point (PSAP), the carrier shall provide PSAPs with the telephone number and the cell site location for this 911 call.
- **Phase II**
  - Within six months of a request by a PSAP, more precise location information, such as the latitude and longitude of the caller, shall be provided.
    - For network-based solutions, 100 meters for 67%; 300 meters for 95%.
    - For handset-assisted solutions, 50 meters for 67%; 150 meters for 95%.
  - By September 11, 2012, even more precise location information shall be provided.
    - The new rule requires wireless operators to average their compliance over each local region before 2012.
- **Phase II Compliance Status**
  - In August 2007, FCC fined three carriers, Sprint Nextel, Alltel and US Cellular, $2.8M for failing to meet the mandate (December 2005) to provide E911 service to 95 percent of their networks.

GPS Error Budget for E911 (FYI)

	Absolute		Differential	
Error Source	**P Code**	**L1 C/A Code**	**P Code**	**C/A Code**
Sat. Clock & Ephemeris Errors	3.9	3.9	0	0
Ionospheric delay	3.1	9	0	0
Tropospheric Delay	2.0	2.0	0.15	0.15
Receiver Noise and Resolution	1.1	11.1	1.1	11.1
Multipath	1.2	12	1.2	12
Other			0	0
*Selective Availability		30	0	0
Total System Error 1σ	5.6	35.6	1.3	16
Position Error (m) PDOP = 2.92	**16.3**	**104**	**3.8**	**48**



DOP	Rating	Description
1	**Ideal**	applications demanding the highest possible precision.
2-3	**Excel.**	Meet all but the most sensitive applications.
4-6	**Good**	the minimum appropriate for making business decisions.
7-8	**Mod.**	Can be used for calculations. A more open view of the sky is recommended.

"Differential operation of Navstar GPS", R. M. Kalafus, Vilcans, N. Knable, Navigation Vol. 30, No. 3, 1983

LBS Standardization

- **3GPP and 3GPP2 (3rd Generation Partnership Project)**
  - Telecommunication industry collaborations to make 3G mobile phone system specifications within the scope of ITU.
  - Interest in positioning technologies in cellular networks and related location services.
- **OMA (Open Mobile Alliance)**
  - A standards organization for delivering open technical specifications for application level and service frameworks.
  - Provide protocols and interfaces that enable the exchange of location data between different networks.
- **IETF (Internet Engineering Task Force)**
  - An open standards organization develops and promotes Internet standards.
  - Specify protocols for integrating location data with Internet or Web-based applications.

Acronyms

- 3G – The Third Generation
- 3GPP – The 3rd Generation Partnership Project
- 3GPP2 – The 3rd Generation Partnership Project 2
- ALI – Automatic Location Identification
- CDMA – Code Division Multiple Access
- CGALIES - the Coordination Group on Access to Location Information for Emergency Services
- EMS – Emergency Medical Services
- EMTEL – Emergency Telecommunications
- ETSI – The European Telecommunications Standards Institute
- GSMA – The GSM Association
- GPS – Global Positioning System
- IETF – Internet Engineering Task Force
- LBS – Location Based Services
- LCS – Location Services
- LORAN – Long Range Navigation
- NGN – Next-Generation Network
- OCG – Operational Co-ordination Group
- OMA – Open Mobile Alliance
- PSAP – Position Service Access Point
- TWC – The Weather Channel
- UMTS – Universal Mobile Telecommunications System
- UTRAN -- UMTS Terrestrial Radio Access Network

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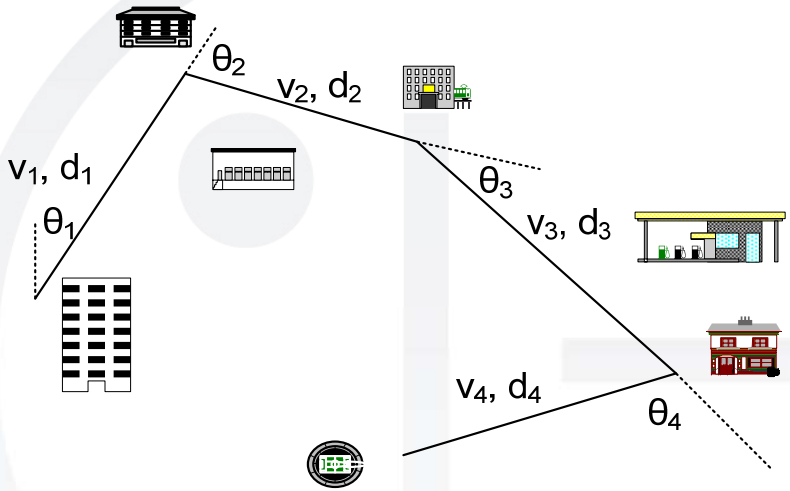
Section II: Wireless Location Technologies

- **Basic positioning methods**
  - Dead reckoning
  - Proximity sensing: signal signature tracking
  - Trilateration: signal strength analysis and TOA
  - Multilateration: TDOA
  - Triangulation: AOA
- **Satellite positioning systems**
  - Global Positioning System (GPS)
  - Galileo
  - Assisted GPS
- **Positioning in 3G networks**
  - Mobile-based technologies: Cell-ID, time advance
  - Network-based technologies: TDOA, AOA
  - Mobile-assisted technologies: A-GPS, AFLT, OTD

Dead Reckoning

- Dead reckoning is the processing of estimating one's current position based upon
  - previously determined positions
  - known speed and acceleration
  - moving direction
  - elapsed time
  - traveled distance
  - courses.

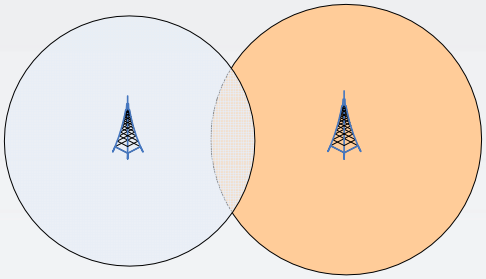


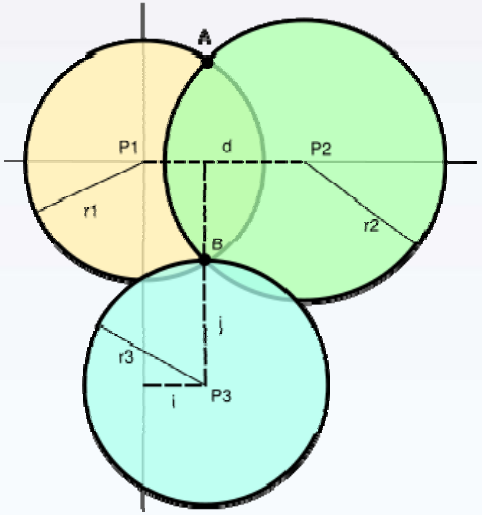
- It is well known to be the method used by Christopher Columbus for discovering the New World and modern inertial navigation systems, for example, for marine navigation and air navigation.

Proximity Sensing: Signal Signature

- In the proximity sensing, the mobile position is derived from the base-station coordinates. It is usually determined by tracking signal signatures or cell identity (Cell ID) of neighboring base stations.
- Every base station has its own signal pattern, which is usually embedded into its pilot and some synchronization channels.
- Signal signature based technologies usually comprise
  - signal signature estimation
  - neighbor list update
  - mobile location analysis
- Traffic Pattern Theory.
  - A person's daily activity pattern is pretty regular, which comprises several major events, such as school, work, home and shopping.

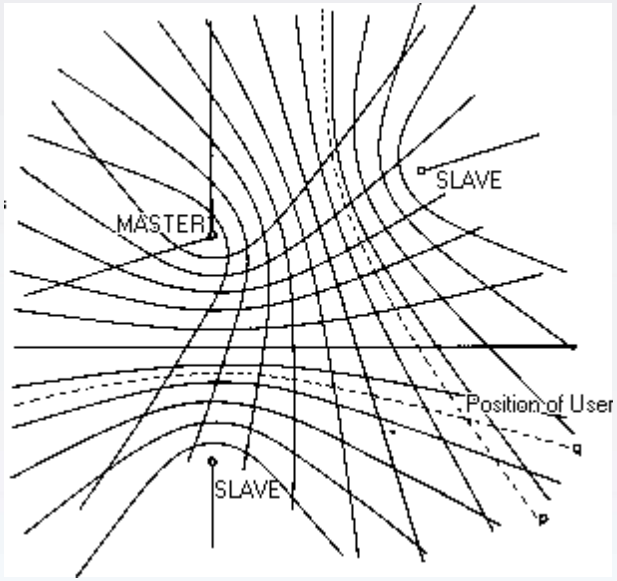
Trilateration

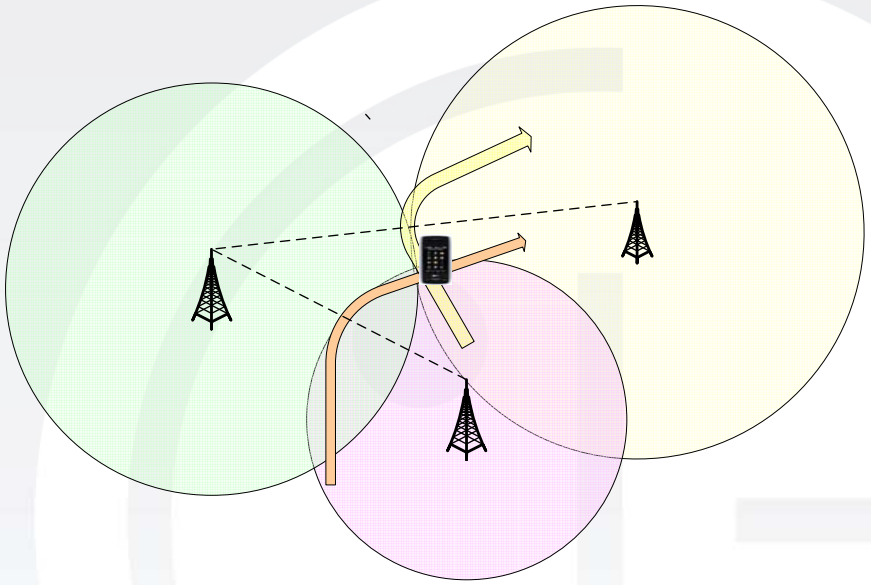




- **Trilateration**: it determines the relative positions of objects using
  - the known locations of two or more reference points, e.g. base stations.
  - the measured distance between the mobile and each reference point.
- **Trilateration with signal strength analysis**:
  - the distance is proportional to its received signal strength,
    $SS_{rx} = P_{tx} - 10\alpha\log(d) + X$ (dB) .
- **Trilateration with time of arrival (TOA)**: the distance can be obtained by estimating TOA of received signals.

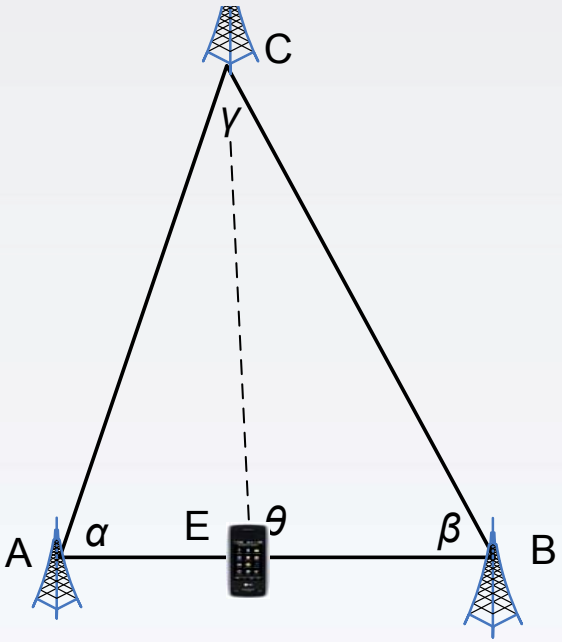
Multilateration: TDOA





- Multilateration, also known as hyperbolic lateration, usually is the positioning process by estimating time difference of arrival (TDOA) of a signal.
- TDOA method is similar to TOA estimation but doesn't need a clock synchronization.

Triangulation: AOA



$$\frac{\sin(\alpha)}{BC} = \frac{\sin(\beta)}{CA} = \frac{\sin(\gamma)}{AB}$$

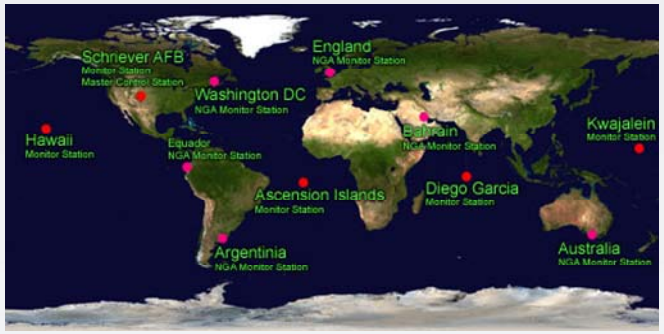
$$\frac{\sin(\theta)}{BC} = \frac{\sin(\beta)}{CE} = \frac{\sin(\pi - \theta - \beta)}{EB}$$

- Triangulation is the process of positioning a mobile with measuring
  - Angles of arrival (AOA) between the mobile and reference points, and
  - sides of the mobile and reference points.
- Triangulation is used for many purposes, including survey, navigation, astrometry, etc.
- The AOA is usually determined by using multiple antennas at a base station
  - The fundamentals are well established in the context of array signal processing.
- Many schemes are developed for estimating AOA, such as
  - Maximum output power,
  - Maximum likelihood estimation,
  - Subspace-based approaches.

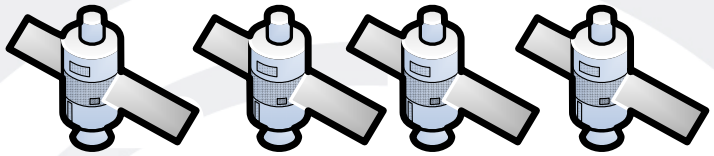
GPS: Overview

- GPS is a Global Navigation Satellite System for determining the positions of receivers using signals broadcast by satellites.
  - The first experimental Block-I GPS satellite was launched in 1978.
- It was developed and operated by US government to enhance the effectiveness of allied and US military forces.
  - As of September 2007, there are 31 actively broadcasting satellites in the GPS constellation.
  - Satellites orbit 20,163 kilometers above the earth at 3.87 km/s
  - 6 orbital planes, each with 4+ satellites. Typically 6 to 12 satellites are visible from any place on the earth.
- Since 1983, GPS has become an aid to civilian navigation worldwide, and a useful tool for survey, commerce, and scientific uses.

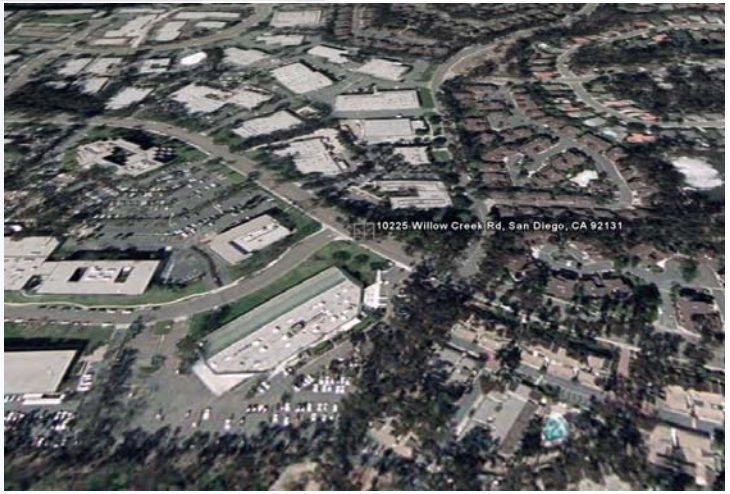
GPS: System Structure



The flight paths of the SVs are tracked by **the control segment**, which consists of multiple monitoring station operated by US Air Force and National Geospatial- Intellignece Agencey

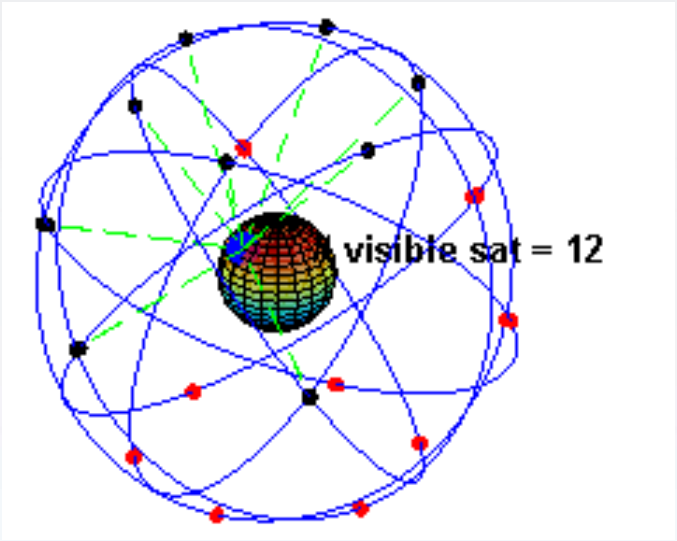


The space segment was originally designed to have 24 time synchronized space vehicles (SVs) with 4 each in six orbital planes. Now it has 31 SVs or possibly more



The GPS receiver is **the user segment**, which is composed of an antenna, a highly reliable local clock, processor's) and I/O interfaces.

GPS: Satellites and Control



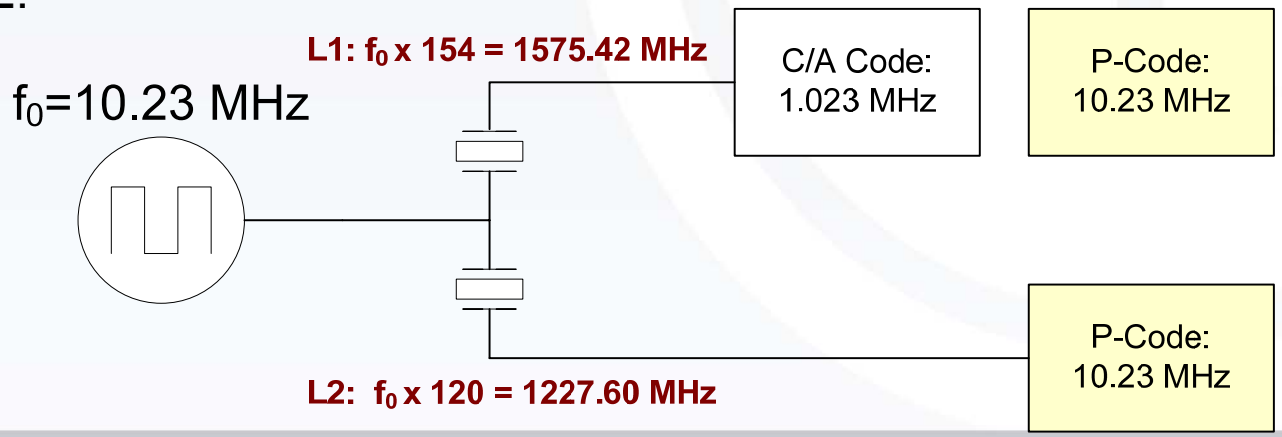
GPS constellation. Wikipedia

Navstar GPS
Satellite IIR-M

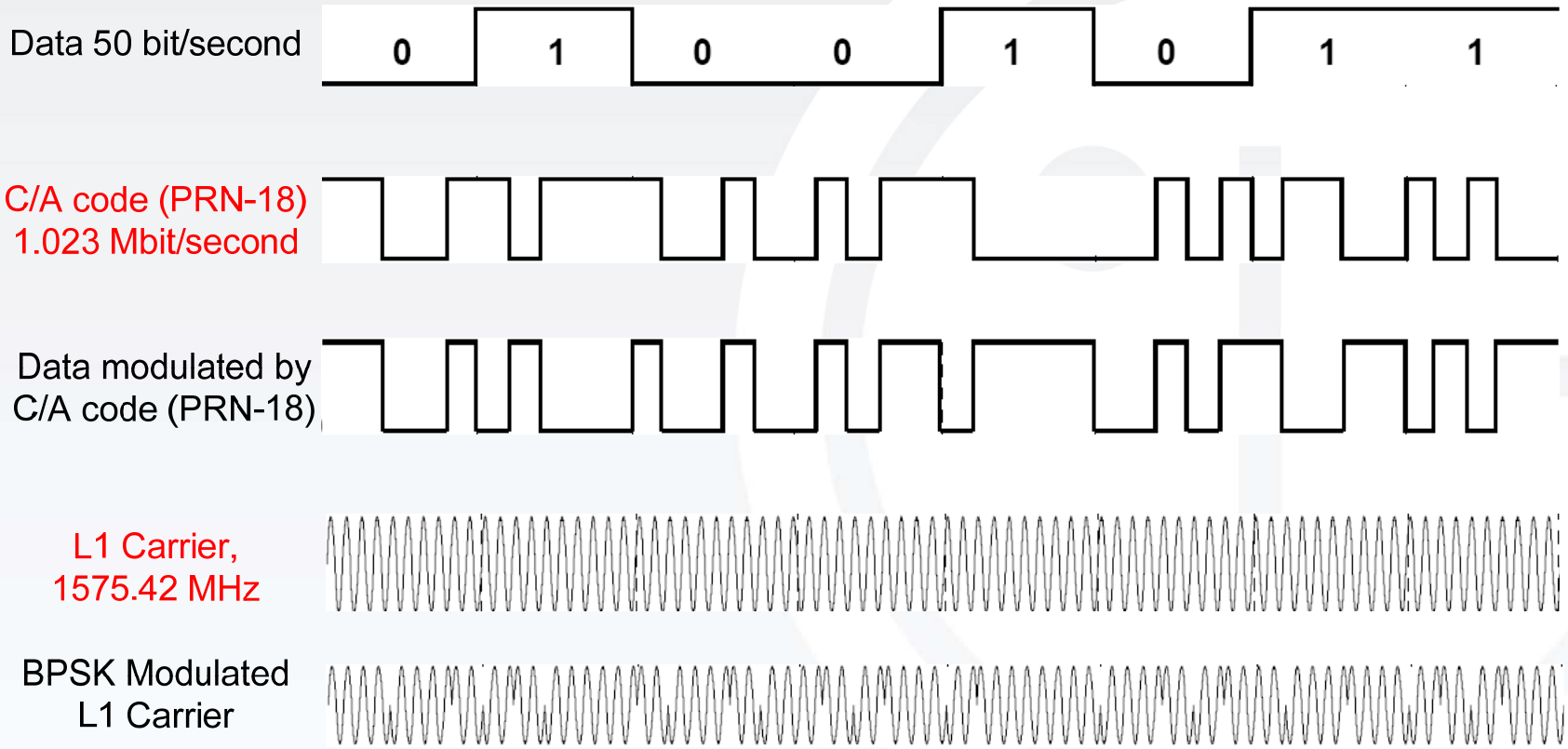
GPS Master Control Station TKSC, Japan

GPS: Satellite Signal Characteristics

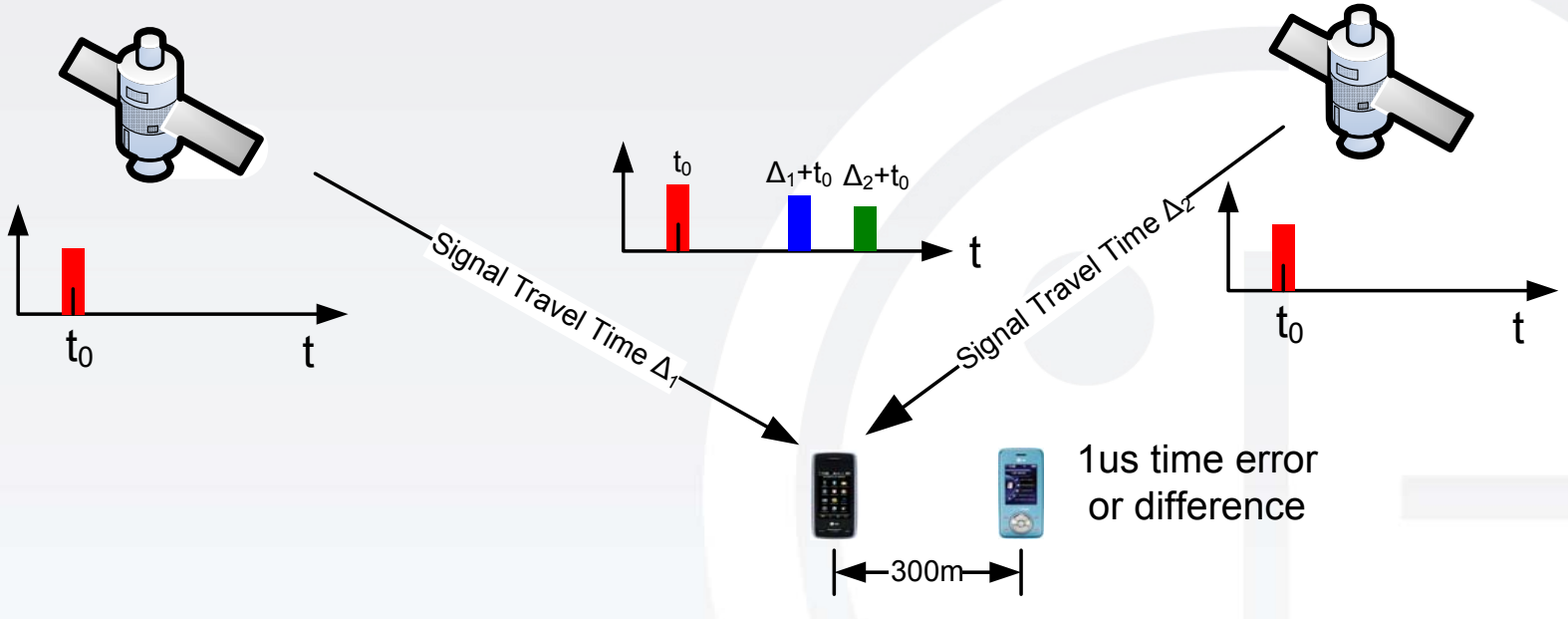
- All GPS satellites transmit on L1 and L2 frequencies.
  - Each satellite uses different ranging codes: C/A code; P-code.
  - L1 band is for civilian use.
- The C/A code (coarse/acquisition code) is modulated onto the L1 carrier only, while the P-code (precise code) is modulated onto both the L1 and L2 carriers.
  - The C/A code is less precise and less complex than the P-code and available to all users.
  - The P-code is intended for military uses and is added to both L1 and L2.

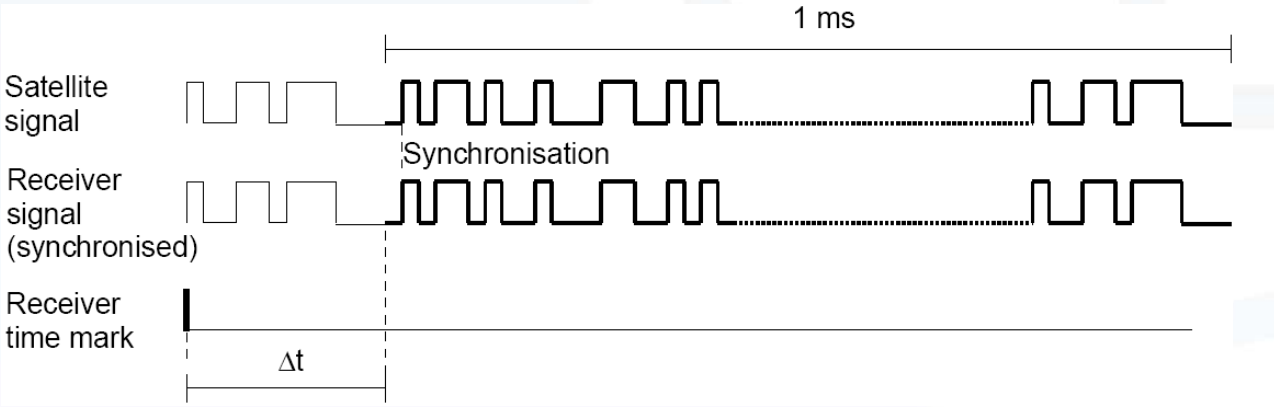


GPS: Signal Waveform

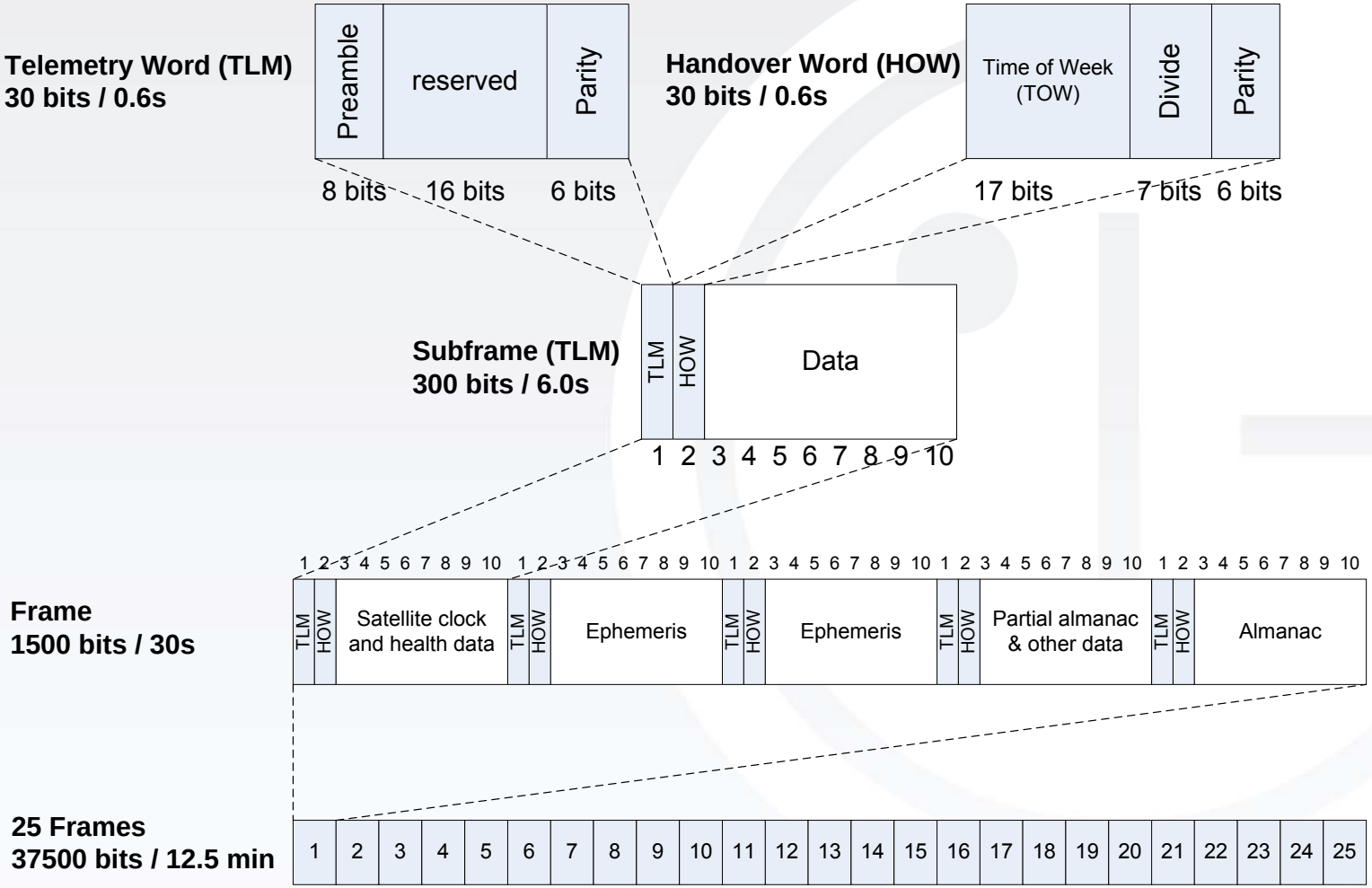


GPS: Positioning Principle





GPS: Message Format



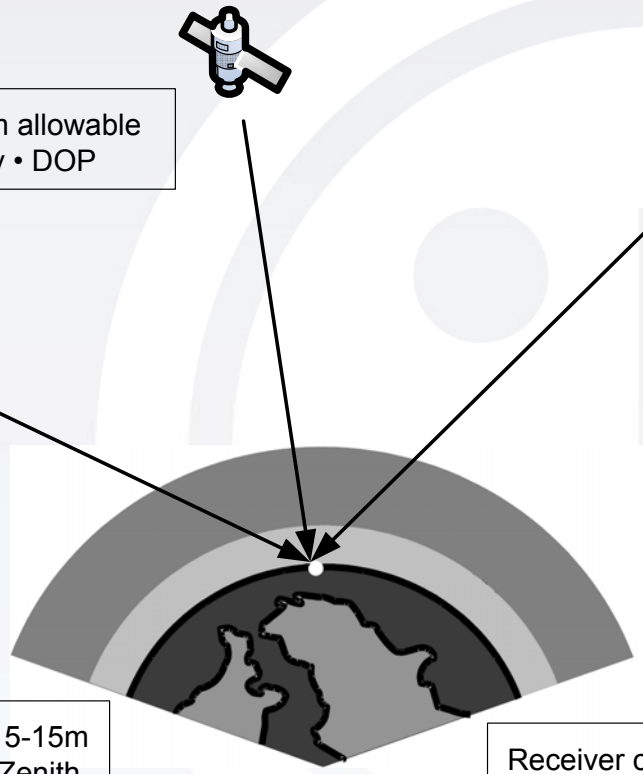
GPS: Navigation Data

- TLM – Telemetry: 30 bits, sent at the beginning of each frame.
  - It is used for data synchronization and satellite maintenance.
  - They are usually constant for any one satellite for a long period of time.
- HOW – Handover Word: 30 bits, sent after TLM.
  - It indicates the time at the beginning of the next subframe.
  - It also contains a sub-frame ID, some flags and parity bits.
- Ephemeris: It is sent in each frame by each satellite.
  - It may take the GPS receiver up to 30 seconds to acquire Ephemeris.
- Almanac: It is spread out over all 25 frames of the message.
  - For receiving the complete Almanac, the GPS receiver may need about 12.5 minutes.

GPS Receiver

- Measure approximate distance to 3 or more satellites.
  - The receiver measures the time required for signal to get from the satellite to the receiver.
  - Calculate the distance.
- Obtain satellite positions from satellite broadcasts.
  - Almanac: approximate positions used to set approximate satellite search ranges, etc.
  - Ephemeris: precise position used in trilateration calculations.
- Calculate the position using trilateration.
- Correct for errors to improve accuracy.
  - Calibrate the clock bias.
- (Optional) Apply differential correction.
  - Correct deliberate noise, such as selective availability.
  - Caliberate variable ionospheric and tropospheric propagation delays.

GPS Positioning Error Sources



Dilution of precision: Maximum allowable error = GPS receiver accuracy • DOP

Ephemeris (orbital) error: in the order of 2-5m
Selective availability: 03/1990 – 05/2000
Satellite clock error: in the order of 2.3m with ephemeris effect

Ionospheric delays: in the order of 5-15m
tropospheric delay: about 2.3m at Zenith and 20-28m for a 5^{o} elevation angle

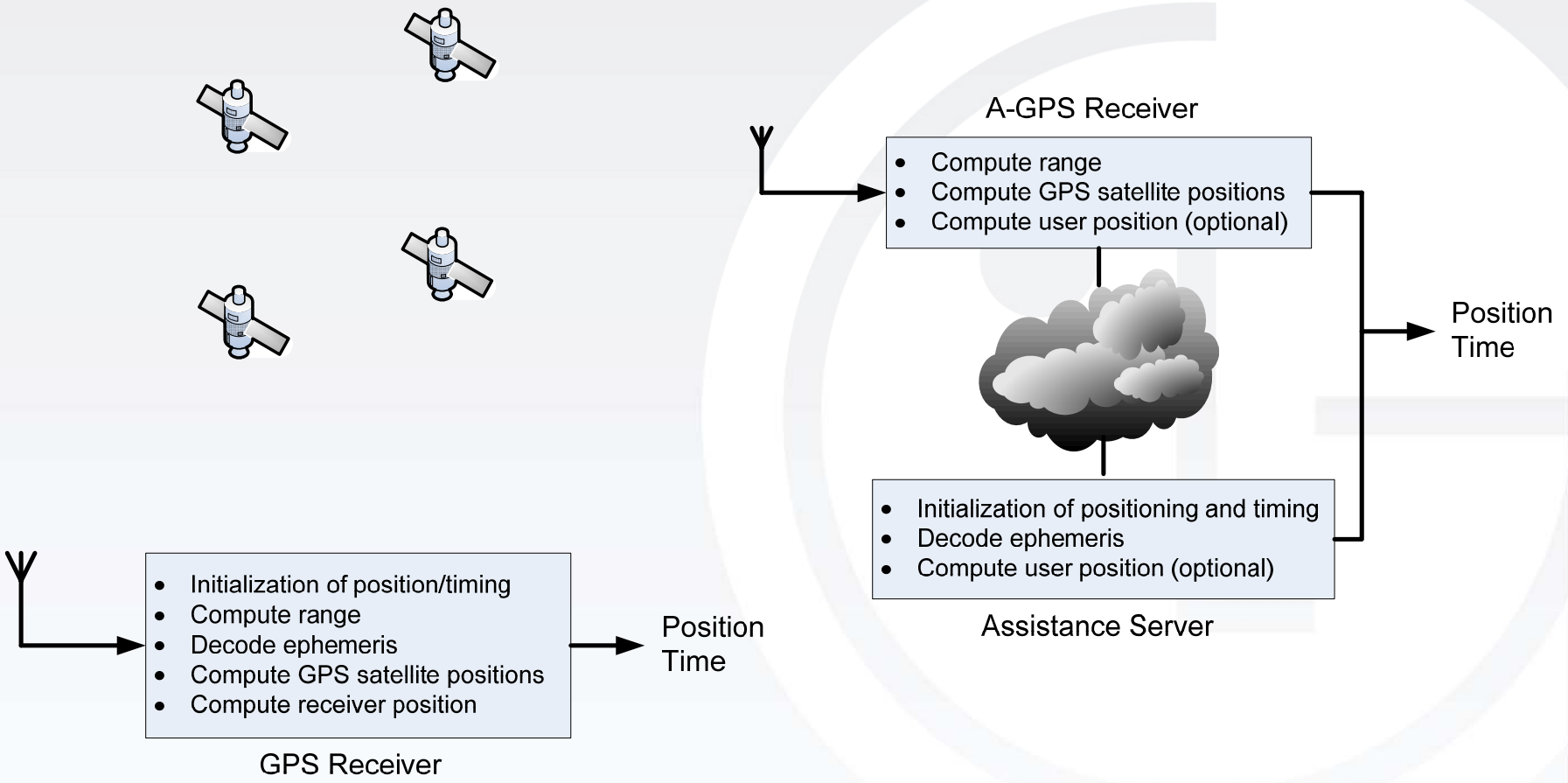
Receiver clock error
Multipath error
System noise: in the order of 0.6m
Antenna distortion: in the order of a few centimeters

Assisted GPS: Overview

- A-GPS with assistance server were developed to enhance the positioning performance of a GPS receiver and satisfy FCC's E911 mandate.
  - It was firstly come out by Bell Labs before the 1996 FCC ruling.
- Assistance server can increase the capability of a stand-alone receiver.
  - It can roughly locate mobiles along by itself.
  - It can supply more GPS orbital data to the mobile.
  - It has better knowledge of atmosphere conditions and other errors as well as better augmentation capability.
- A-GPS help improve positioning in terms of
  - Location accuracy: the positioning error.
  - Yield: the positioning success rate.
  - Time to fix: the time for positioning.
  - Battery consumption: power consumption for positioning.
  - Mobile device cost.

  - swang@lge.com

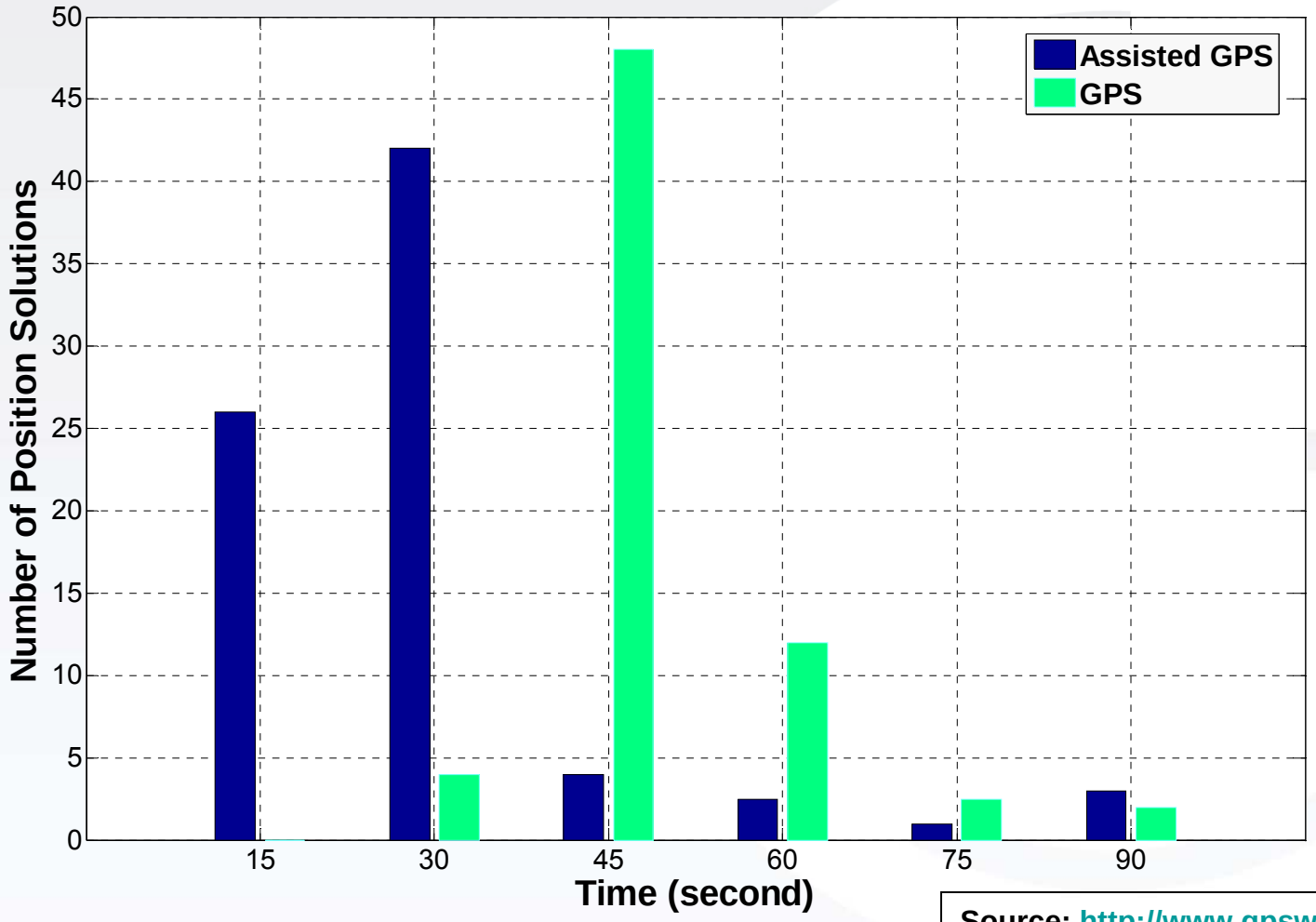
Assisted GPS: GPS vs. A-GPS



Assisted GPS: Assisting Information

- Precise GPS satellite orbit and clock information
  - Reference time
  - Reference location
- Initial position and time estimate
  - Almanac
  - Acquisition assistance
  - Real-time integrity.
  - Universal Time Co-ordinates
- Satellite selection and range information
  - Differential GPS (DGPS) corrections
  - Navigation model (contains satellite ephemeris and clock corrections)
  - Ionospheric model
  - UTC model

Assisted GPS: Performance



Source: http://www.gpsworld.com

Galileo : Overview

- Galileo is a Global Navigation Satellite System by the European Union.
  - It is a joint initiative of the European Space Agency and the European Commission.
  - The goal is to provide an accurate, guaranteed global positioning service under civil control.
- With Galileo, the European Union wants
  - to control the geopositioning system and guarantee the access.
  - to develop more civilian applications including new paid services and have it under civil control.
- The current status of Galileo project
  - Participants: the 27-state European Union, the 15-state European Space Agency and some non-EU country partners.
  - Budget: €5.4 billion.
  - Schedule: constellation deployment around 2011; full operation around 2013.

Galileo System

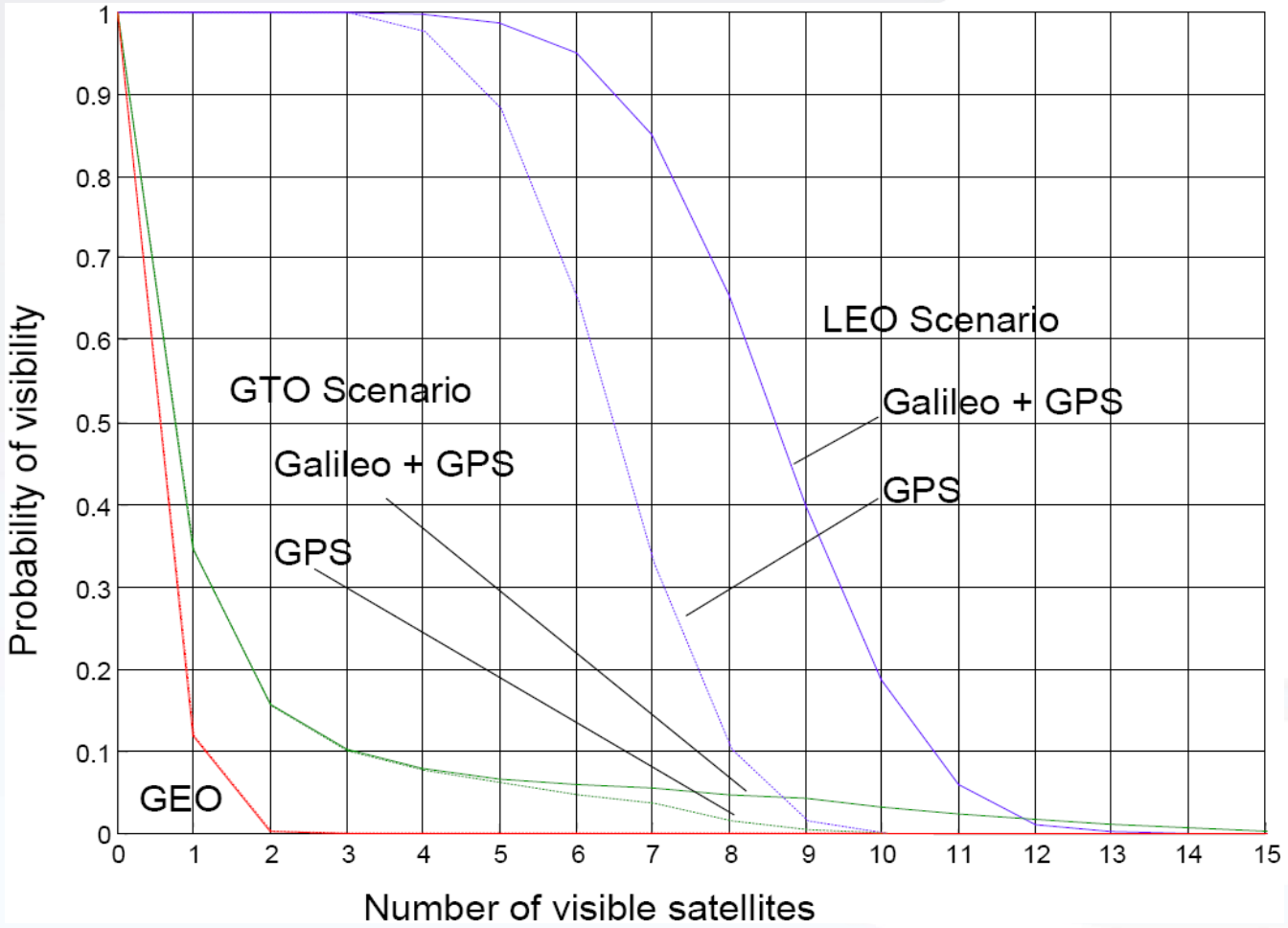
- Technically, Galileo is similar to GPS
  - Satellites transmit signals with PN codes for ranging.
  - Additional data like the Almanac and Ephemeris in GPS are provided to support the position determination.
  - Similar number of satellites and orbits are planed.
  - Galileo receivers are expected to also have the basic pseudoranging, calibration, trilateration and clock bias compensation components as GPS receivers.

Parameters	Galileo	GPS
Space Vehicles	30, including 3 spares	31
Constellation	Walker 27/3/1	Walker 24/6/1
Planes	3	6
Altitude	23,616 km	20,163 km
Inclination	56 degree	55 degree

Galileo Services

- Open services of higher accuracy.
  - Free service for mass market.
  - Meter-level accuracy.
- New paid commercial services.
  - Encrypted.
  - Guaranteed services for a fee.
  - Claimed centimeter-level accuracy
- Enhanced governmental services
  - Encrypted.
  - Continuous availability even in times of crisis.
- Safety of life services
  - Open service but encrypted.
  - For applications such as automated aircraft landing
- Two-way search and rescue services.
  - Feasible to send feedback.

Galileo and GPS in Comparison



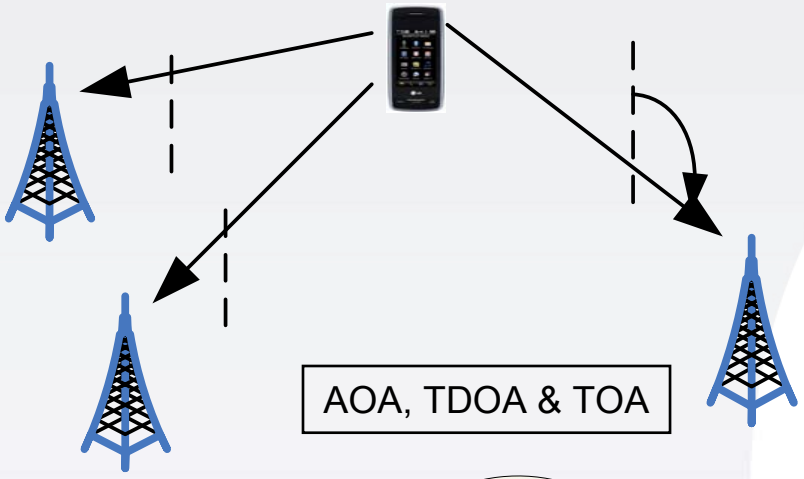
W. Enderle, Galileo: Impact on Spacecraft Navigation System, J. of GPS, 2003

Positioning Technologies for Mobiles (1/2)

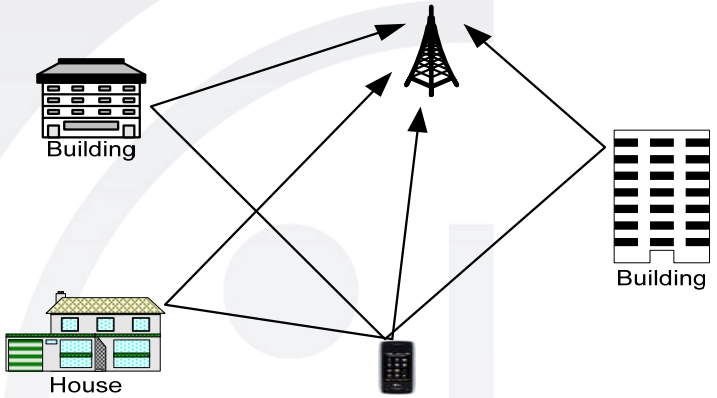
- **Mobile-based solutions**
  - positioning is carried out in handset and sent back to the network.
  - Potential security risk
- **Mobile-assisted solutions**
  - Handset makes the measurements, reports these to the network where the serving mobile location center node calculates the handset position.
  - Location information is not stored in the handset and remains in the network.
- **Network-based solutions**
  - Positioning is done by the network.

	Cell ID	Cell-ID/TA	EFLT	AFLT	AOA	TDOA	EOTD	GPS	A-GPS
Network-Based					■				
Mobile-Assisted			■			■	■		■
Mobile-Based	■	■		■				■	■

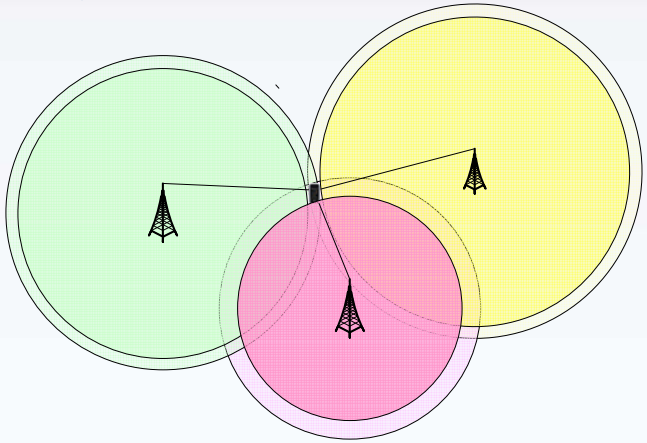
Positioning Technologies for Mobiles (2/2)



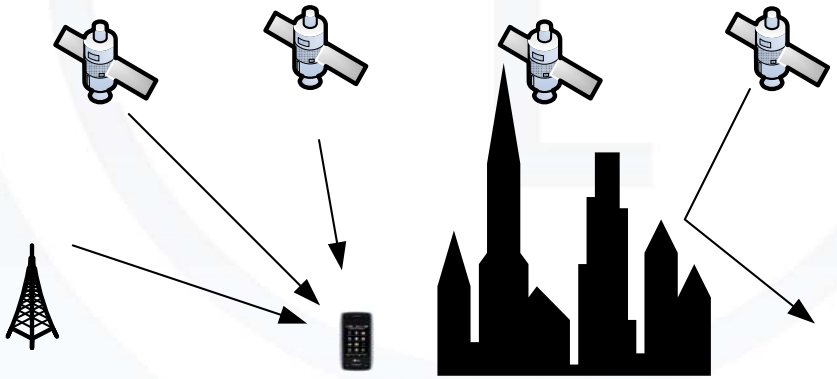
AOA, TDOA & TOA



Multipath or Signal Strength Analysis



E-OTD & A-FLT

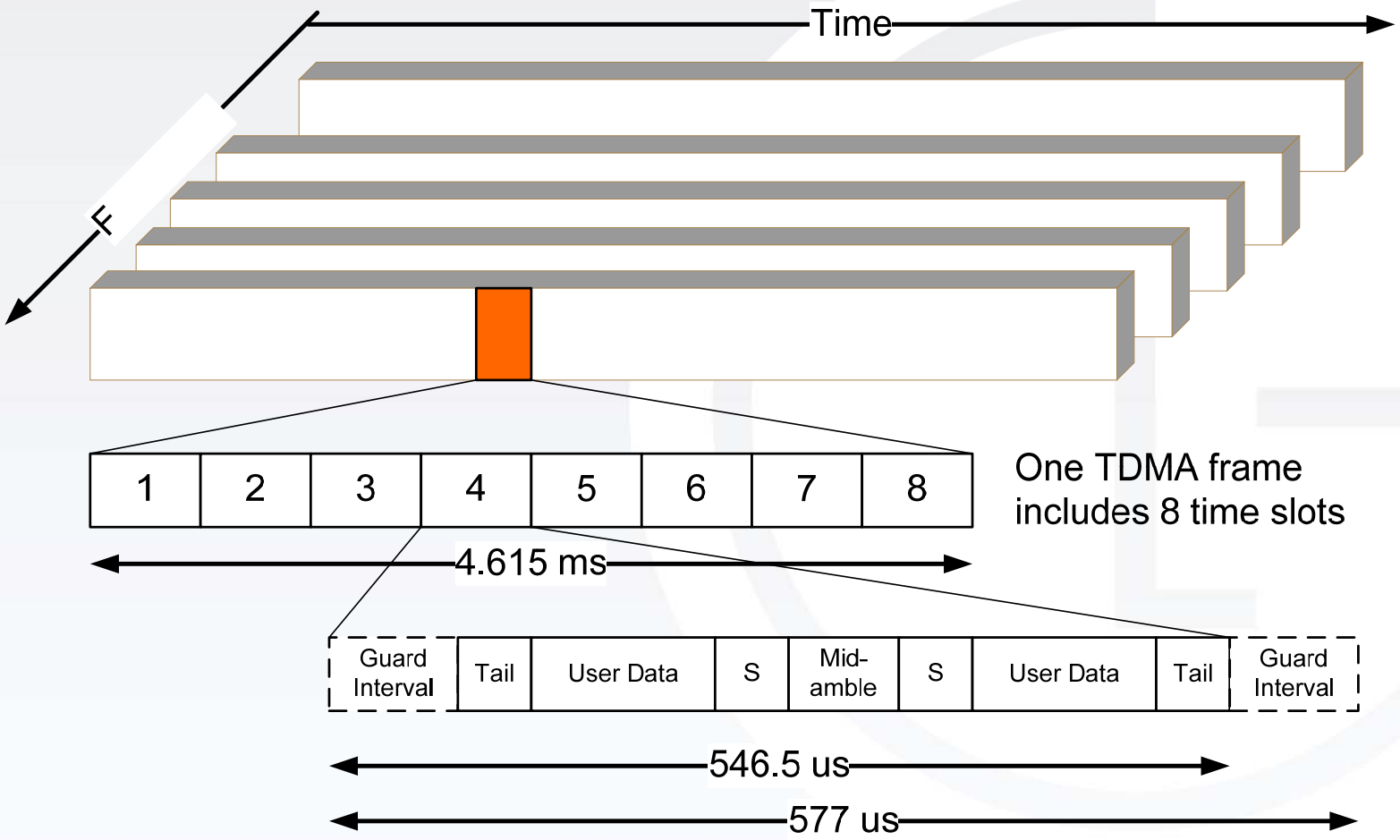


GPS & A-GPS

Positioning in GSM

- In 1997, TIA led the standardization activities for the positioning in GSM. Four positioning methods were included.
  - Cell identity and timing advance
  - Uplink time of arrival (TOA)
  - Enhanced observed time difference (E-OTD)
  - Assisted GPS
- There were two stages of standardizations
  - The first version specification supports circuit-switch connections.
  - The second version specification provides the same support in the packet-switch domain.

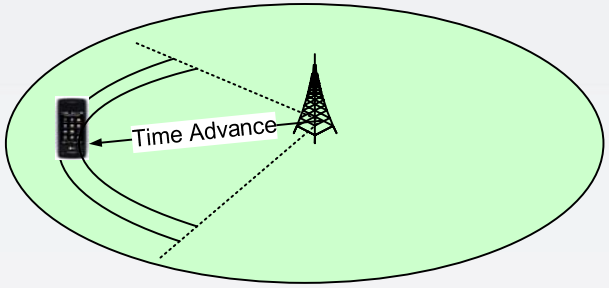
GSM Signal Feature



Cell Identity and Time Advance for GSM (1/3)

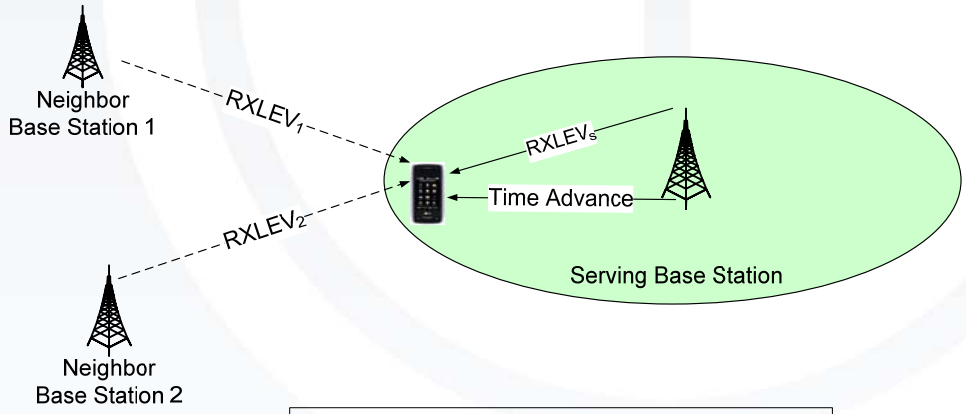
- Cell identity (CI) is the signature and identity of a BTS. A CI-based approach assumes
  - the mobile is at the serving cell's antenna coordinates in a omni-directional cell, or
  - the center point of a sector in a sector cell.
- Time advance (TA) represents the round trip delay between the mobile and the serving BTS.
  - TA is used in a TDMA-liked system to avoid overlapping of bursts transmitted by multiple users.
  - It is represented by a 6-bit integer number in the unit of the GSM bit period.
- In addition, RXLEV is the measurement of the strength of signals received by a mobile.
  - With suitable propagation models, the distance between a mobile and the BTS can be estimated.

Cell Identity with Time Advance for GSM (2/3)



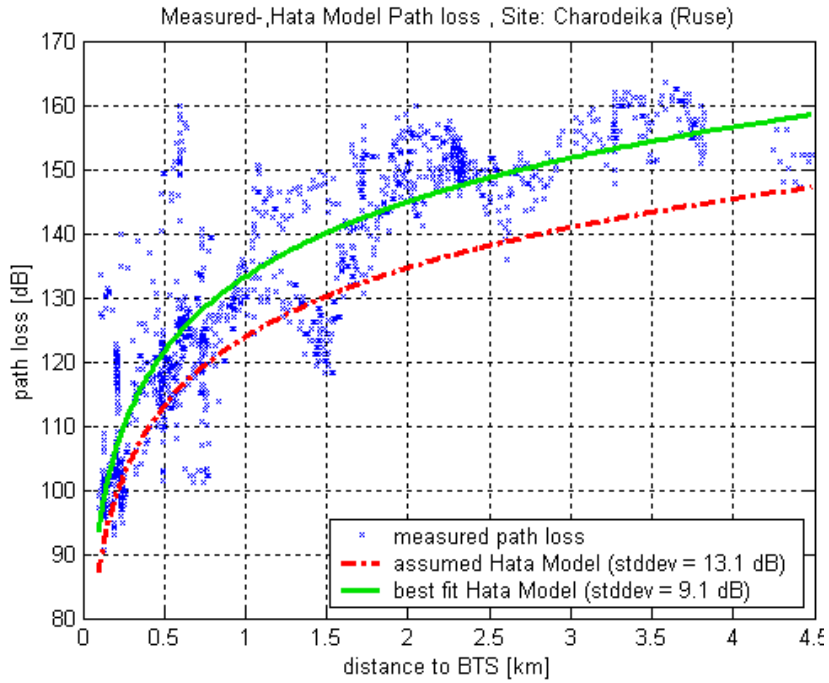
Cell Identity + Time Advance

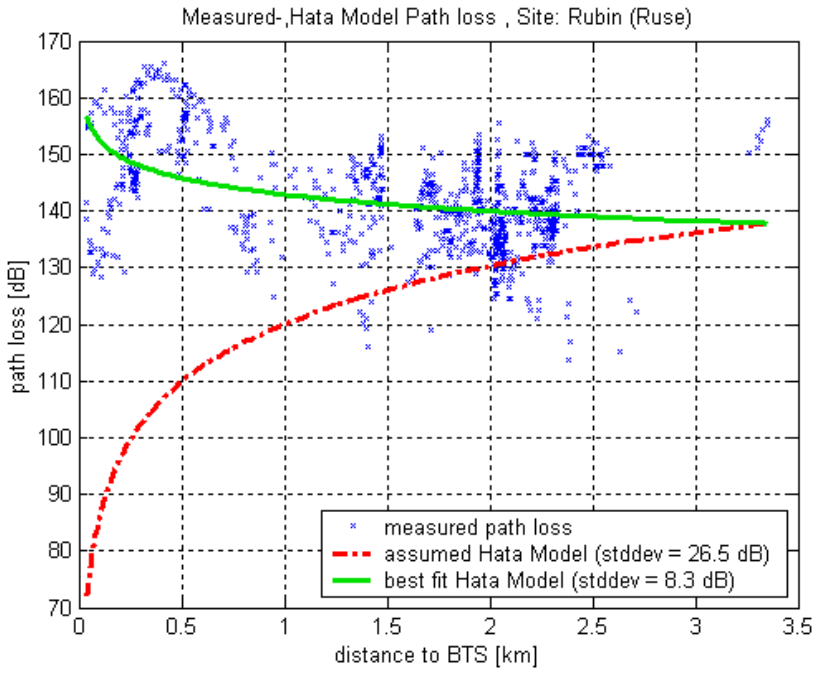
m.r.	RXLEV_UL	RXLEV_DL	RXQUAL_UL	QXQUAL_DL	TA	BS_RED	MS_RED	BSIC	BCCH	RXLEVNC1
1	24	36	0	0	4	0	10	35	5	22
2	22	31	0	0	4	0	10	35	5	23
3	24	40	0	0	4	0	10	35	5	26
4	26	35	0	0	4	0	10	35	5	25
5	25	36	0	0	4	0	10	35	5	24
6	24	36	0	0	4	0	10	35	5	29
7	25	37	0	0	4	0	10	35	5	36
8	23	34	0	0	4	0	10	35	5	40
9	19	33	0	2	4	0	10	35	5	42
10	23	36	0	1	4	0	10	35	5	43
11	22	35	0	1	4	0	10	35	5	42
12	26	39	0	0	4	0	10	35	5	42
13	22	38	0	0	4	0	10	35	5	42



Cell Identity + Time Advance + RXLEV

Cell Identity with Time Advance for GSM (3/3)





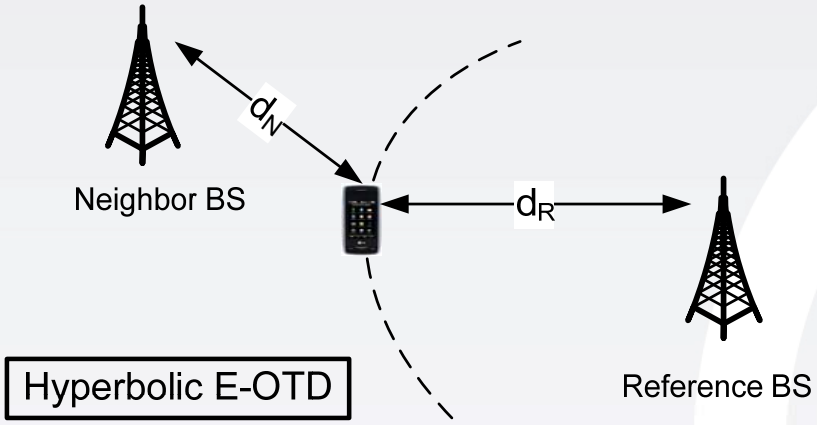
Source: Alcatel-Lucent.

There may be a big difference between the channel model used by mobiles and the actual path loss and distance mapping.

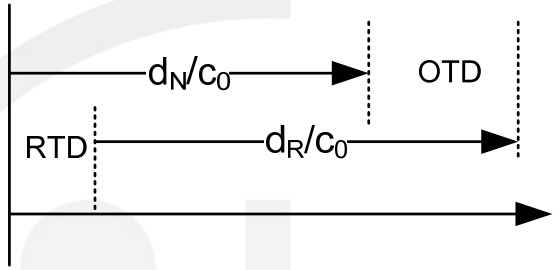
Enhanced Observed Time Difference for GSM (1/3)

- Observed Time Difference (OTD)
  - Time difference measured by the mobile between the receptions of bursts transmitted from the reference BTS and each neighboring BTS.
  - It mostly is for handover.
- Enhanced OTD (E-OTD) is the OTD measurement for positioning purposes.
- E-OTD essentially is the sum of two components
  - Real-Time Difference (RTD): the synchronization difference between two base stations.
  - Geometric Time Difference (GTD): propagation time difference between two base stations.

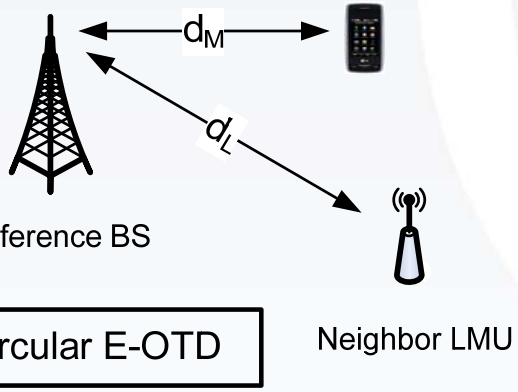
Enhanced Observed Time Difference for GSM (2/3)



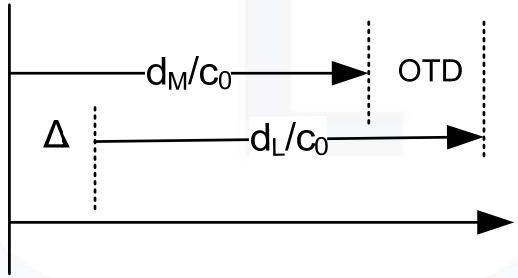
Hyperbolic E-OTD



GTD = OTD – RTD
= $(d_N-d_R)/c_0$

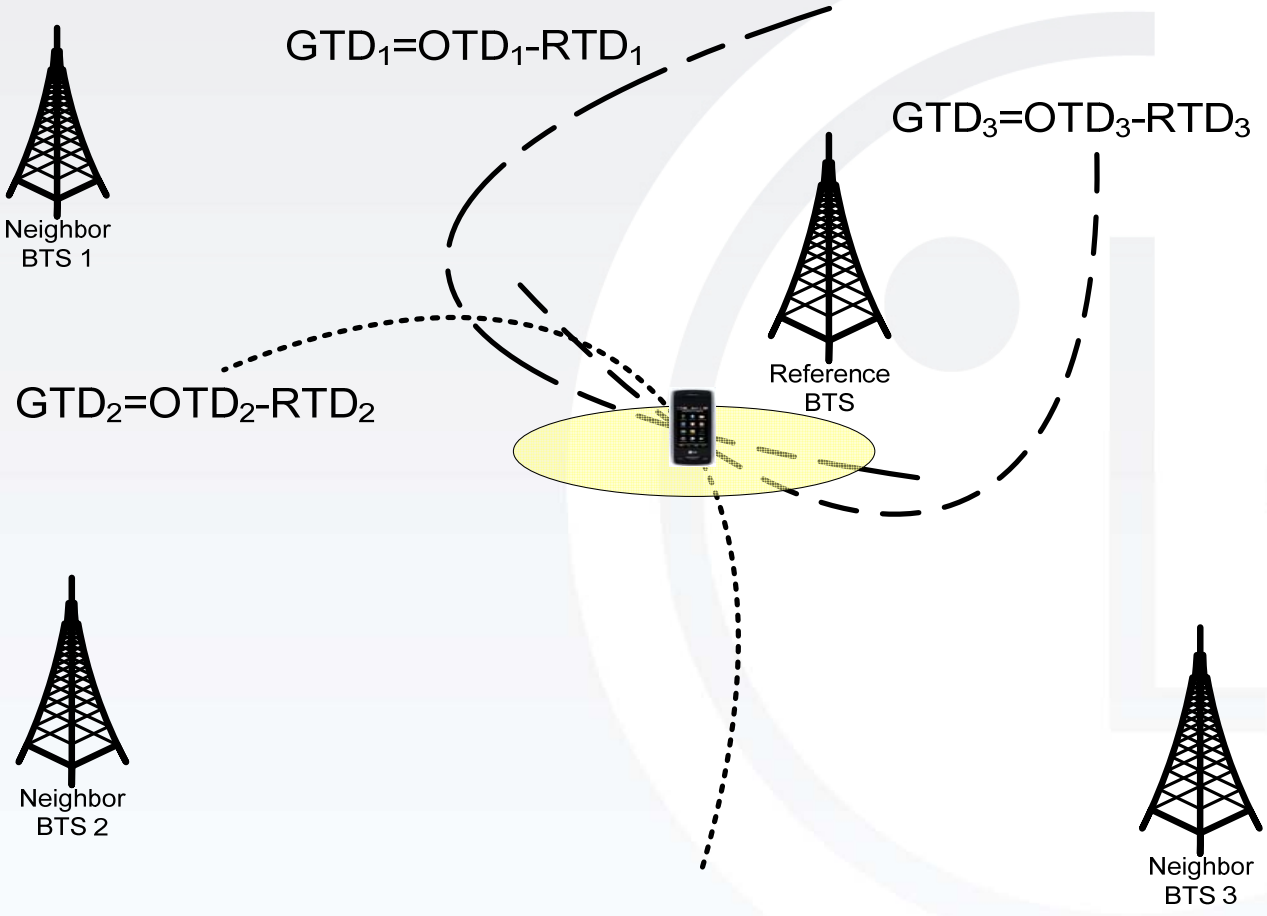


Circular E-OTD



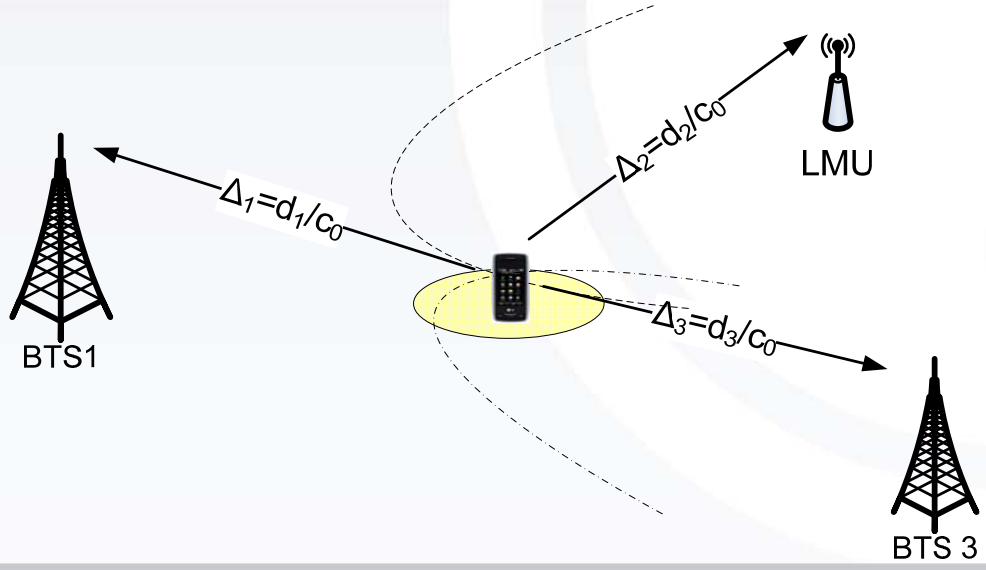
$d_M/c_0 = OTD + t_L + \Delta$
$= OTD + d_L/c_0 + \Delta$

Enhanced Observed Time Difference for GSM (3/3)



Time of Arrival/Time Difference of Arrival for GSM

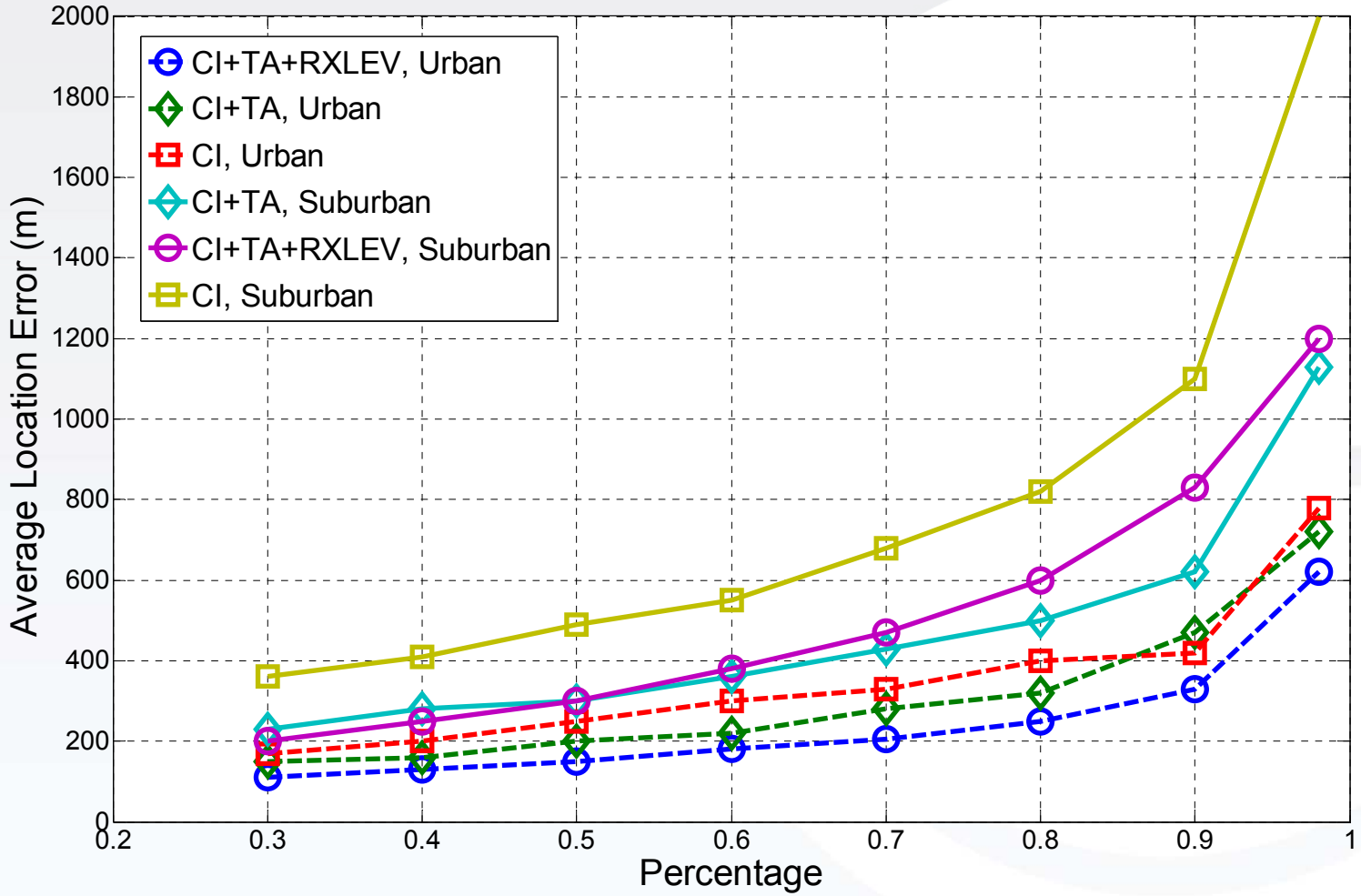
- The TOA of random access bursts in the random access channel from a mobile is measured by the BTS or LMU (location measurement unit).
- The location estimation schemes are similar to E-OTD.
  - In TOA approaches, one TOA measurement by one BTS or LMU determines a circle.
  - In TDOA approaches, the difference in TOA measures by two different BTS or LMUs determines a hyperbola.
- The mobile is usually signaled to perform an asynchronous handover for sending out random access bursts.



Assisted GPS for GSM

- Two basic A-GPS are supported
  - Mobile-based A-GPS
  - Network-based A-GPS
- In the A-GSP for GSM
  - The GSM network measures the difference between GSM time and GPS time.
  - The GSM network informs the mobile about the data that the GPS satellites are sending.
  - The GSM network sends the acquisition assistance data including
    - the Doppler shift and code phase of the signal from a certain satellite.
    - the real-time status of certain GPS satellites
- High Positioning Performance Expectations
  - High Sensitivity: inside, urban canyons, etc.
  - Rapid First Fix: several seconds from cold start.
  - Accuracy suitable for location services: 5-50m.

Positioning Performance for GSM (1/2)



Spirito M. A., P¨oykk¨o S., Knuuttila O, VTC2001

Positioning Performance for GSM (2/2)

Number of measurements	50% Accuracy	67% Accuracy	90% Accuracy	Comments
267	58m	90m	232m	7 LMUs; 0~50 km/h
150	35m	42m	85m	6 LMUs; 0~50 km/h
200	87m	120m	240m	6 LMUs; 0~50 km/h
45	28m	31m	33 m	5 LMUs; stationary

Test results for E-OTD, M. Weckstrom, M. Spirito and V. Ruutu, John Wiley & Sons, 2003

Positioning in UMTS

- In Europe, the European Telecommunications Standards Institute (ETSI) with its 3G Partnership Project (3GPP) is responsible for the standardization of the location services and positioning techniques for UMTS.
- Release ’99 of UMTS specifies the following positioning methods:
  - cell coverage based positioning methods,
  - observed time difference of arrival (OTDOA) based methods,
  - assisted GPS methods.

UMTS Features for Positioning (1/2)

- Common Pilot Channel (CPICH). It is an unmodulated code channel, which is scrambled with the cell-specific primary scrambling code.
  - Two types of CPICH: primary CPICH and secondary CPICH
  - It aids the channel measurements at the mobile for handover, cell selection, beamforming, etc.
- Downlink/Uplink Dedicate Pilot Channel
- Synchronization Channel (SCH)
  - It consists of two channels: Primary SCH and Secondary SCH
  - The SCH is time multiplexed with the Primary Common Control Physical Channel.
  - It is needed for the cell search.

UMTS Features for Positioning (2/2)

- Idle Periods in Down Link (IPDL)
  - In UMTS, Node B transmissions are synchronously ceased for a short period of time, which is called Idle Period
  - Mobiles can measure neighbor Node B's signal strength during the idle periods.
  - Two popular techniques:
    - Standard IPDL
    - Time aligned IPDL (TA-IPDL)
- Intra-mode handover measurements.
  - Received signal code power (RSCP)
  - Received signal strength indicator (RSSI)
  - Ec/N0

Cell ID with RTT for UMTS

- Essentially it is identical to Cell ID with TA method in GSM.
- Round trip time (RTT) is the time difference between the start of a downlink frame and the reception of the corresponding uplink frame.
  - It can be used to calculate the distance from a Node B to a mobile using propagation models.
- The accuracy of RTT measurements in UMTS is significantly higher. With the resolution of 1 chip, the positioning accuracy can be about 80m.
- The performance of Cell ID with RTT can be further enhanced by
  - incorporating the RTT measurements from all Node Bs in the mobile active set, and
  - forced handover (FHO).

Cell ID with RSPB for UMTS

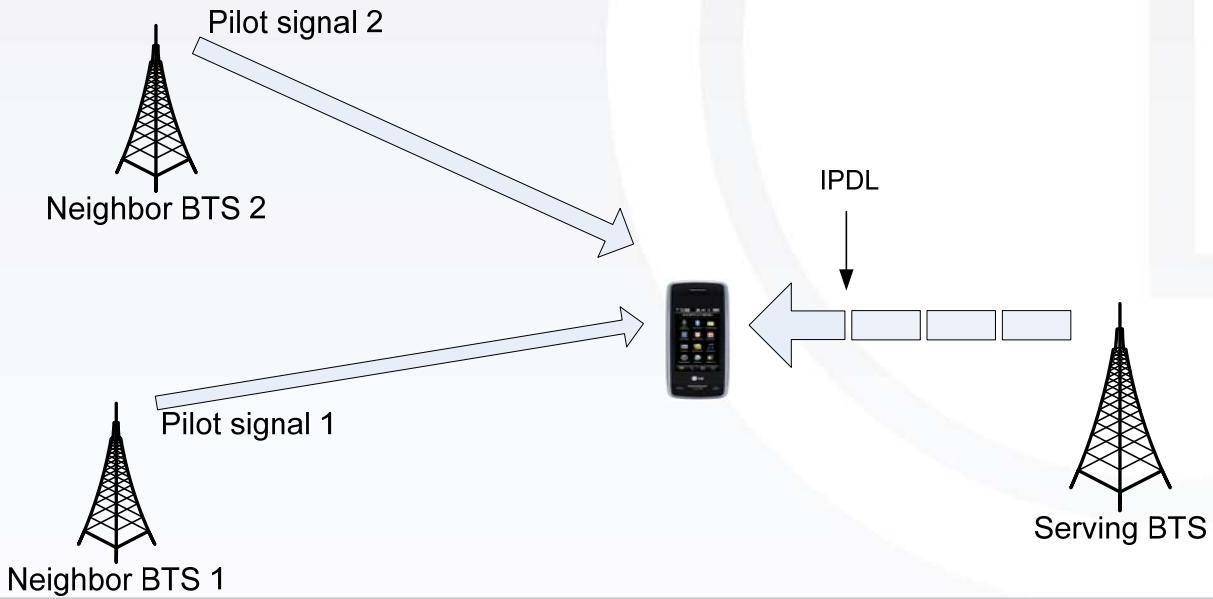
- The coverage area of a cell can be determined by using reference signal power budget (RSPB).
- RSPB gives the information about
  - node B transmitted power,
  - isotropic path loss,
  - coverage threshold at coverage area border for a given location probability,
  - cell radius for indoor and outdoor coverage.
- Serving RNC may compare the received power levels with the power budget to accurately position the mobile.

OTDOA for UMTS

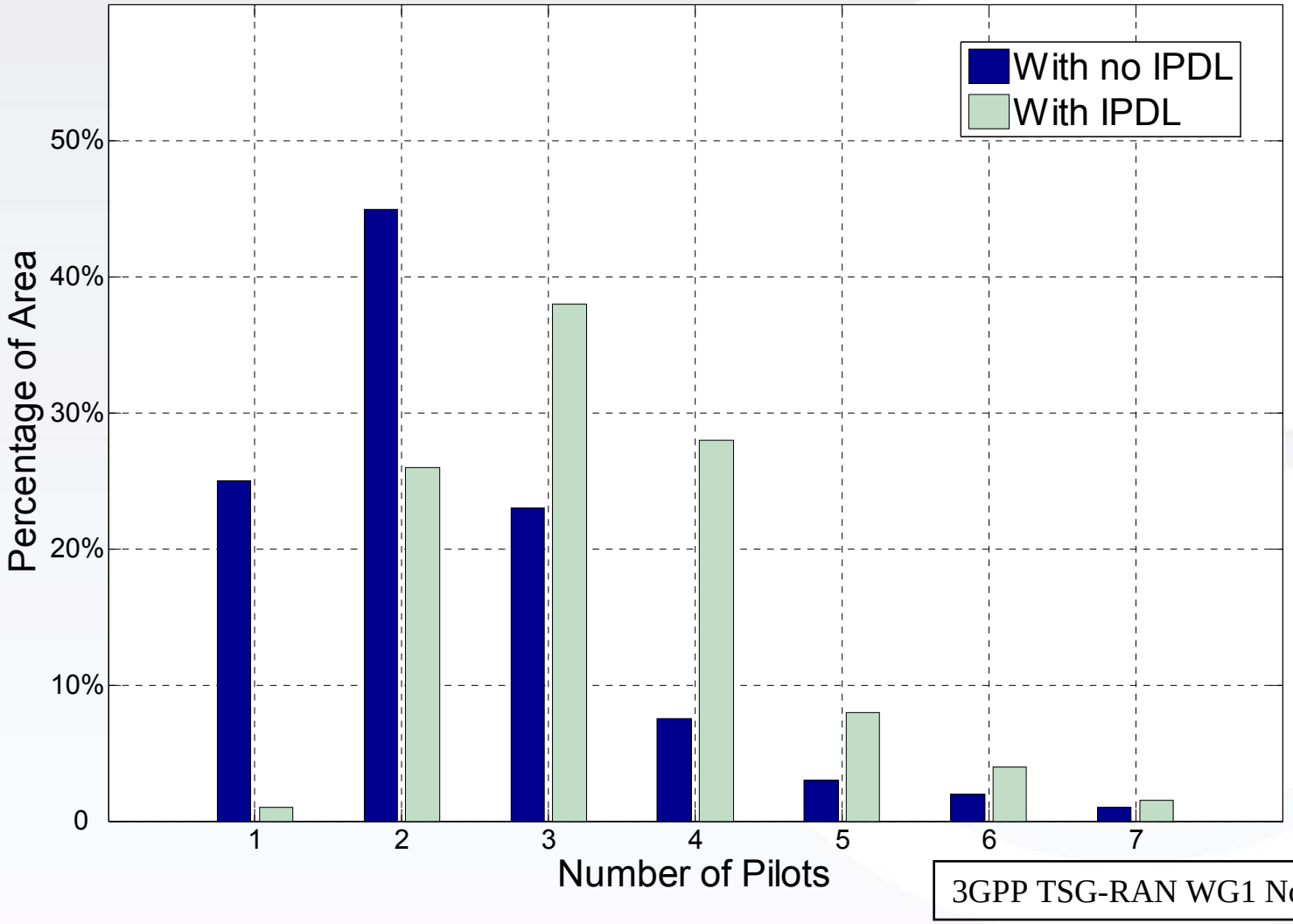
- Observed time difference of arrival (OTDOA) is based on the mobile measurements of the relative arrival times of pilot signals from different based stations.
  - Signals from at least three base stations must be received by the mobile for location determination.
- Timing synchronization of different Node Bs is essential. This can be obtained by
  - the location measurement unit at the base station, or
  - the GPS receiver at the base station.
- There is a near-far problem with OTDOA methods
  - It is also a challenge for network planning.
  - Serving Node B drowns the signals from distant Node Bs
  - With the assistance of other techniques, OTDOA methods can be enhanced.

OTDOA with IPDL for UMTS (1/2)

- Idle Period Downlink (IPDL) is a techniques used by UMTS network, where Node B transmissions are synchronously ceased for a short period of time.
- Mobiles measure the OTDOA of each neighbor Node B's pilot signals during the IPDLs of serving BTS.
- IPDL maximizes the hearability of distant pilots.



OTDOA with IPDL for UMTS (2/2)

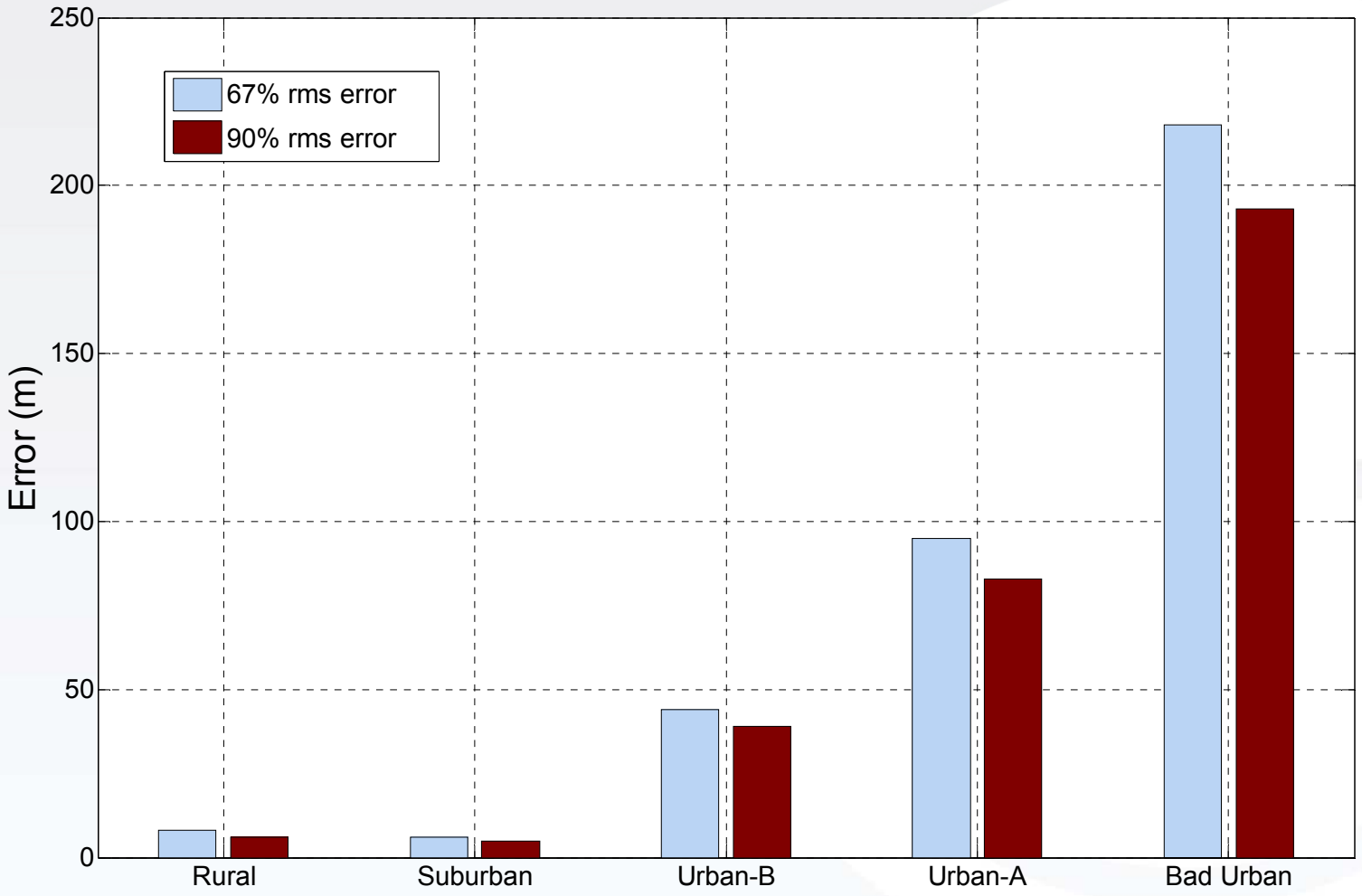


3GPP TSG-RAN WG1 No R1-99b79

OTDOA with TA-IPDL for UMTS (1/2)

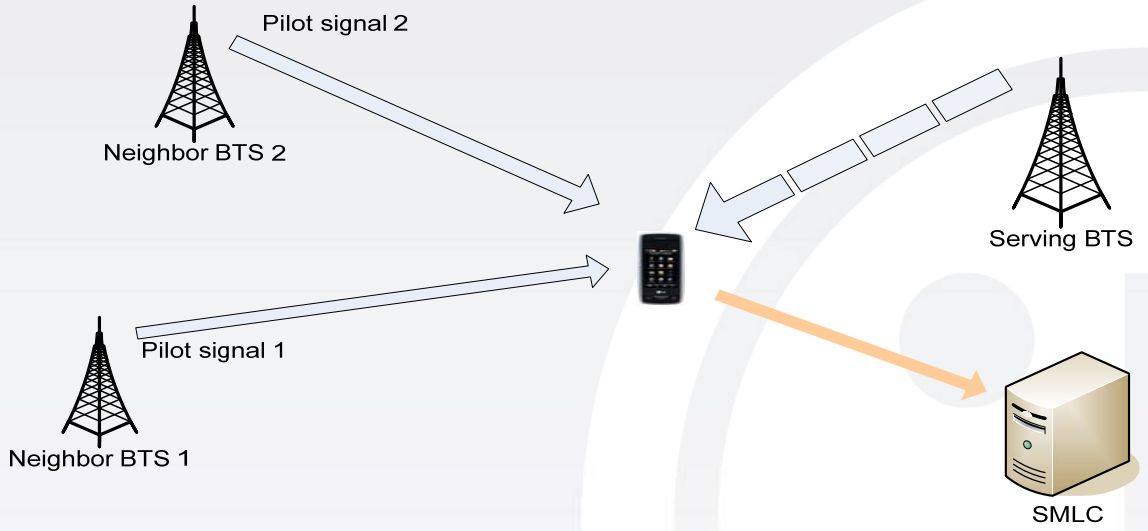
- Time-aligned idle periods downlink (TA-IPDL) is a modification of the standard IPDL, where the idle periods are intentionally time aligned approximately 30us across the node Bs.
- During the ‘common’ idle period, each node B transmits a signal, which is only useful for location estimation, randomly, pseudo-randomly or periodically.
- OTDOA of these common pilots is measured in the mobile for different Node Bs. Compared with standard IPDL, TA-IPDL
  - is more accurate,
  - reduces the mobile complexity.
- However, OTDOA with TA-IPDL
  - adds complexity to the network operation.
  - reduces communication efficiency.

OTDOA with TA-IPDL for UMTS (2/2)



3GPP TSG-RAN WG1 R1-99b79

OTDOA with CVB for UMTS (1/3)



- OTDOA with cumulative virtual blanking (CVB)
  - It uses the virtual blanking of Node B downlink signals in the software domain.
  - It is based on the principle of interference cancellation
- With advanced signal processing techniques, the hearability can be further enhanced.

OTDOA with CVB for UMTS (2/3)

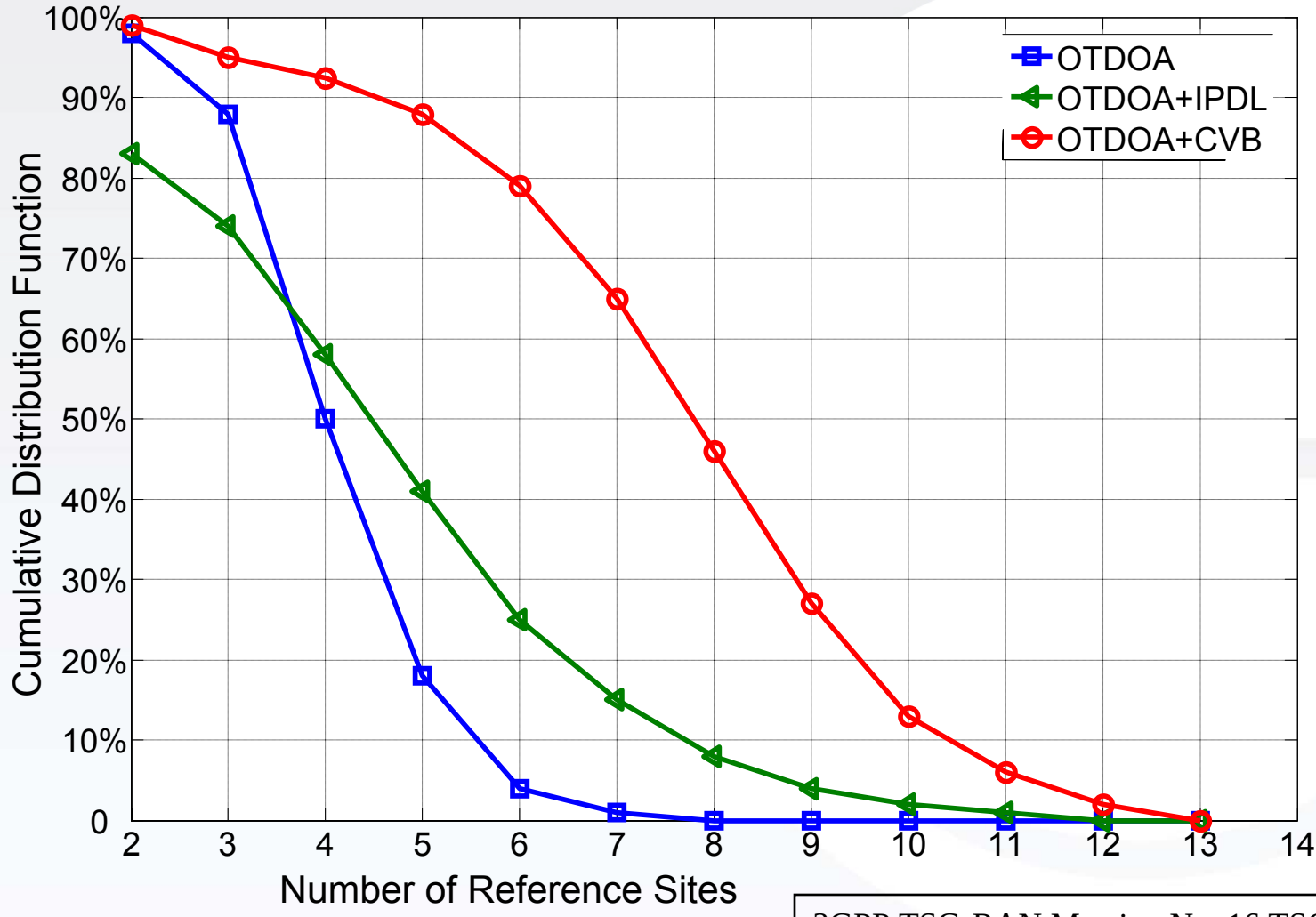
- Downlink signals are measured simultaneously by mobiles and neighbor Node Bs. The measurements are transferred to the location server.
  - Mobiles make snapshots of received signals
  - Node Bs make time co-incident snapshots of the signals
- The location server estimates the OTDOA of weak Node B's signal by subtracting interfering signals. Multiple node B signals are blanked allowing weaker ones to be measured.
- Final positioning is done using standard OTDOA algorithm.
  - No impact on downlink capacity
  - More robust in the presence of multipath
  - Reduced operational complexity compared with IPDL

OTDOA with CVB for UMTS (3/3)

Number of References	Positioning Time	Positioning Error
1	16:26	22.8 m
2	16:43	27.6 m
3	17:11	16.9 m
4	17:13	5.7 m
5	17:16	26.2 m

3GPP TSG-RAN Meeting#16, TSG RP-020372

Performance of OTDOA Methods for UMTS



3GPP TSG-RAN Meeting No. 16 TSG RP-020372

cdma2000 Features for Positioning

- Forward pilot channel (F-PICH) and reverse pilot channel (R-PICH).
- Forward transmit diversity pilot channel (F-TDPICH);
- Forward auxiliary pilot channels
  - Forward auxiliary pilot channel (F-APICH);
  - Forward auxiliary transmit diversity pilot channel (F-ATDPICH).
- Sync channel (SCH)
- Power up function (PUF)
  - Triangulation techniques can be used to locate the mobile if several BTS sites can receive the mobile's signal.
  - However, CDMA mobile transmitters are carefully power controlled to specifically prevent their reception by unintended BTS's.
  - The PUF has specially been developed to require a brief increase in mobile transmit power to enable the reception by several BTS's that may not normally detect the mobile's signal.

EFLT for cdma2000

- Enhanced forward link trilateration (EFLT) uses existing pilot signal measurement message (PSMM) from mobile to BS
- The PSMM information sent from BTS to MSC and then to PDE
- EFLT supports legacy handsets with up to about 1-chip resolution.
- EFLT is typically used as a backup for non-AFLT/AGPS phones

AFLT for cdma2000

- Advanced Forward Link Trilateration (AFLT) is a TDOA-based technique.
  - It needs system-wide synchronization among base stations.
  - It uses IS 801 messaging to transmit location data from mobiles.
- AFLT also requires that the mobile
  - has precise timing and
  - is receiving 3 or more BS signals at sufficient signal strength to triangulate its position.
- AFLT has about 1/8 chip resolution reporting and is commonly used as a hybrid with AGPS.

Positioning Technologies Comparison

	Attributes	Network	Handset	Accuracy
Cell ID	Obtains Cell ID based on pilot measurements	All	Both	100m-3km, depending on cell size and density
Cell ID + TA	Combines Cell ID with time advance	GSM	Both	Default is 500m. Depends on bandwidth
EFLT	Mobile measures the forwardlink pilot timing.	CDMA	Both	250-350m
AFLT	Mobile measures the forwardlink pilot timing.	CDMA	Upgrade	50-200m
AOA	Network measures the angle of arrival.	All	Both	100-200m
U-TDOA	Network measures the timing difference.	All	Both	< 50 m.
EOTD	Mobile measures time difference.	GSM	Upgrade	50-200m
GPS/A-GPS	GPS receivers in handsets and/or network.	All	Upgrade	5-30m

Positioning Technologies by US Carriers

Carrier	Network	Solution
T-Mobile	GSM	E-OTD
AT&T	GSM/TDMA	E-OTD
Sprint-Nextel	CDMA/IDEN	AGPS/AFLT
Verizon	CDMA	AGPS/AFLT
QWEST	CDMA	AGPS/AFLT
Alltel	CDMA	AGPS/AFLT

Acronyms

- AFLT – Advanced Forward Link Triangulation
- AOA – Angle of Arrival
- DOA – Direction of Arrival
- EMS – Emergency Medical Services
- EMTEL – Emergency Telecommunications
- ETSI – The European Telecommunications Standards Institute
- GSMA – The GSM Association
- GPS – Global Positioning System
- IETF – Internet Engineering Task Force
- LBS – Location Based Services
- LCS – Location Services
- LORAN – Long Range Navigation
- LOS – Line of Sight
- NGN – Next-Generation Network
- OCG – Operational Co-ordination Group
- OMA – Open Mobile Alliance
- PSAP – Position Service Access Point
- TDOA – Time Difference of Arrival
- TOA – Time of Arrival
- UMTS – Universal Mobile Telecommunications System
- UTRAN -- UMTS Terrestrial Radio Access Network

Section II References

- James Jr. Caffery, Gordon L. Stuber, Georgia Institute of Technology, "Overview of Radiolocation in CDMA Cellular Systems", IEEE Communications Magazine, April 1998
- James Jr. Caffery, "Wireless Location in CDMA Cellular Radio Systems", 1st Edition, Springer, 1999
- Timo Halonen, Javier Romenro and Juan Melero, "GSM, GPRS and EDGE Performance", 2nd Edition, Wiley, 2003
- P. J. Duffett-Smith, M. D. Macnaughtan, "Precise UE Positioning in UMTS Using Cumulative Virtual Blanking", 3G Mobile Communication Technologies, May 2002
- 3GPP TS 25.305, UMTS; UE Positioning in Universal Terrestrial Radio Access Network (UTRAN); Stage 2, ver. 7.1.0, Rel. 7
- 3GPP TS 23.271: Functional stage 2 Description of Location Services
- 3GPP TS 25.305: User Equipment (UE) Positioning in UTRAN; Stage 2
- 3GPP TS 43.059: Functional stage 2 Description of Location Services in GREAN
- 3GPP TSG-RAN WG1 R1-99b79, Time Aligned IP-DL positioning technique, 1999
- 3GPP TSG-RAN WG1 R1-00-1186, Initial Simulation Results of the OTDOA-PE Positioning Method, 2000
- 3GPP TSG-RAN Meeting No. 16, TSG RP-020372, "Software blanking for OTDOA positioning", June 2002, Marco Island, Florida, USA
- 3GPP2 C.S0022-0: Position Determination Service Standard for Dual Mode Spread Spectrum Systems
- 3GPP2 C.S0022-A: Position Determination Service for cdma2000 Spread Spectrum Systems

Outline

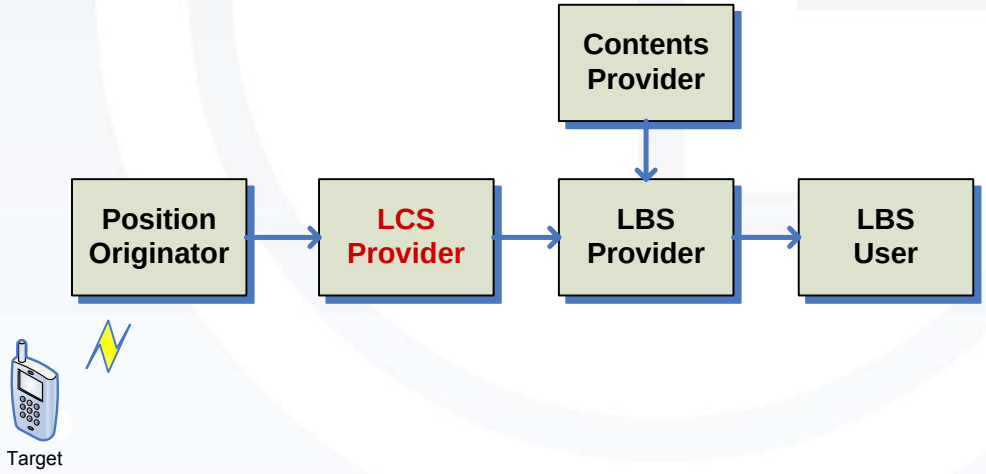
- **Section I: Introduction**
  - View of the wireless business domain above 30000 feet
  - Historic overview
  - LBS concept
  - LBS applications and market
  - LBS in mobile standards
- **Section II: Wireless Positioning Technologies**
  - Basic positioning methods
  - Satellite positioning systems
  - Positioning in mobile networks
- **Section III: Location Services in Mobile Networks**
  - **LCS design considerations**
  - **Location management in mobile networks**
  - **LCS architecture: control plane and user plane**
  - **LCS procedure in mobile standards**
- **Section IV: Challenges for Mobile Location Based Services**
  - New mobile technologies
  - Interoperability
  - Security design

LCS Concept

- "**LCS (LoCation Services)** is a service concept in system standardization. LCS specifies all the necessary network elements and entities, their functionalities, interfaces, as well as communication messages, due to implement the positioning functionality in a cellular network. Note that LCS does not specify any location based (value added) services except locating of emergency calls." [3GPP TS 23.271]

- **Service categories**
  - Commercial LCS
  - Internal LCS
  - Emergency LCS
  - Lawful intercept LCS

- **Service types**
  - Push
  - Pull
  - Tracking



LCS Design Considerations in Standards

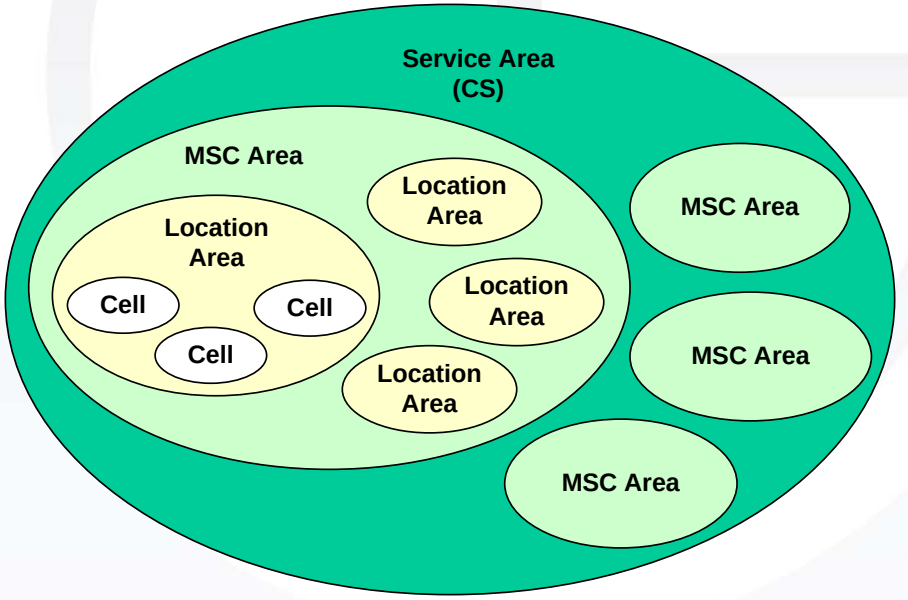
- **Privacy**
  - "Who owns positioning data and how to handle permissions."
  - Users have control over who may locate them.
  - Users are informed when they are being located.
  - Privacy check is performed by the home network of mobiles.
  - Default treatment is included in the subscription profile of the target mobile.
  - All location requests are privacy-checked except location requests related to lawful interception, emergency calls, network operation and management, and home network's internal purposes.
- **Interoperability and roaming**
  - It is important to standardize the network entities, interfaces and protocols to support the cooperation between a variety of LBS participants.
  - While being compatible with existing mobile networks, LCS also needs to be seamlessly integrated into IP-based services.
- **Emergency services**
  - Mobile network carriers are responsible for ensuring that they can provide the appropriate emergency services mandated by regulatory organizations.
  - The visited or home network is responsible to induce emergency location requests depending on the architecture.

Location Management

- **Location management for supporting mobility**
  - An inherent part of cellular network: paging, roaming, handover, etc.
  - It helps enable LCS for mobiles
    - by transferring a network location into a spatial or descriptive location,
    - by providing basic functions that positioning methods rely on.
- **Location management strategies**
  - Location update (report): Mobiles notify the network of their locations.
  - Location discovery (paging): Network determines a mobile's location.
- **Location management database**
  - HLR: centralized location database of all subscribers in cellular network
  - VLR: distributed location database of a user, associated with part of network. HLR is updated when serving VLR changes.

Location Management for 3GPP

- **Location concepts**
  - Location area, routing area, UTRAN registration area (URA), cell area
- **Location updates**
  - Location update on location area crossing
  - Location update on routing area crossing (GPRS)
  - Location update on URA crossing (UMTS PS)
  - Location update on cell crossing
  - Periodic location update



Location Management for 3GPP2

- **Packet zones (PZ) for data services**
  - Each PZ is uniquely identified by a packet zone ID (PZID).
  - Each BS periodically broadcasts its PZID.
  - A mobile receives such broadcast information for determining which zone it is in.
  - When the mobile moves into a new PZ belonging to a different PCF, PCF will update PDSN.
- **Multiple location update strategies**
  - Power-on/off location updates
  - Requested update
  - Implicit location update
  - Zone-based update

LCS Architecture: C-Plane and U-Plane

- **Control Plane**
  - A standard based implementation in which messages are transported over logical signaling channels.
  - It was designed in conjunction with E911 mandate: wide availability, high accuracy.
  - Positioning data are sent over the control channel: voice and location data transactions can occur simultaneously.
- **User Plane**
  - An architecture where the location related signaling appears as user data to the wireless network.
  - Position determination related messaging between terminal and network is transmitted as user data over IP.
  - An alternative/complementary implementation to existing 3GPP or 3GPP2 control plane

LCS Architecture Comparison

Control Plane	User Plane
• Interface between system entities is signaling-based. • It requires upgrades to network elements to handle all the standard protocols: positioning server, gateway server. • It supports legacy terminals. • Voice-centric, network-based • Centralized control • 3GPP, 3GPP2	• Interface between system entities is IP-based. • Quick time to market, lower deployment costs, various applications, and adaptive implementation to a carrier's specific needs. • More options in terms of roaming: the mobile always interacts with the home server. • Application-focused, handset-intelligent • Client-server architecture • OMA, 3GPP2

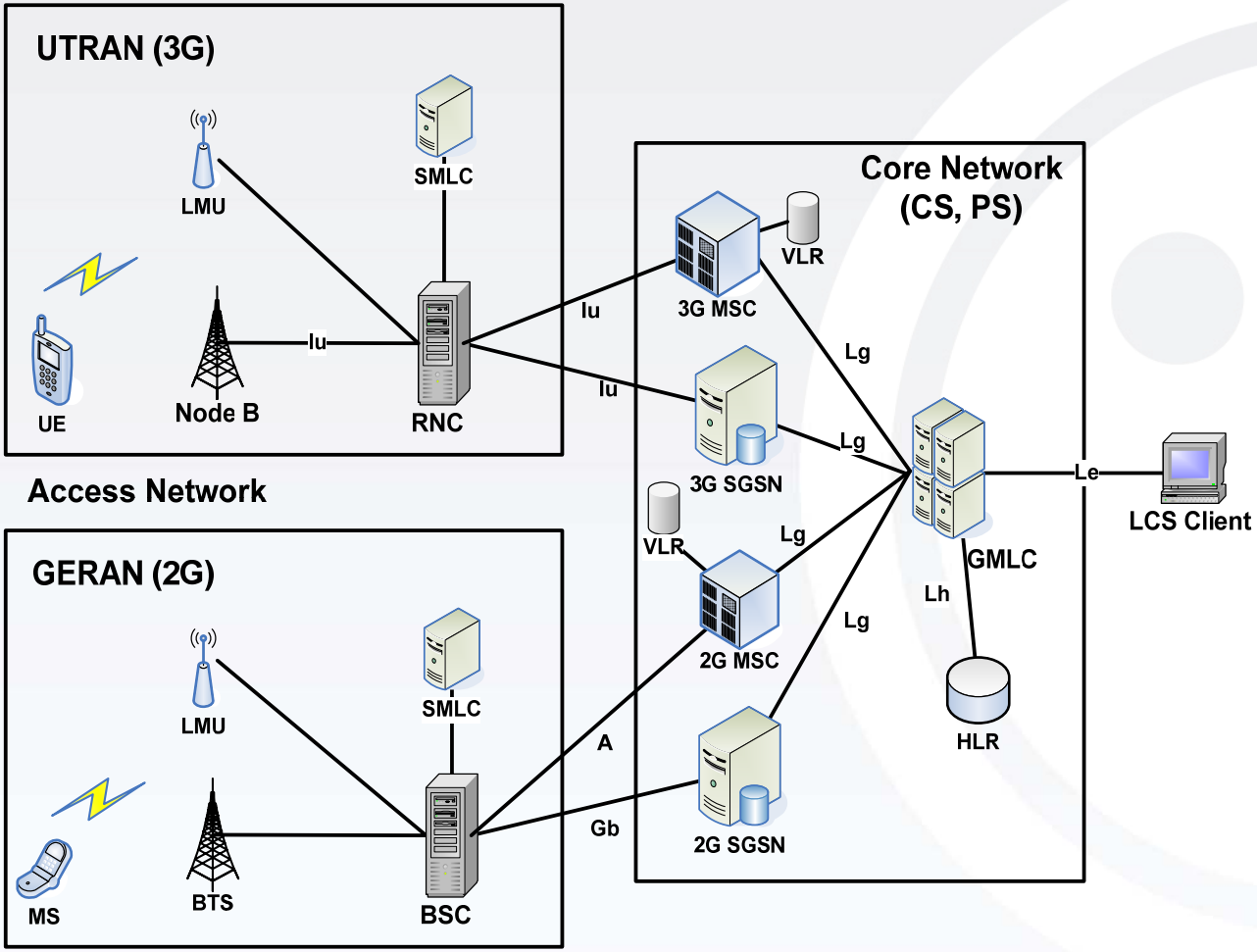
3GPP LCS

- **Two modes of operation in GSM/UMTS**
  - UE-based mode: UE determines position.
  - UE-assisted mode: UE assists network to position the UE.
- **Two types of location request**
  - Mobile-terminating location request (MT-LR):
    - MT-LR is initialized by an entity that is not the mobile itself.
    - MT-LR appears in two variants: immediate location request and deferred location request.
  - Mobile-originating location request (MO-LR):
    - MO-LR is initialized by the target's mobile itself in order to perform self-positioning.
    - MO-LR is available with the following options: basic self location, autonomous self location, transfer to third party.

3GPP LCS Network Elements

- **Gateway Mobile Location Center (GMLC)**
  - GMLC passes the request to the core network to initiate location services when it receives an location request, and returns the location result back to the querying LCS client.
  - It manages location requests for both control plane and user plane applications.
  - It is called Mobile Positioning Center (MPC) in 3GPP2
- **Serving Mobile Location Center (SMLC)**
  - SMLC coordinates measurements for positioning.
  - It determines the location.
  - It talks to access network and user device.
  - It can be standalone equipment (SAS) or integrated into BSC, RNC or MSC.
  - It is called Position Determining Entity (PDE) in 3GPP2
- **Location Measurement Unit (LMU)**
  - LMU is required or not, depending on location technology approach adopted

3GPP LCS – Control Plane Architecture



GMLC: Gateway Mobile Location Center

SMLC: Serving Mobile Location Center

LMU: Location Measurement Unit

HLR: Home Location Register

VLR: Visited Location Register

MSC: Mobile service Switching Center

SGSN: Serving GPRS Support Node

Le: Interface between external user and GMLC– MLP(OMA)

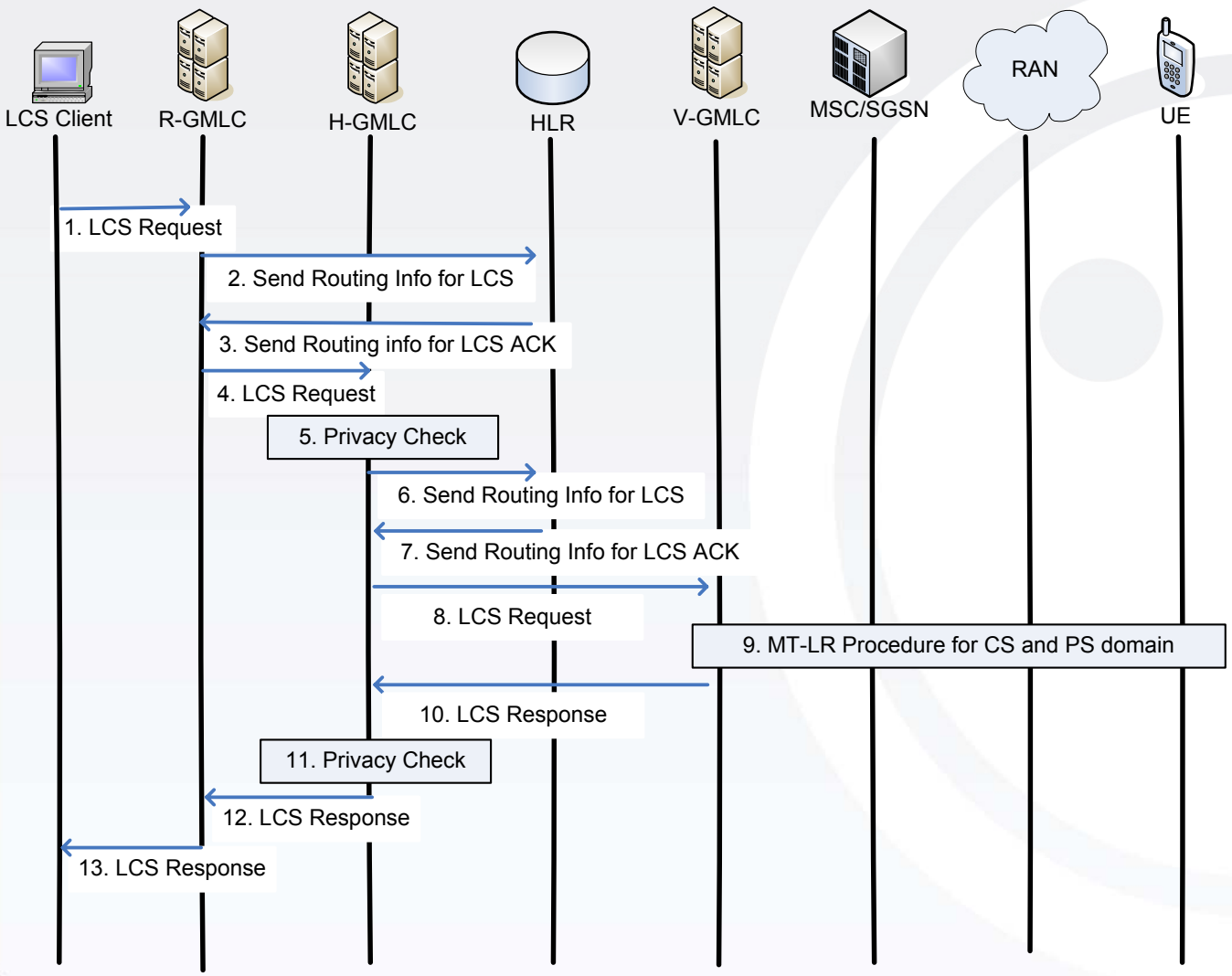
Lg: Interface between GMLC-VMSC, GMLC-MSC server, GMLC-SGSN

Lh: Interface between gateway MLC and HLR

3GPP C-Plane: Supplementary Service Messages

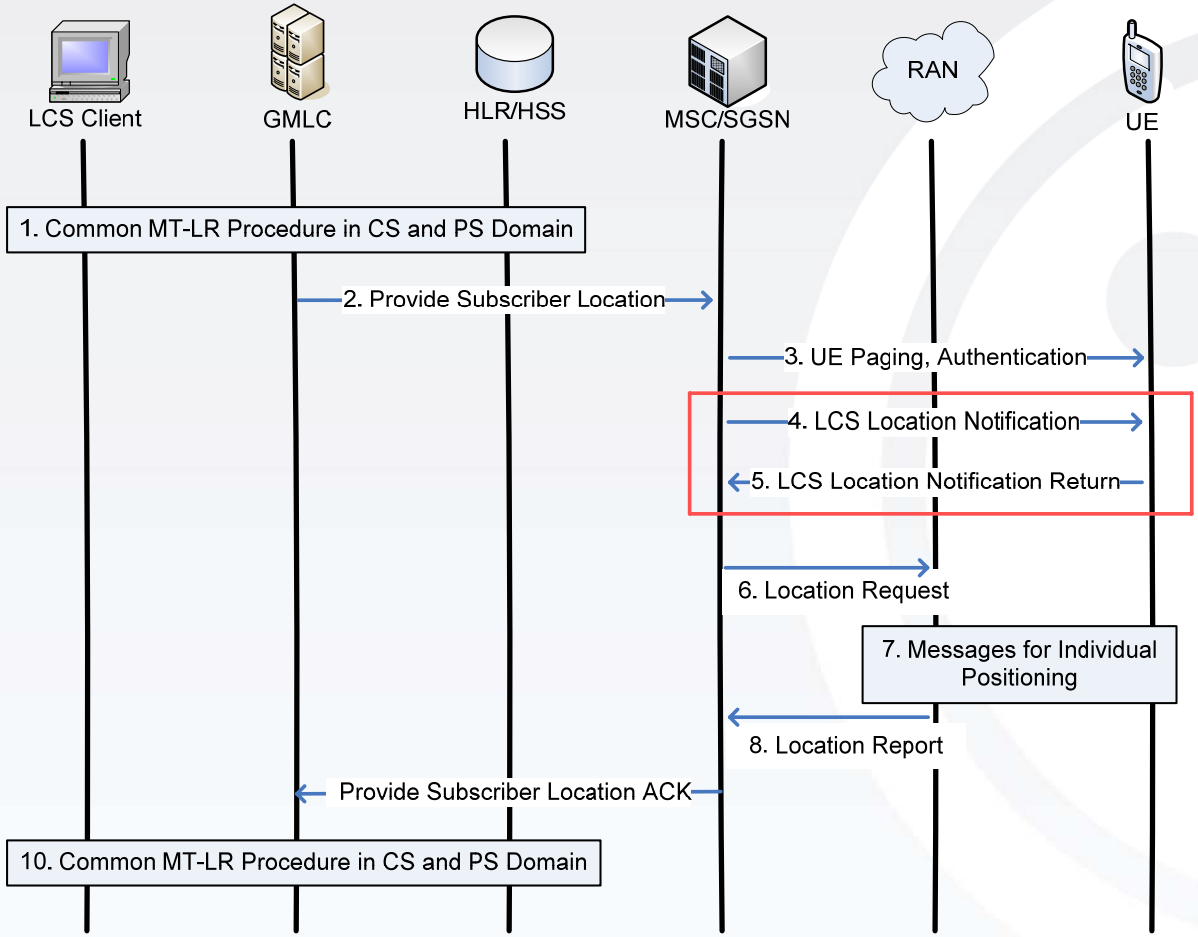
- **MT-LR invoke**
  - Notification type
  - Location type
    - Location estimate type
    - Deferred location event type
  - LCS client external ID
  - LCS client name
  - LCS requestor ID
  - LCS code word
  - LCS service type ID
- **MO-LR invoke**
  - Basic self location
    - MO-LR type
    - LCS QoS
    - Supported GAD Shapes
  - Transfer to third party
    - MO-LR type
    - LCS QoS
    - Supported external ID
    - MLC number
  - Assistance data
    - MO-LR type
    - Location method
    - GPS assistance data

3GPP C-Plane: Common MT–LR in CS and PS



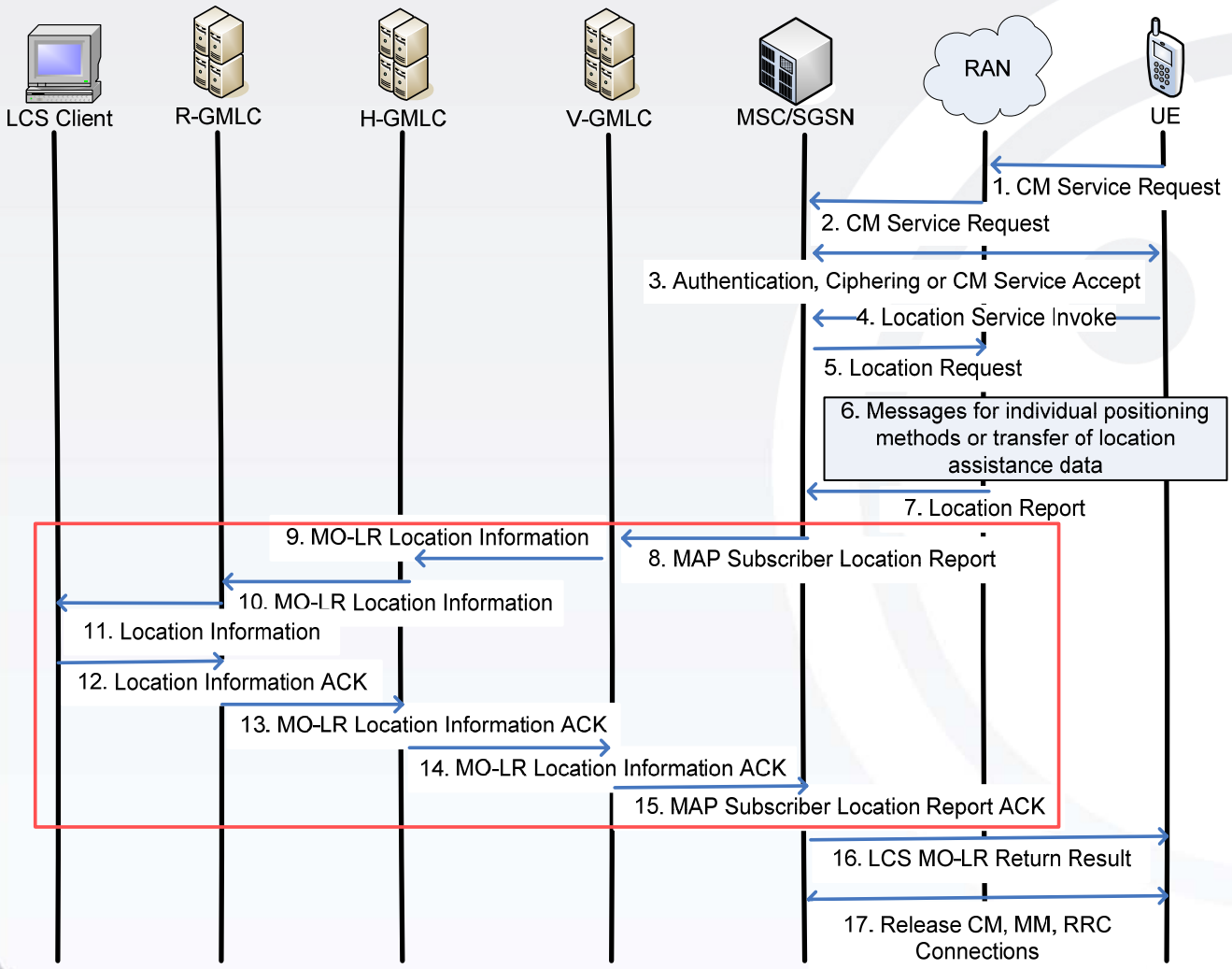
- **5:** H-GMLC performs privacy check on the basis of the UE user's privacy profile stored in the H-GMLC and the capabilities of the serving nodes (MSC, SGSN).
- **5:** In 911 case, the privacy check procedures in H-GMLC are skipped.
- **11:** If the privacy check in step indicates that further privacy checks are needed, H-GMLC shall perform an additional privacy check.

3GPP C-Plane: CS–MT–LR



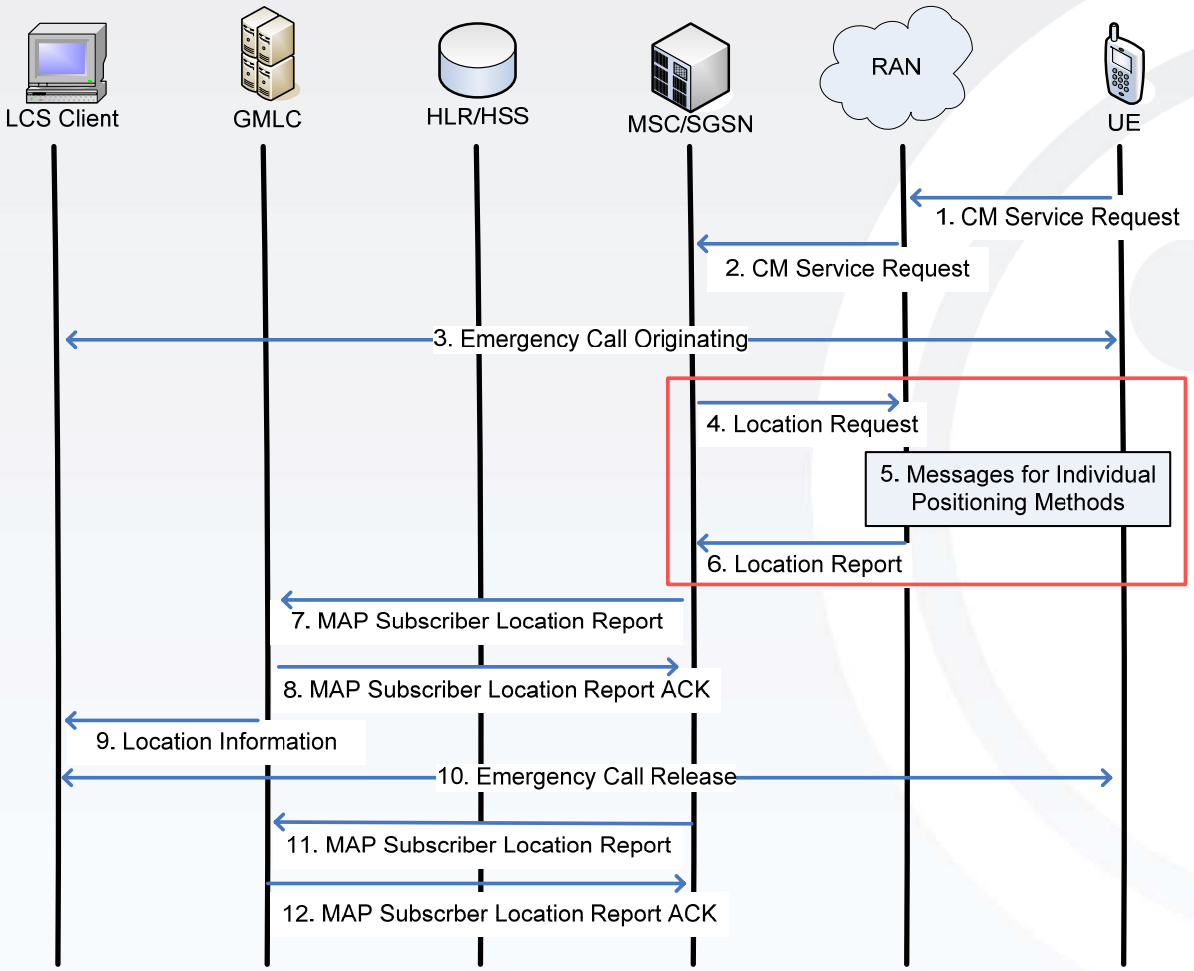
- **CS-MT-LR:** Circuit Switched Mobile Terminating Location Request (ex. buddy finder)
- **4-5:** UE is notified with privacy verification. Notification message includes the type of location request, the identity of the LCS client, the requestor ID, and whether privacy verification is required. It may also carry the service type and the codeword.
- **6:** Optionally, it can be parallel to 4.
- **7:** Details of “Messages for Individual Positioning” are different for different positioning techniques.

3GPP C-Plane: CS–MO–LR



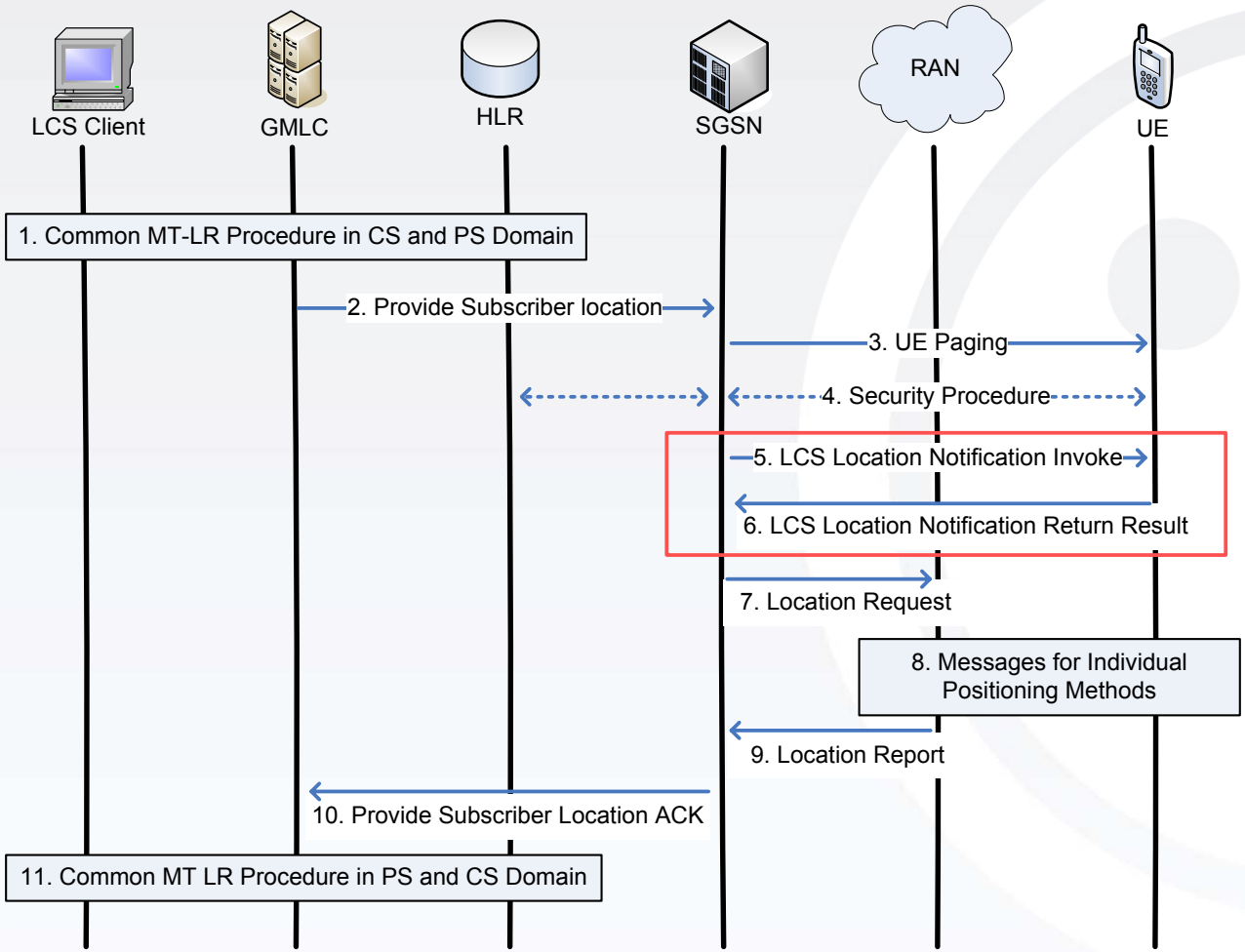
- **CS-MO-LR:** Circuit Switched Mobile Oriented Location Request (ex: UE's own location)
- **6:** Details of "Messages for Individual Positioning" are different for different positioning techniques.
- **8-15:** The procedure is needed only for transferring locating information to the third party.

3GPP C-Plane: NI–LR



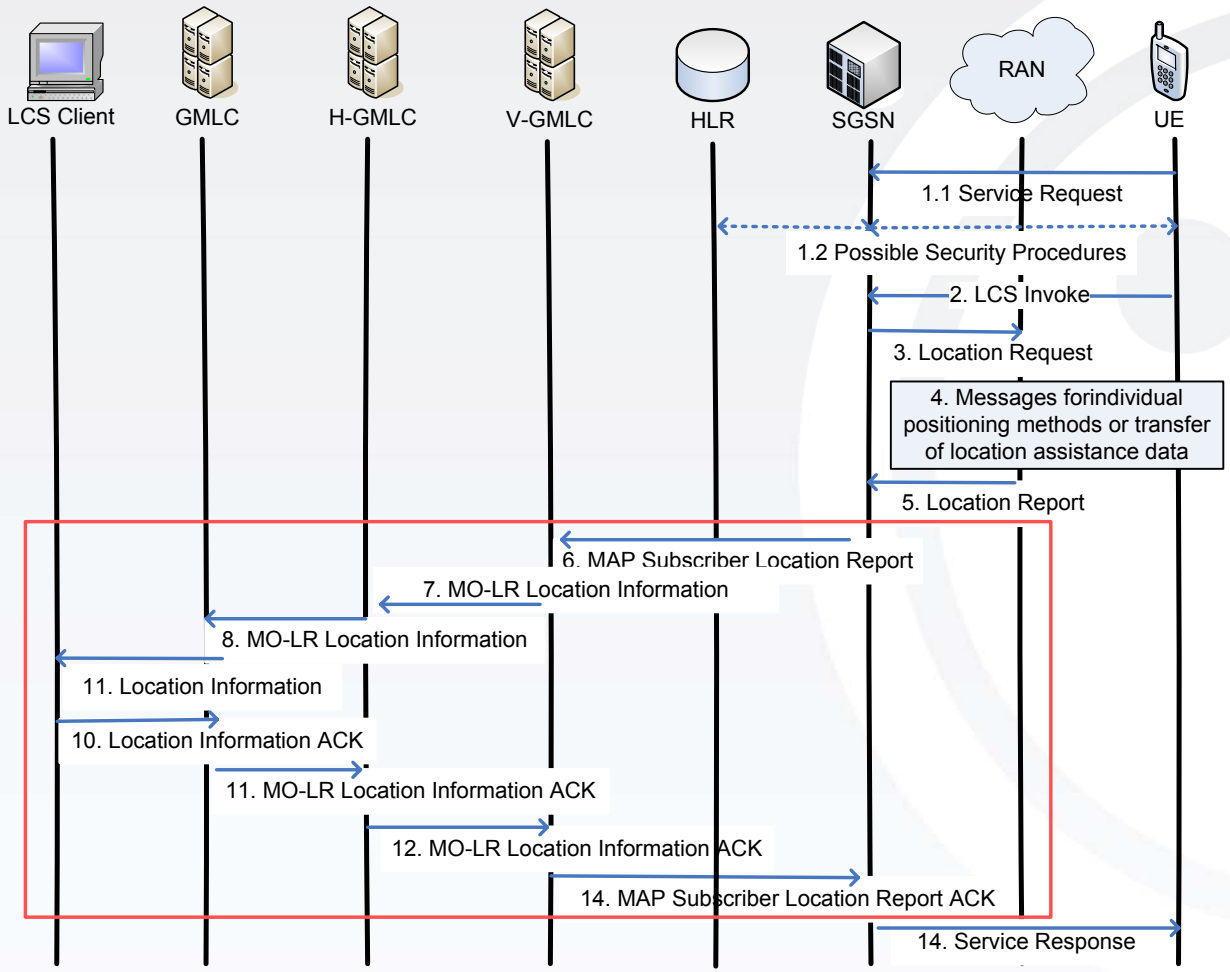
- **NI-LR:** Network Induced Location Request (ex: 911 emergency call)
- MSC figures out whether the call is for emergency service and then skips signaling procedure for privacy check.
- **3-4:** Emergency call and location request can be done parallel.
- **4-6:** Network induces location request and have location information.
- **5:** RAN determines the positioning method and instigates the particular message sequence for this method. [TS 25.305], [TS 43.059]
- **7-8:** The location information is saved at gateway.
- **11-12:** no position information and termination indication

3GPP C-Plane: PS–MT–LR



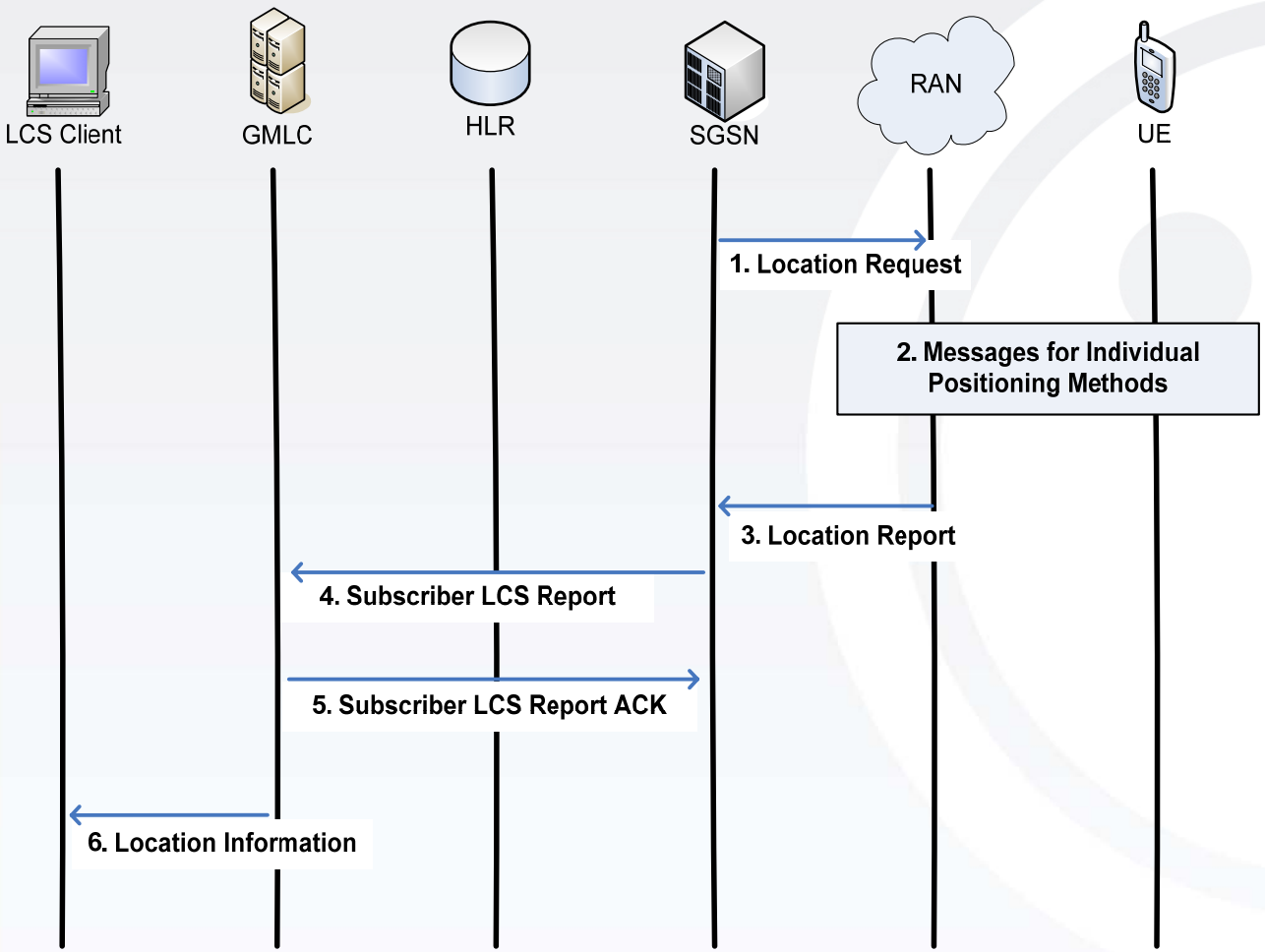
- **PS-MT-LR:** Packet Switched Mobile Terminating Location Request
- **4:** Security procedures are defined in TS 23.060.
- **5-6:** UE is notified with privacy verification. Notification message includes the type of location request, the identity of the LCS client, the requestor ID, and whether privacy verification is required. It may also carry the service type and the codeword.
- **7:** It can be parallel with 5.
- **8:** Details of “Messages for Individual Positioning” are different for different positioning techniques.

3GPP C-Plane: PS–MO–LR



- **PS-MO-LR:** Packet Switched Mobile Originating Location Request
- **1.2:** Security procedures are defined in TS 23.060.
- **3-5:** It can be skipped if SGSN already has the proper location information of the UE.
- **4:** Details of “Messages for Individual Positioning” are different for different positioning techniques.
- **6-14:** It is needed only for transferring the location information to the third party.
- **6:** MAP subscriber location request carries the MSISDN/IMSI of the UE, the location estimate, its age, obtained accuracy indication, the LCS QoS class.

3GPP C-Plane: PS–NI–LR



- **PS-NI-LR:** Packet Switched Network Induced Location Request
- For control plane, E911 service is the responsibility of the visited network.

3GPP LCS – Specifications

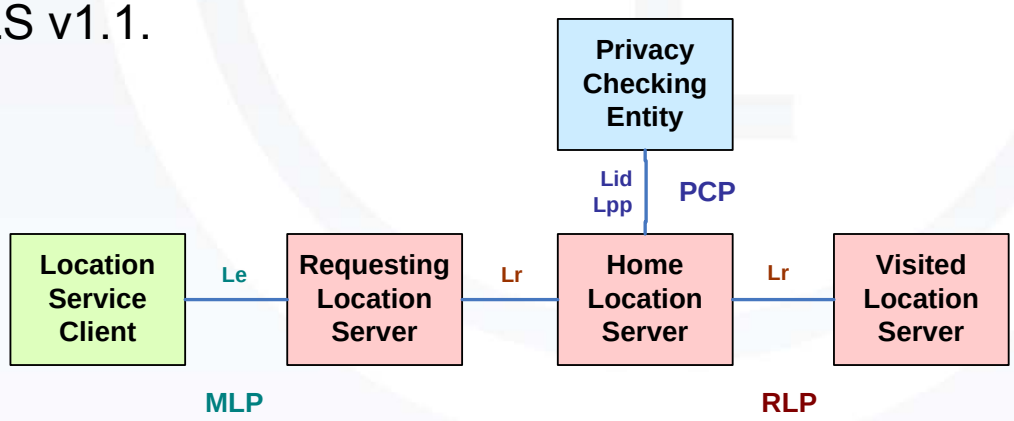
- <http://www.3gpp.org/ftp/Specs/archive>
- 3GPP TS 22.071: “Location Services (LCS); Service description; Stage 1”
- 3GPP TS 23.171: “LCS Stage 2 Description”
- 3GPP TS 23.032: “Universal Geographical Area Description (GAD)”
- 3GPP TS 24.008: “Mobile Radio Interface-Layer 3 MM/CC Specification”
- 3GPP TS 25.331: “RRC Protocol Specification”
- 3GPP TS 23.271: “Functional stage 2 description of Location Services (LCS)”
- 3GPP TS 25.305: “User Equipment (UE) positioning in UTRAN; Stage 2”
- 3GPP TS 43.059: “Functional stage 2 description of Location Services in GREAN”
- 3GPP TS 23.871: “Enhanced support for user privacy in Location Services (LCS)”
- 3GPP TS 29.002: “Mobile Application Part”
- ETSI TS 102.164: “Emergency Location Protocols”
- ETSI TS 102.424: “Requirements of the NGN network to support Emergency Communication from Citizen to Authority”

OMA LCS: User Plane

- **Open Mobile Alliance**
  - OMA LOC (Location Working Group) develops specifications to ensure interoperability of location services (LCS).
  - LIF (Location Interoperation Forum) has consolidated into OMA. OMA LOC continues the work originated in the former LIF.
- **MLS (Mobile Location Service)**
  - MLS is a set of three protocols.
    - MLP: Mobile Location Protocol
    - RLP: Roaming Location Protocol
    - PCP: Privacy Checking Protocol
- **SUPL (Secure User Plane Location)**
  - SUPL utilizes existing standard to transfer assistance data and positioning data over a user plane bearer.
  - SUPL is an alternative and complementary solution to existing 3GPP and 3GPP2 control plane architecture.
  - SUPL supports all handset based and assisted positioning technologies.
  - SUPL is data bearer independent.

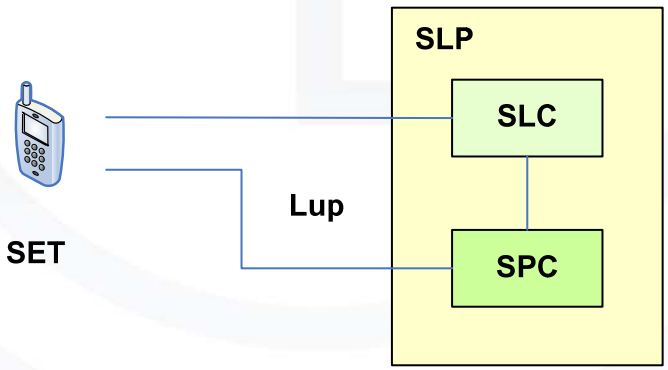
OMA U-Plane: MLS

- **Mobile Location Protocol (MLP)**
  - MLP is a protocol for querying the position of mobile station between location server and a location service client.
  - MLP v3.1 already published as a stand alone protocol.
  - MLP v3.2 is part of MLS v1.0.
- **Roaming Location Protocol (RLP)**
  - RLP is a protocol between location servers while UE is roaming.
- **Privacy Check Protocol (PCP)**
  - PCP is a protocol between location server and privacy checking entity.
  - PCP is included only in MLS v1.1.

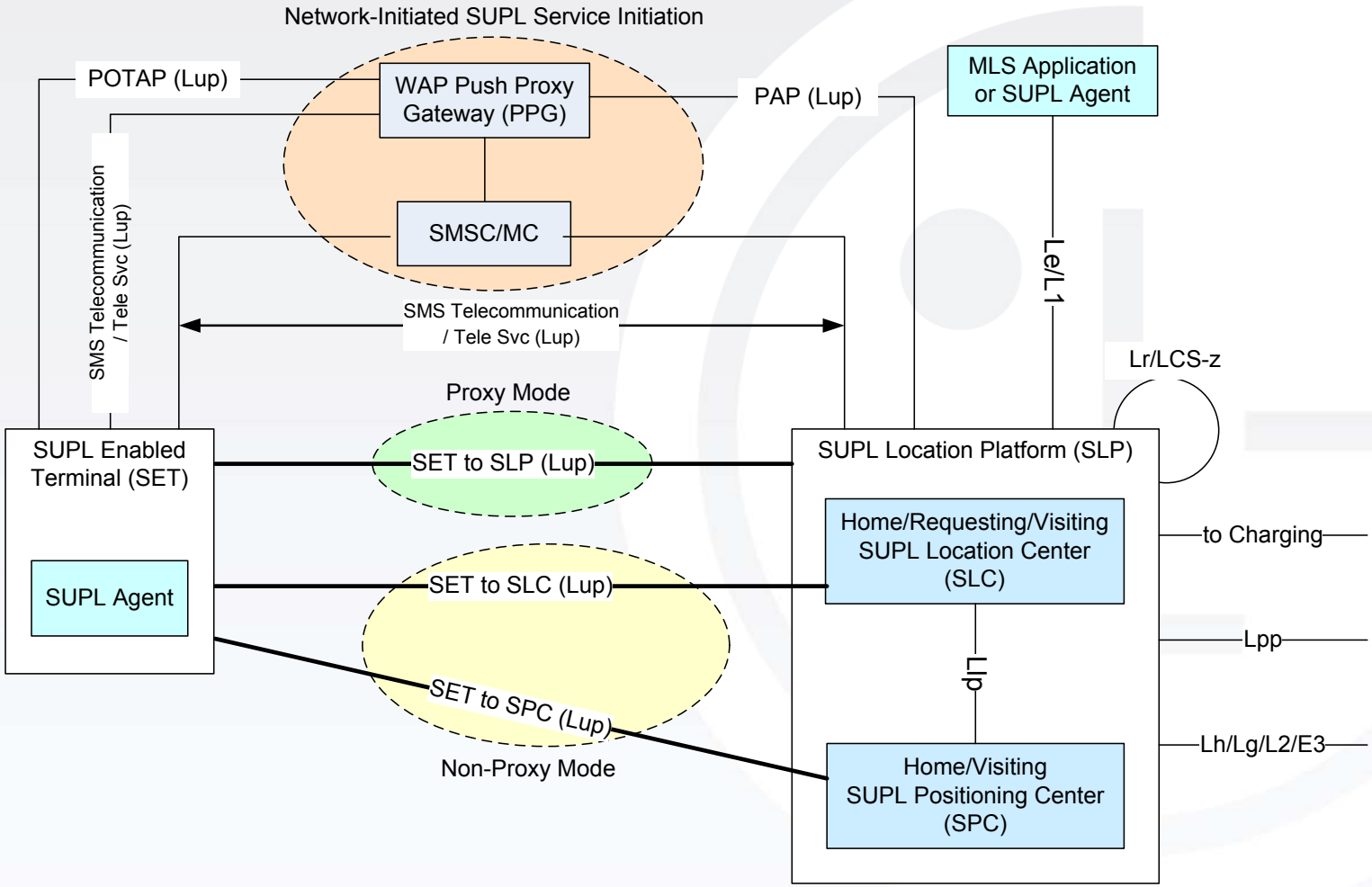


OMA U-Plane: SUPL

- **SUPL components**
  - SUPL Enabled Terminal (SET)
    - SET supports SET-based or SET-assisted positioning calculation.
  - SUPL Location Platform (SLP)
    - SUPL Location Center (SLC) coordinates the operation of SUPL in the network and manages SPCs.
    - SUPL Positioning Center (SPC) provides positioning assistance data to the SET and calculate the SET position.
  - Lup between SET and SLP
- **Two modes between SET and SLP**
  - Proxy Mode
  - Non-Proxy Mode
- **SUPL services**
  - SET initiated services
  - Network initiated services



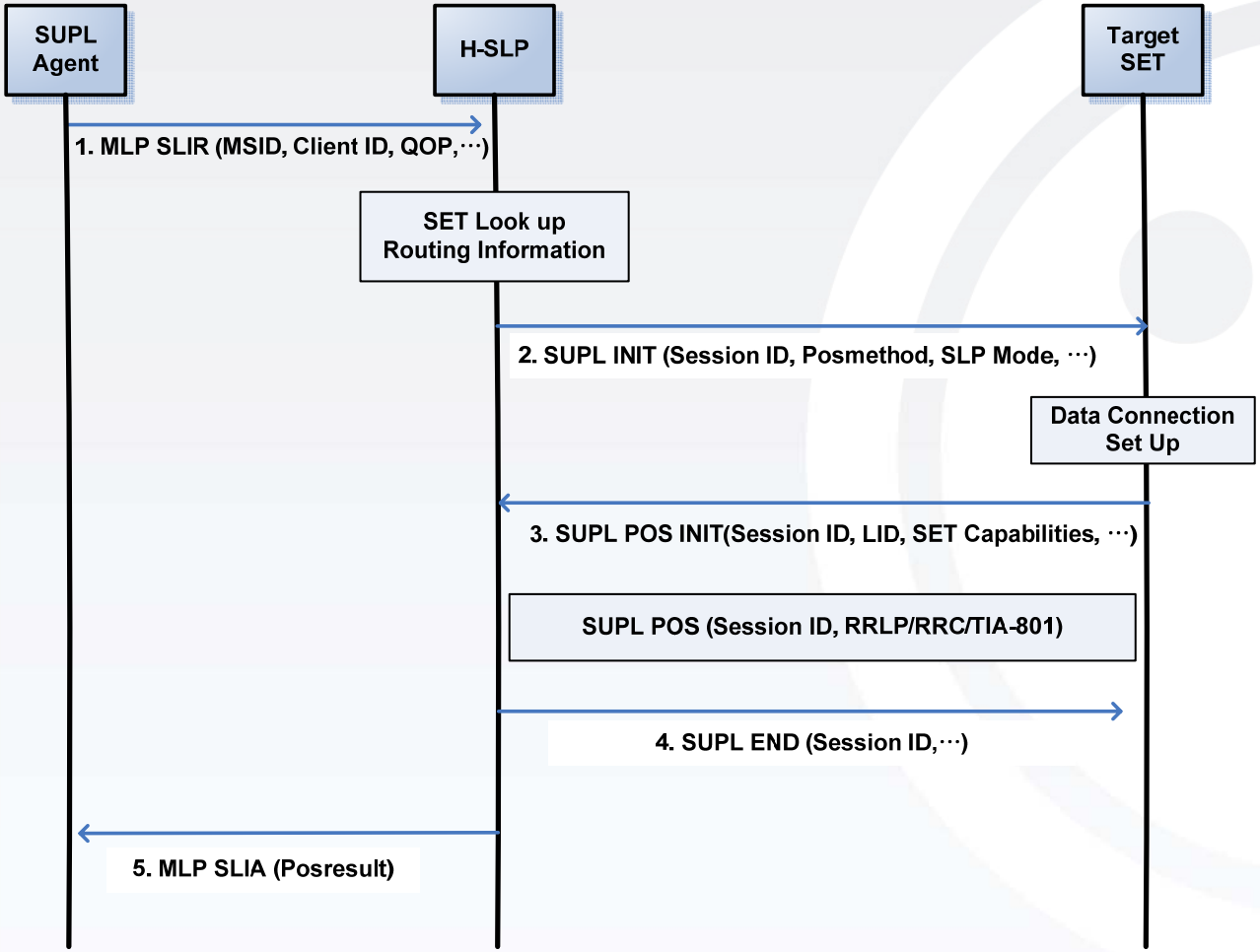
OMA U-Plane: SUPL Architecture



OMA U-Plane: SUPL Messages over Lup

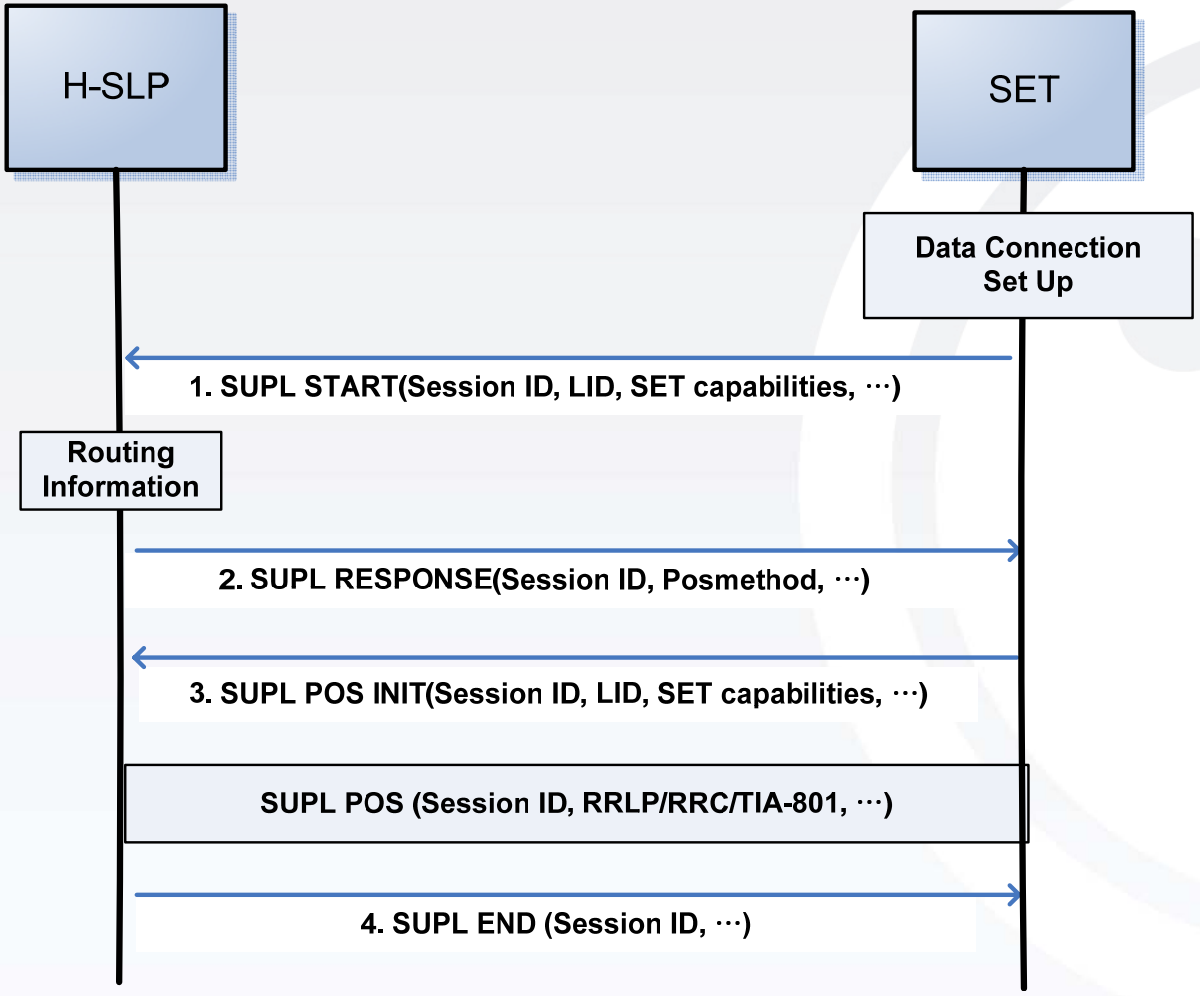
- **Service management**
  - SUPL INIT (NI only)
  - SUPL START (SI only)
  - SUPL RESPONSE (SI only)
  - SUPL AUTHREQ (Non-proxy only)
  - SUPL AUTHRESP (Non-proxy only)
  - SUPL END
- **Positioning determination**
  - SUPL POS
  - SUPL POS INIT
  - SUPL END
- **Message format**
  - Message length: length in octets
  - Version: version of ULP
  - Session ID: unique value consisting of a SET part and a SLP part
  - Message payload
- **Message payload:**
  - SUPL_INIT
    - Positioning method, notification, QoP, SLP mode
  - SUPL_START
    - SET capability, location ID, QoP
  - SUPL_RESPONSE
    - Positioning method
  - SUPL_POS_INIT
    - SET capabilities, location ID, requested assistance data, position, ver
  - SUPL_POS
    - Positioning payload, velocity
  - SUPL_END
    - Position, status code, ver

OMA U-Plane: SUPL – Network Initiated



- Proxy Mode
- SET assisted positioning
- **2:** Either short message or WAP Push
- SET sets up IP connection.
- **3:** Based on the SUPL POS INIT , H-SLP determine the Posmethod.
- **3:** H-SLP determines the supported positioning protocols from the SUPL POS INIT message.
- **3:** H-SLP and SET may exchange several successive positioning procedure messages.

OMA U-Plane: SUPL – SET Initiated

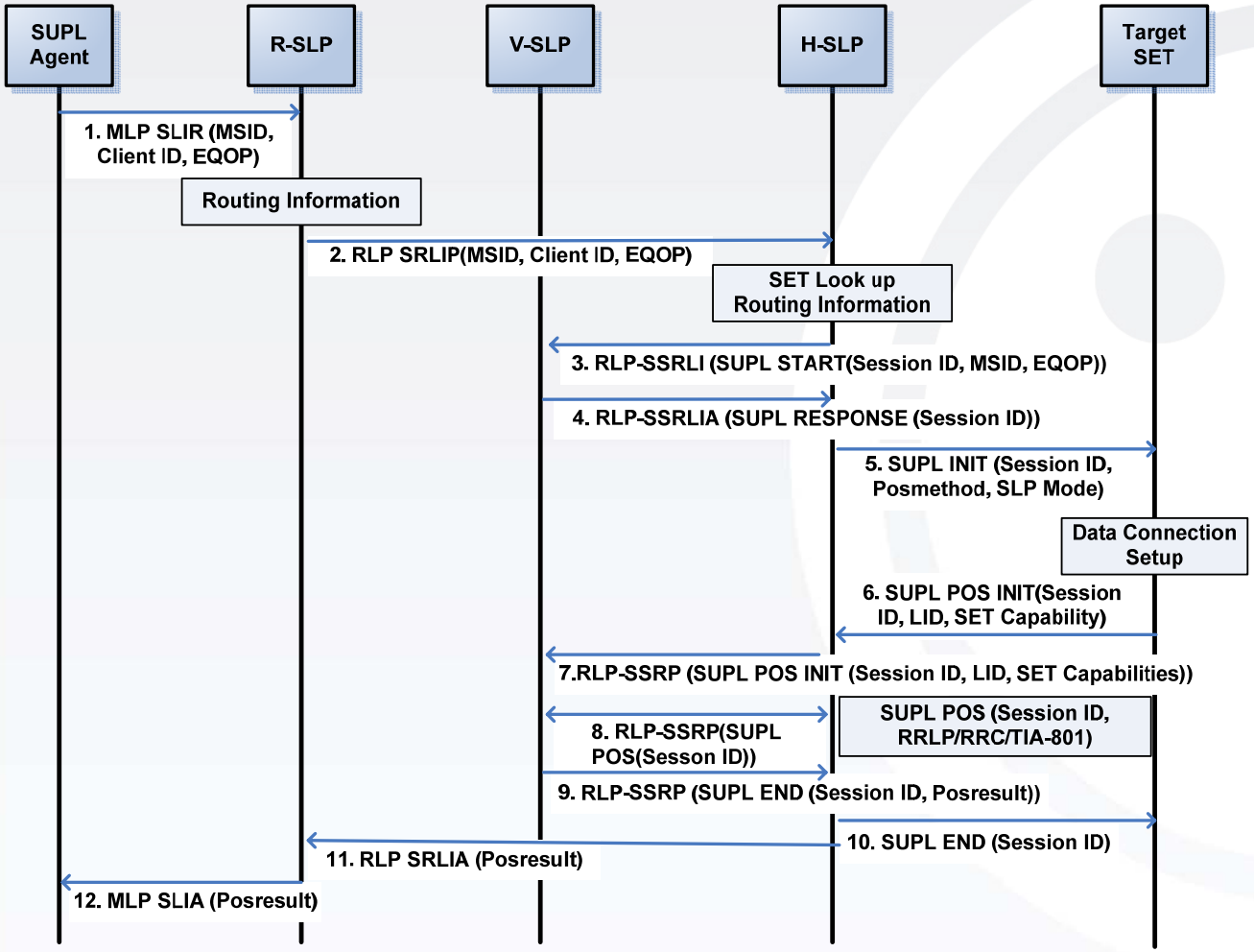


- Proxy Mode
- SET assisted/based positioning
- SUPL START always comes from SET.
- SUPL END always comes from SLP to release the IP connection.
- Positioning result is sent by SET inside SUPL POS INIT after SET receives SUPL RESPONSE or is sent inside SUPL END after SUPL POS procedure.

OMA U-Plane: SUPL Roaming

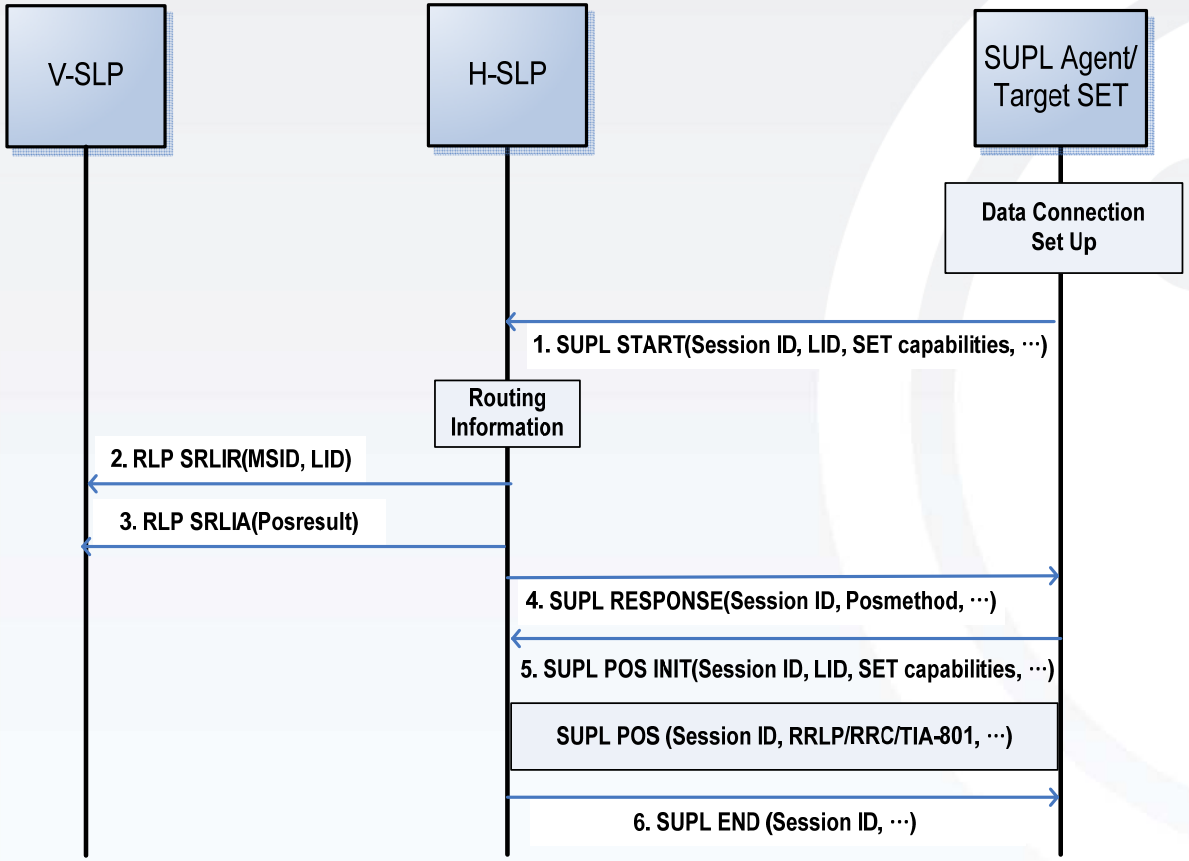
- **SUPL roaming**
  - SUPL roaming occurs when a SET leaves the service area of its H-SLP.
  - The service area of a H-SLP includes the area where the H-SLP can provide a position estimate for a SET or assistance data to a SET without contacting other SLPs.
  - A H-SLP service area is not necessarily associated with the service area of underlying wireless networks.
- **Types of SUPL roaming**
  - H-SLP Positioning
    - The H-SLP may request the V-SLP to provide an initial position estimate based upon Location ID.
    - The H-SLP itself provides the Lup positioning determination and SPC functionality.
  - V-SLP Positioning
    - The H-SLP requests the V-SLP to provide the Lup positioning determination and SPC functionality.

OMA U-Plane: NI SUPL Roaming (V-SLP)



- Proxy Mode
- Network Initiated
- V-SLP is involved in positioning.
- **3:** H-SLP sends an RLP SSRLIP to the V-SLP to inform the V-SLP that the target SET will initiate a SUPL positioning procedure.
- **7:** Based on the SUPL, the V-SLP determines positioning method
- **8:** The SET and the V-SLP may exchange several successive positioning procedure messages tunneled over RLP via the H-SLP.
- **7-10:** Positioning is performed either by the V-SLP or by the SET.

OMA U-Plane: SI SUPL Roaming (H-SLP)



- Proxy mode
- Set Initiated
- H-SLP is involved in positioning.
- **2-3:** In SET-assisted positioning methods, H-SLP requests V-SLP to determine a coarse position. If the computed position meets the requested QoP, the H-SLP goes to step 6.
- **4:** The H-SLP determines the position method.
- The H-SLP calculates the position estimate based on the received positioning measurements (SET-Assisted) or the SET calculates the position estimate based on assistance obtained from the H-SLP (SET-Based).

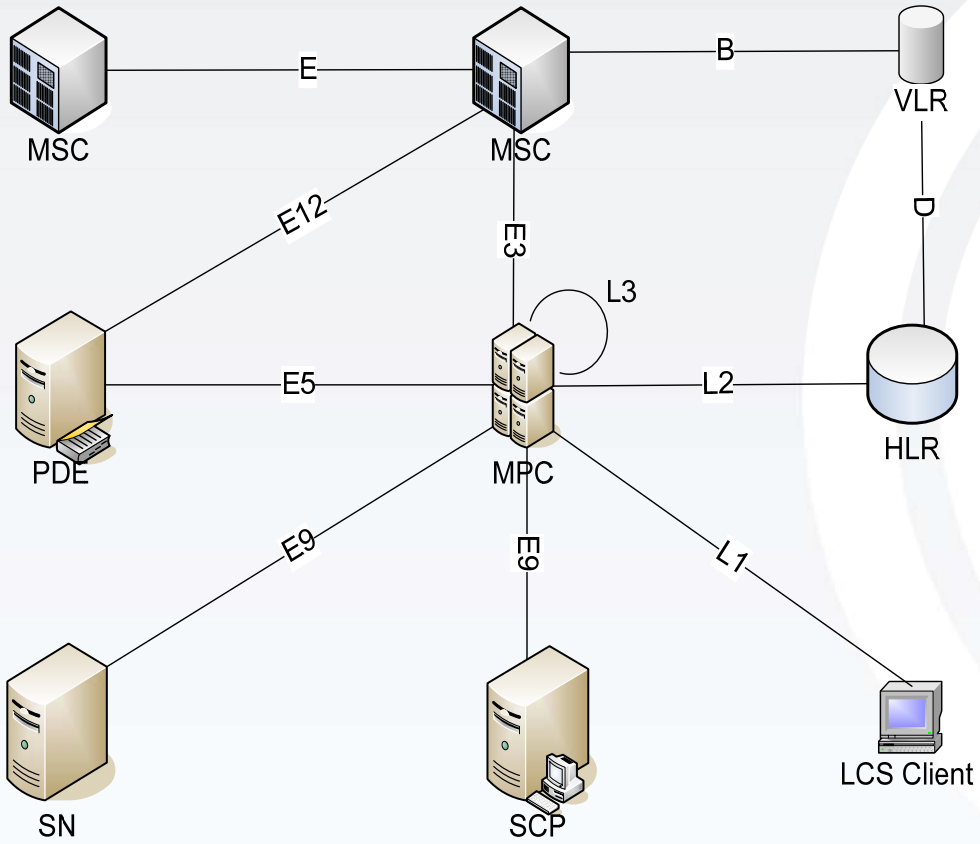
OMA LCS Specifications

- <http://www.openmobilealliance.org>
- OMA RD MLS V1.0: “OMA Mobile Location Service Enabler Requirements”
- OMA AD MLS V1.0: “OMA Mobile Location Service Architecture”
- OMA TS MLP: “Mobile Location Protocol”
- OMA TS RLP V1.0: “Inter-Location Server Interface Specification”
- OMA TS PCP V1.0: “Privacy Checking Protocol”
- OMA RD SUPL V1.0: “Secure User Plane Location Requirement”
- OMA AD SUPL V1.0: “Secure User Plane Location Architecture”
- OMA TS ULP V1.0: “User Plane Location Protocol”

3GPP2 LCS: Control Plane and User Plane

- 3GPP2 has defined both the control plane and the user plane.
  - 3GPP has only the control plane and OMA provides only the user plane.
  - Usually, a control plane and a user plane support mobile originated and mobile terminated services.
  - 3GPP2 control plane is not well suited for mobile originated services that is used for self-positioning.
  - 3GPP2 control plane does not fully support mobile station resident applications.
  - User plane for CDMA networks are limited since the simultaneous voice and data cannot be supported.
  - Also, current user plane solutions does not perform reliably for emergency service.
- TSG-X and TSG-C are the working groups responsible for location service.

3GPP2 C-Plane: Architecture



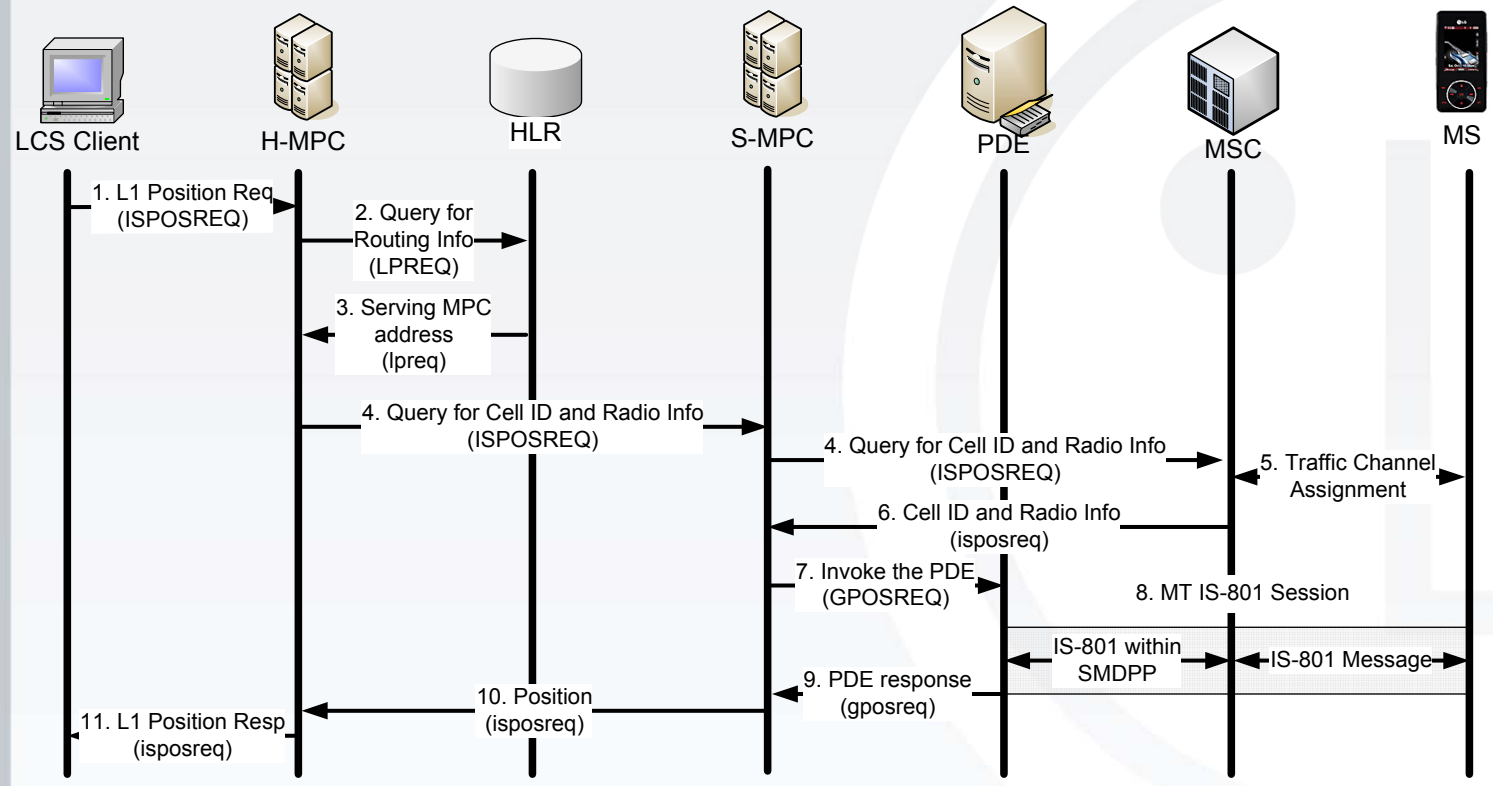
Mobile Position Center (MPC):

- MPC serves as the point of interface to the wireless network for the position determination network.
- MPC serves as the entity which retrieves, forwards, stores, and controls position information within the position network.
- MPC selects the PDE to use in position determination and forwards the position estimate to the requesting entity or stores it for subsequent retrieval.

Position Determining Entity (PDE):

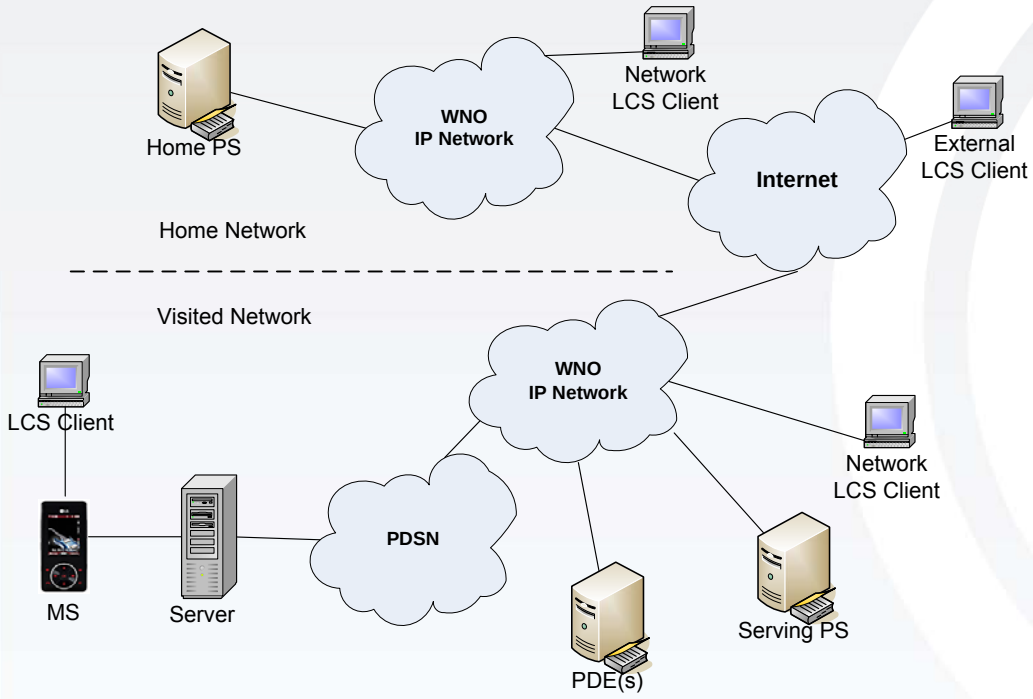
- PDE facilitates determination of the geographical position for a target MS.
- Input to the PDE for requesting the position is a set of parameters such as PQoS requirements and information about the current radio environment of the MS.

3GPP2 C-Plane: Mobile Terminated



- **ISPOSREQ**: request position from MPC or positioning-related information from MSC.
- **LPREQ**: request serving MPC address and other information from HLR.
- **GPOSREQ**: tell PDE to initiate positioning.
- **SMDPP**: carry IS-801 information from PDE to MSC and vice versa.

3GPP2 U-Plane: Architecture



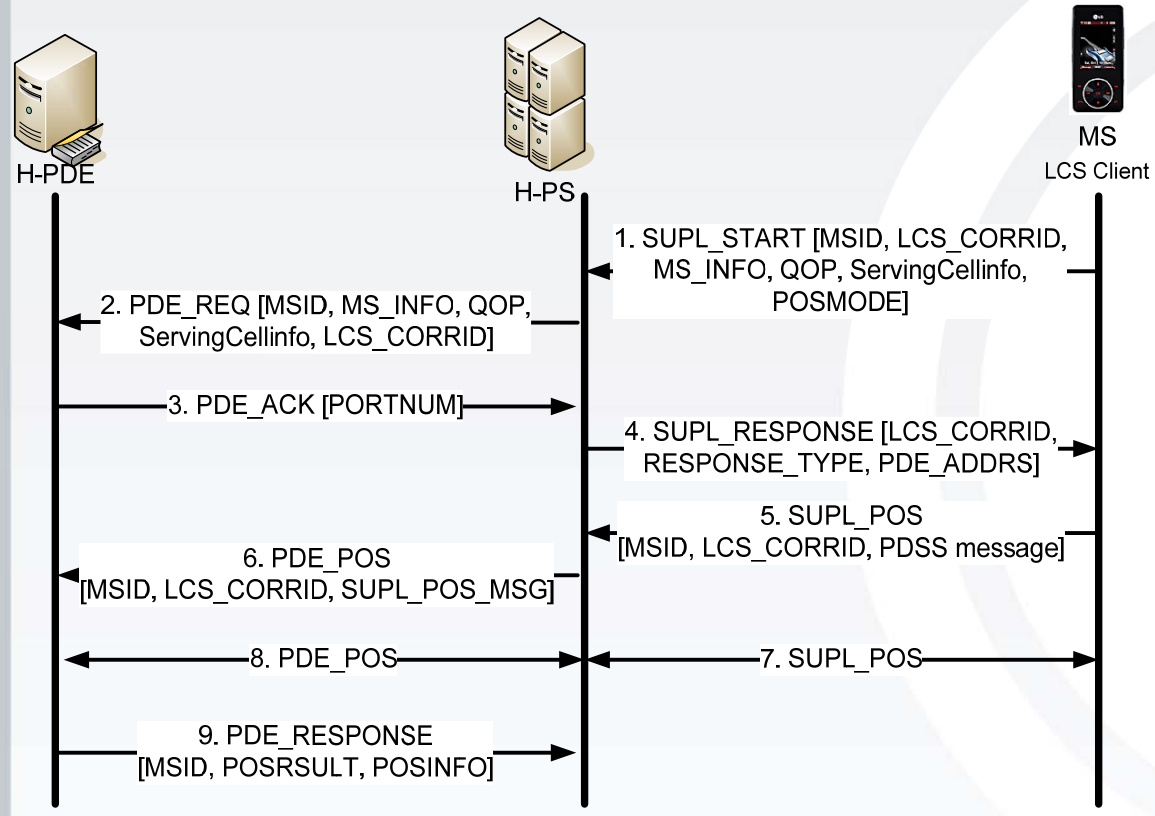
Multiple services:

- MT: single fix, periodic fix
- MO: single fix, periodic fix

Position server (PS):

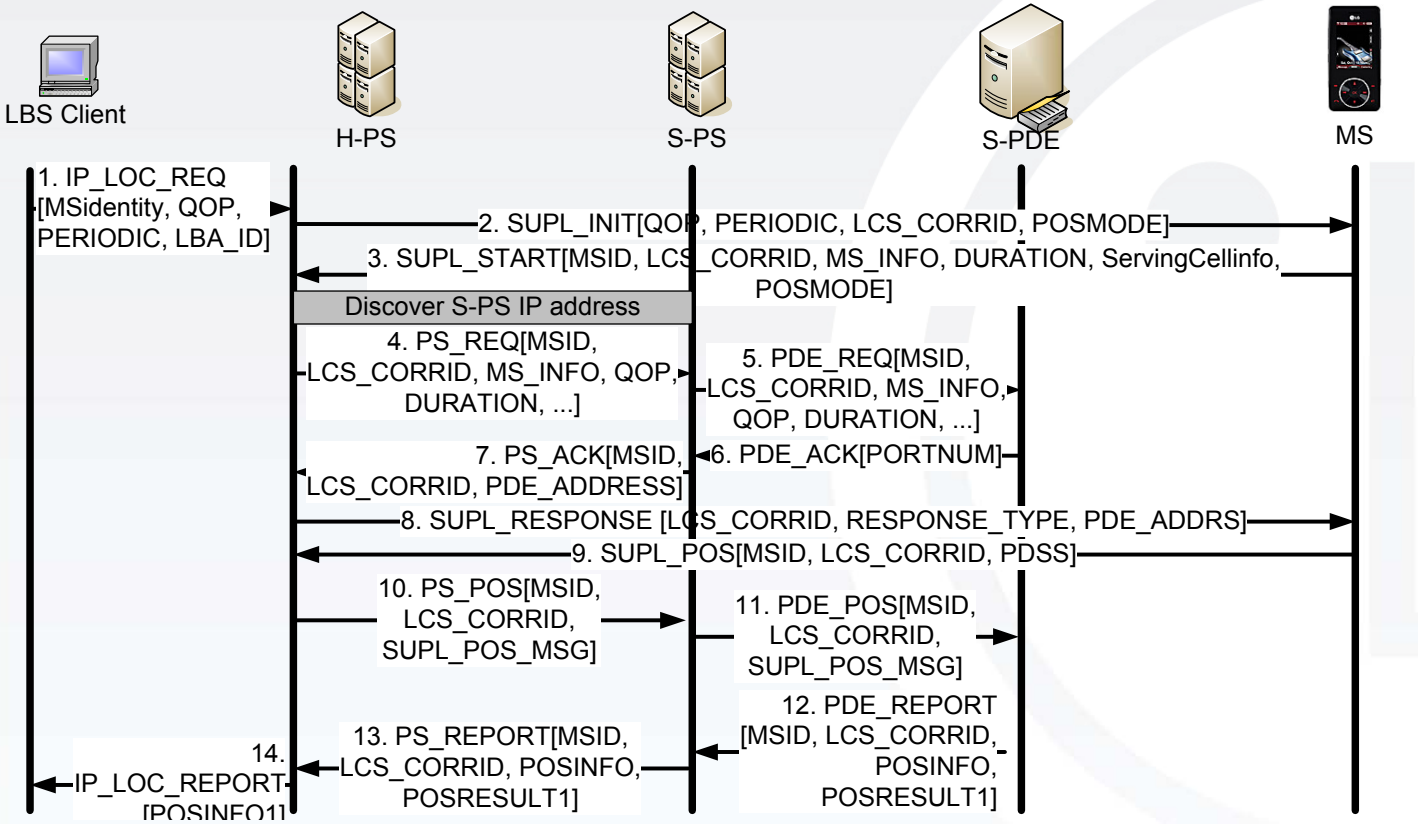
- PS provides geographic position information of a target MS to requesting entities.
- PS serves as the point of interface to the LCS server functionality in the wireless packet data network.
- PS performs functions such as accepting and responding to the requests for location estimate of a target MS, authentication, service authorization, privacy control, billing, and allocation of PDE resources for positioning.

3GPP2 U-Plane: Mobile Initiated



- MS in home with proxy mode
- **2:** PS selects a PDE and sends a PDE_REQ to the PDE requesting allocation of PDE resources for positioning determination.
- **3:** PDE_ACK includes the port number and other information elements needed for secure communication between the PDE and target MS.
- **4:** LCS_CORRID is set to the value previously assigned by the MS for the position information request.
- **7-8:** PDSS messages are exchanged between the PDE and the MS via the PS until the target position information is available. Each PDSS message is included in a SUPL_POS between the MS and the PDE.

3GPP2 U-Plane: Network Initiated



- MS Roaming-Proxy Mode
- **4:** Visited PS sends a PDE _REQ message to the selected PDE assigned to assist the MS in PDSS positioning and informs that PDE to reserve resources and expect an IP session from the target MS.
- **9-11:** SUPL_POS includes initial PDSS message. The H-PS forwards the SUPL_POS to the S-PS in the PS-POS, and S_PS forwards the SUPL_POS to the PDE in the PDE_POS.

3GPP2 Specifications

- <http://www.3gpp2.org/Public_html/specs/index.cfm>
- 3GPP2 X.S0002-0 v2.0 (TIA-881-1): “MAP Location Services Enhancements”
- 3GPP2 X.S0009-0 (TIA-843): “Wireless Intelligent Network Support for Location Based Services”
- 3GPP2 X.S0024: “IP Based Location Services”
- 3GPP2 C.S0022-0: “Position Determination Service Standard for Dual Mode Spread Spectrum Systems”
- 3GPP2 C.S0022-A: “Position Determination Service for cdma2000 Spread Spectrum Systems”
- ANSI J-STD-036: “Enhanced Wireless 9-1-1 Phase 2”
- S.R0115-0 v2.0: “All-IP Network Emergency Call Support - Stage 1 Requirements”
- X.P0049: “Multi-Media Domain (MMD) Emergency Call Support”

Acronyms

- UE: User Equipment
- MS: Mobile Station
- BSC: Base Station Center
- HLR: Home Location Center
- BTS: Base Transceiver Station
- RNC: Radio Network Controller
- LMU: Location Measurement Unit
- SGSN: Serving GPRS Support Node
- SMLC: Serving Mobile Location Center
- MSC: Mobile services Switching Center
- GMLC: Gateway Mobile Location Center
- UTRAN: Universal Terrestrial Radio Access Network
- UMTS: Universal Mobile Telecommunication System
- GERAN: GSM/EDGE Radio Access Network
- GSM: Global System for Mobile Communication
- GPRS: General Packet Radio Service
- EDGE: Enhanced Data Rate GSM for Evolution

- IMSI: International Mobile Subscriber Identity
- MSISDN: Mobile Subscriber USDN Number
- MSRN: Mobile Station Roaming Number
- TMSI: Temporary Mobile Subscriber Identity
- LAI: Location Area Identifier
- CGI: Cell Global Identity
- SLC: SUPL Location Center
- SPC: SUPL Position Center
- SET: SUPL Enabled Terminal
- SAS: Stand Alone SMLC
- SUPL: Secure User Plane Location
- MLS: Mobile Location Service
- MLP: Mobile Location Protocol
- RLP: Roaming Location Protocol
- PCP: Privacy Checking Protocol
- PDE: Position Determining Entity
- MPC: Mobile Position Center
- SN: Service Node
- SCP: Service Control Point

Section III References

- Axel Küpper, “Location-Based Services: Fundamentals and Operation”, Willey, West Sussex, England, 2005
- K. Kolodziej and J. Hjelm, “Local Positioning Systems: LBS Applications and Services”, CRC Taylor & Francis, 2006
- Tomislav Kos, et al., “Location Technologies for Mobile Networks”
- Alberto Montilla Bravo, et al., “Advanced Positioning and Location Based Services in 4G Mobile IP Radio Access Networks”, IEEE, 2004
- GSM Association, “Location Based Services”, PRD SE.23, January 2003
- Larry A. Young, OMA, “Location Services Overview”, SDO Emergency Services Coordination Workshop, October 2006
- Mark L. Younge, ATIS, “High Internet Subject: Location Based Services”, Global Standards Collaboration, September 2005
- David Tipper, University of Pittsburgh, Lecture Note, “Location Based Services”
- A. Gum, K. Burroughs, “Control Plane and User Plane Architecture”, March 2nd 2006, GPS World
- <http://brew.qualcomm.com/bnry_brew/pdf/brew_2006/101pc23_burroughs_lbsgoing.pdf>
- <http://www.3gpp.org> Specifications
- <http://www.3gpp2.org> Specifications
- <http://www.openmobileallience.org> Specifications

Outline

- **Section I: Introduction**
  - View of the wireless business domain above 30000 feet
  - Historic overview
  - LBS concept
  - LBS applications and market
  - LBS in mobile standards
- **Section II: Wireless Positioning Technologies**
  - Basic positioning methods
  - Satellite positioning systems
  - Positioning in mobile networks
- **Section III: Location Services in Mobile Networks**
  - LCS design considerations
  - Location management in mobile networks
  - LCS architecture: control plane and user plane
  - LCS procedure in mobile standards
- **Section IV: Challenges for Mobile Location Based Services**
  - **New mobile technologies**
  - **Interoperability**
  - **Security design**

New Mobile Technologies

- Many existing network technologies were not originally designed for LBS.
  - They are typically optimized for voice or data services.
- However, the wide acceptance of 3G data services is expected to help promote LBS.
  - High data throughput may enable more attractive LBS applications.
  - People start looking for more personalized services.
- New location-related add-ons are actively in discussion.
  - Highly detectable pilot is in standardization processes for cdma2000 1xEV-DO.
  - Galileo system may add more features and improve the current performance of positioning.
  - Indoor positioning by interworking with WLAN is becoming important.
- The impact of new technologies on LBS is still uncertain.
  - Femto cell
  - Relay network
  - Multiple antenna

Interoperability

- **Existing and emerging mobile networks**
  - LBS should be used by customers of other networks in the same market.
  - Interworking with WLAN system provides new source of positioning data.
  - Different mobile networks have their own mobile positioning technologies.
  - Interoperability increases the chances of LBS becoming mass-market services rather than remaining niche products.
- **International roaming**
  - The nature of LBS requires interoperability between operators at national as well as international level. Without solving the roaming problems, a huge market potential will not be realized.
  - A roaming customer who is on vacation in the foreign country would like to use LBS such as navigation.
- **Quality of positioning (QoP)**
  - Accuracy is not consistent over various mobile networks in all environments.
  - Service user wants LBS to be consistent in terms of accuracy and availability.

Security Design for Privacy

- LBS can be highly beneficial while it could do harm to the user's privacy.
- There is consumer's concern about potential threats to personal security and use of personal location records for commercial purposes and legal actions.
- Preventing unauthorized access to personal location information is a prerequisite to protect privacy.
- Carriers should protect their location information by not forwarding it to advertisers or other service providers unless the users authorize them to do so.
- Security design is more challenging in user plane than in control plane, and there should be appropriate privacy management models for user plane deployments.

Section IV References

- Ian Brown, “Privacy, Human Rights and Location Based Services”, < http://www.cs.ucl.ac.uk/staff/I.Brown/privacy-location-based-services.ppt>, UCL Computer Science
- Location Based Services: Considerations and Challenges, <http://www.northstream.se >
- I.K. Adusei, et al., “Location Based Services: Advances and Challenges”, IEEE, 2004
- D. Dao, et al., “Location-based Services: Technical and Business Issues”, GPS Solutions, 2002
- L. Perusco and K. Michael, “Control, Trust, and Security: Evaluating Location-Based Services”, IEEE Technology and Society Magazine, Spring 2007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