Enhance Downlink Positioning in WiMAX/16m

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None

Re: Call for Contributions on Project 802.16m System Description Document (SDD): PHY aspects of enhanced LBS

Purpose: Discussion and Approval

Enhance Downlink Positioning in WiMAX/16m

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Outline

- LBS Requirements in 802.16m SRD
- Introduction to LBS
  - FCC E911 and EU E211
  - Downlink or Uplink Positioning
- Challenges in Downlink Positioning
  - Hearability Issues.
  - Indoor positioning and Femto cell synchronization
- Proposed Downlink Positioning Enhancements
  - **Proposal I**: Downlink Silent Period
  - **Proposal II**: LBS Zone and LBS Pilots
- Proposed ToC
- Proposed SDD Text

Related Section in 802.16m SRD

- ***7.6 Location-based services performance***
  - IEEE 802.16m systems (this may include MS, BS, or both depending on the solution) should provide support for LBS. IEEE 802.16m systems should satisfy the requirements in Table 15.

Feature	Requirement	Comments
Location determination latency	< 30 s	
Handset-based position accuracy (in meters)	50 meter (67%-tile of the CDF of the position accuracy) 150 meter (95%-tile of the CDF of the position accuracy)	Need to meet E911 Phase II Requirements
Network-based position accuracy (in meters)	100 meter (67%-tile of the CDF of the position accuracy) 300 meter (95%-tile of the CDF of the position accuracy)	

Table 15–Location-based service requirements

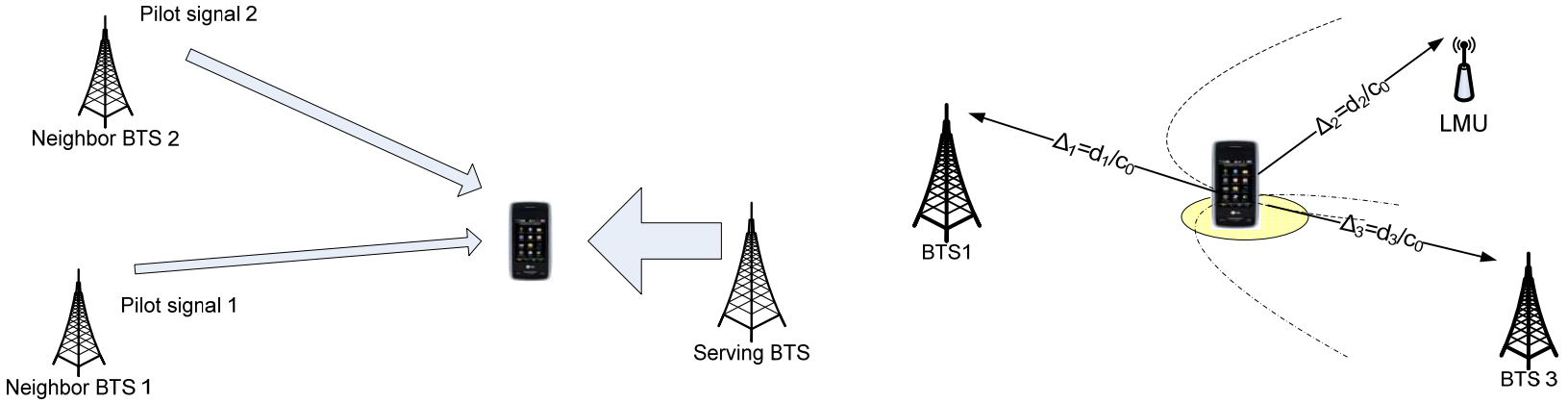
Introduction (1/2): E911 and E112

- **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%.
  - **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.
- **EU Location-Enhanced 112**
  - In 2000, the EU launched activities for enhanced 112 (E-112) and CGALIES (the Coordination Group on Access to Location Information for Emergency Services) is initiated.
  - In September 2002, an EMTEL ad hoc group under the ETSI OCG (Operational Co-ordination Group) was set up to look at standardization requirements.
  - In July 2003, the EU issued a Recommendation for the Europe-wide implementation of the location-enhanced 112.
- Mission Unaccomplished.
  - It is not a easy job to completely satisfy the mandates alone.
  - LBS is also believed to be a key feature of next generation mobile standards including 16m.

Introduction (2/2): Downlink or Uplink Positioning

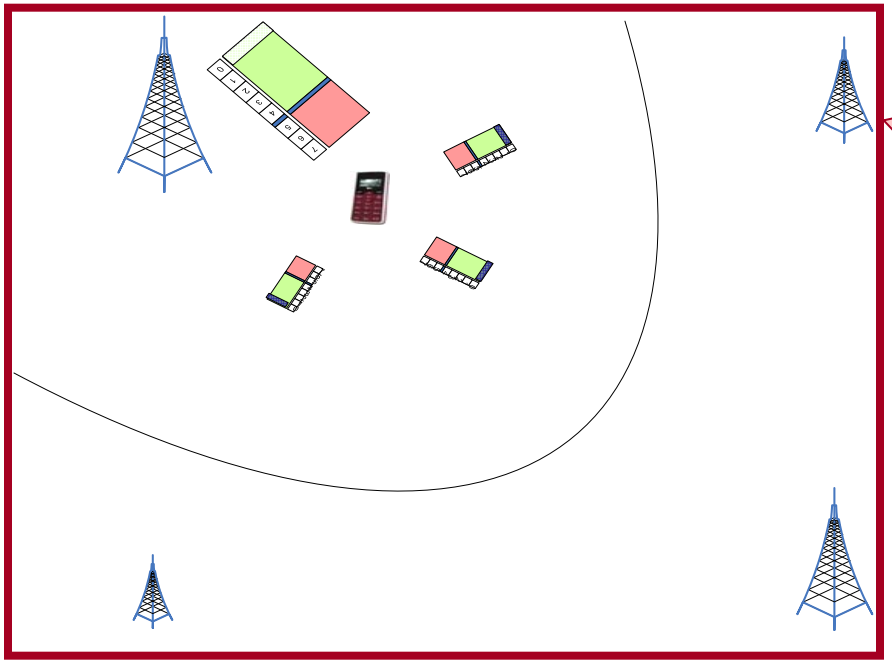
- Most mobile positioning services are provided through a hybrid approach, a combination of GPS-based positioning and network-based positioning.
  - Though A-GPS can provide an accuracy of less than 10 meters, it may not perform well in the scenarios where there are no enough clear paths between GPS satellites and a receiver, such as indoor environments, some urban environments.
- There are certain tradeoffs between downlink and uplink approaches for location services.
  - Downlink approaches require mobiles to be explicitly involved into positioning procedures.
    - Existing DL pilot channel power usually is very strong and consistent.
    - Additional feedback channel is required, though it may be shared with other channels.
    - Extra positioning delay may happen.
    - In general, mobile has limited resources and knowledge for positioning.
  - Uplink approaches put most burdens on the network side instead.
    - The network side usually has enough resources for positioning.
    - Low latency with no feedback channel necessary.
    - Flexible and standards-independent.
    - The transmit signal from mobile usually is not strong.
- Typical downlink positioning approaches include
  - GSM: E-OTD.
  - UMTS: OTDOA
  - cdma2000: EFLT and AFLT

Challenges in Downlink Positioning

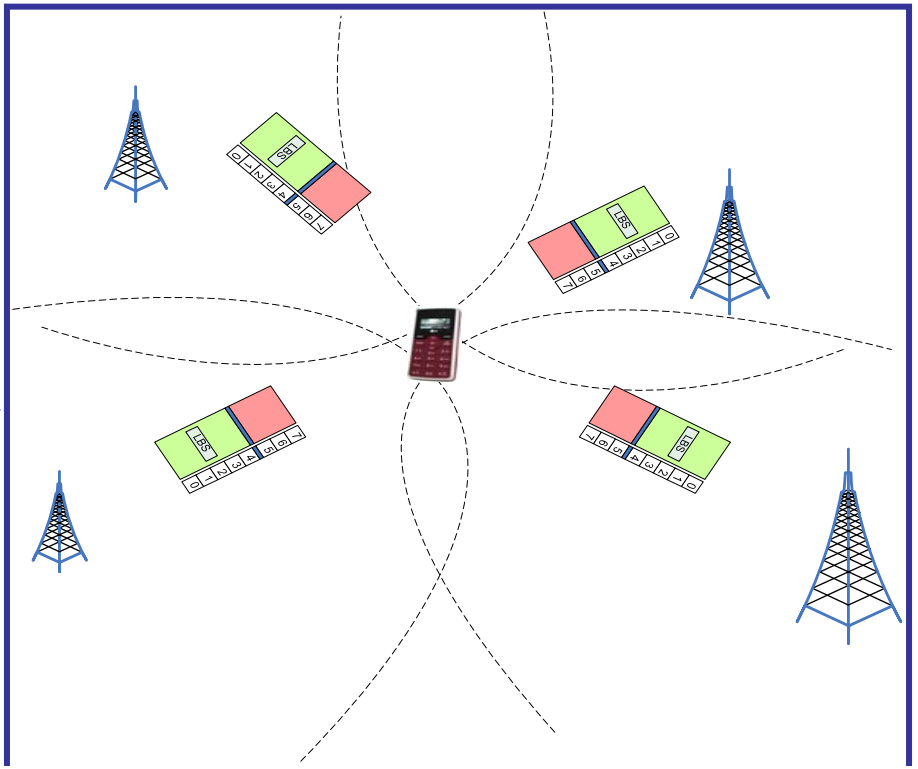


- There are hearability issues for DL positioning approaches. (It is also a challenge for network planning.)
  - Inside the cell, the serving base station blocks the signals from distant base station. ← a near-far problem
  - On the cell edge, the signals from nearby base stations seriously interferes with each other. ← a cell-edge issue.
- In addition for indoor positioning and Femto cell synchronization, it is strongly recommended to provide additional mechanisms for downlink pilot/preamble measuring.

Enhance Downlink Positioning for WiMAX



The near-far problem can be mitigated by the technique, Downlink Silent Period (DSP), where the serving BS intentionally control its transmission during some preamble periods of neighbor BS's.



The cell edge issue can be mitigated by the technique, LBS zone and LBS pilots, where each involved BS sends an unique positioning pilot that is orthogonal to the others.

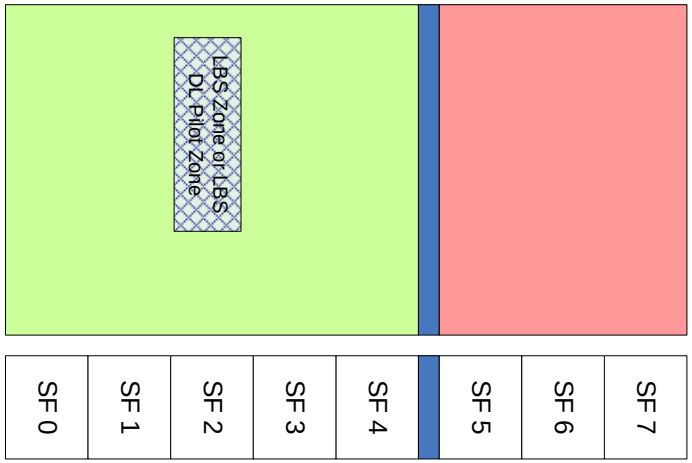
Proposal I: Downlink Silent Period (DPS) (1/2)

- Downlink Silent Period (DSP) is a technique proposed for WiMAX, where a base station's transmission is specially controlled for a short period of time.
  - The serving BS can keep silent, e.g., on some of its preamble/data periods after informing served mobiles of the timing.
  - A served mobile can clearly measure the neighbor base stations' pilot signals during the DSPs of a serving BS.
  - DSP helps maximize the hearability of distant pilots.
- Before a base station start DSP on its transmission, it will inform the served mobiles the details of the next DSP.
  - This can be implemented independently by each base station
  - Or it can be done with some coordination among multiple base stations. Therefore there will be fewer collisions on applying DSP between base stations.

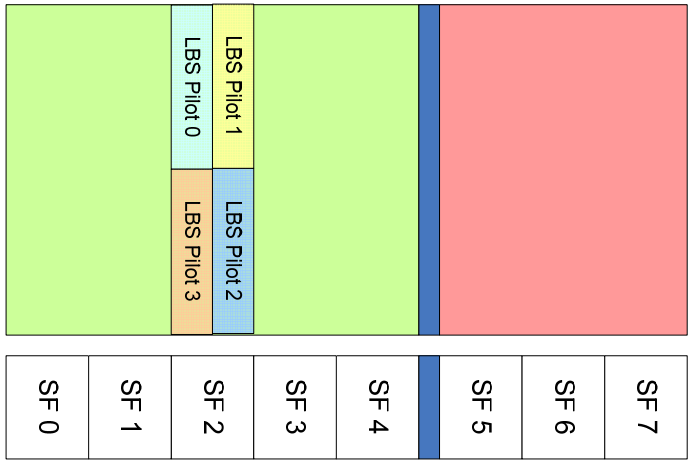
Proposal I: Downlink Silent Period (DPS) (2/2)

- The application of DSP may depend on
  - the request of the served mobiles,
  - the request of neighbor base stations, or
  - the request from the network, mobile location center (MLC) or positioning determination entity (PDE).
- DSP for two possible preambles
  - **Synchronous Preambles**, where the preambles from the nearby BS's are sent at the same time. In this case, DSP on preambles helps mitigate the interference between the preambles and maximize the hearability of preamble.
  - **Asynchronous Preambles** , where the preambles from the nearby BS's aren't sent at the same time. In this case, the serving BS can apply DSPs on any symbols where the nearby BS's preambles are being broadcasted.
- DSP can be used for increasing the hearability of signals from neighbor base station, which includes both preamble and other possible LBS pilots.

Proposal II (1/2): LBS Zone and LBS Pilots



Distributed Allocation Example



Localized Allocation Example

- The network reserves certain resources for transmitting LBS pilots or other LBS related information. ← It may be called LBS pilot zone
- Each BS has its own LBS pilot waveform with a unique positioning code.
- All LBS pilots are orthogonally multiplexed and distinguished from each other in terms of time, frequency position and/or scrambling positioning codes.

Proposal II (2/2): LBS Pilot Design

- LBS pilot design can reuse the existing or future uplink ranging channel design.
  - One option: reuse the existing 16e ranging sequences
    - The PRBS generator shall be initialized by the seed b14...b0 = 0,0,1,0,1,0,1,1,s0,s1,s2,s3,s4,s5,s6, where
      - s6 is the LSB of the PRBS seed, and
      - s6:s0 = UL_PermBase, where s6 is the MSB of UL_PermBase.
    - The length of each ranging code is 144 bits. The number of available codes is 256.
      - For example, the first 144 bit code obtained by clocking the PN generator as specified, with UL_PermBase = 0, the first code shall be 011110000011111...00110000010001... The next ranging code is produced by taking the output of the 145th to 288th clock of the PRBS generator, etc.
    - The bits are mapped to the subcarriers in increasing frequency order of the subcarriers.
  - **It is open for future discussions.**
- The positioning of LBS pilot zone can be assigned in the same way as MBS zone.

Proposed ToC

- **Support for Location Based Services**
  - Location Based Services Overview and Protocol Structure
  - Physical Layer Support for Location Based Services
    - Possible Positioning Technologies
    - Physical Layer Enhancements for Location Based Services
      - Physical Layer Downlink Enhancements
        - » LBS Zone and LBS Pilots
        - » Downlink Silent Period
        - » GPS and Galileo Positioning Assistance
      - Physical Layer Uplink Enhancements
  - MAC Layer Support for Location Based Services
    - Location Based Services (LBS-ADV) message

Proposed Text (1/3)

- XX Support for Location Based Services
  - This subclause provides additional enhancements and mechanisms to coordinate the collection, generation, and reporting of information used to determine MS location (e.g. RSSI, CINR, Time Difference of Arrival (TDOA), Time of Arrival (TOA), …). Reporting of BS location information is also described.
  - XX.1 Cell-Id Based Approach
    - Cell-Id is a location determination scheme that a MS periodically report the id of its serving cell with the assumption that the approximate location of this MS is the center of the serving cell. There are two types of cell-Id based enhancements.
      - Cell-Id with RSSI – A MS report RSSI data in its channel quality measurements of its serving BS. The serving BS may predict the distance between the MS and the serving BS. This prediction can be used to calibrate the cell-Id based positioning
      - Cell-Id with Timing Advance – The serving BS periodically measure the delay between a MS transmit time and receive time and use this measurement to predict the distance between the MS and serving BS. This prediction can be used to calibrate the cell-Id based positioning
  - XX.2 Time Difference of Arrival (TDOA)
    - TDOA is a location determination scheme that measures the difference of time arrival for packet transmission between a MS and multiple BSs. There are two types of TDOA - Downlink TDOA (D-TDOA) and Uplink TDOA (U-TDOA) based on whether the measurements are performed in the MS and the BS, respectively.
      - D-TDOA - MS may report D-TDOA data in the Relative Delay parameter in MOB_SCN-REP message that indicates the delay of DL signals from a neighbor BS relative to the serving BS. MOB_SCN-REP also reports RSSI and CINR of DL signals from neighbor BS that can be used for MS location estimation. During SBC-REQ/RSP based capability negotiation, HO Trigger metric support (see 11.8.7) indicates which trigger metric that the MS supports.
      - U-TDOA - As opposed to D-TDOA that is reported each time MS scanning is completed, U-TDOA enables BS to initiate U-TDOA measurement when it is needed. Annex L describes two algorithms to show the U-TDOA measurement through the coordination of MS, serving BS, and one or more neighbor BS for wireless broadband networks: the General U-TDOA Method, for any FRF (Frequency Reuse Factor); and the Special U-TDOA Method, for FRF = 1.

Proposed Text (2/3)

- Downlink Silent Period.
  - Base stations shall be able to control the transmission power of its frequency and time resources for helping the served mobile stations measure the pilots or preambles of neighbor base station or location reference unit (LRU). LRU is any equipment which periodically or constantly broadcast pilot signals for positioning purposes.
    - The serving base station shall be able to low or silent its preamble transmission.
    - The serving base station shall be able to low or silent the transmission of some portions of its data frame.
  - Base stations shall be able to inform each served mobiles before it starts controlling its transmission power and which channel resource it will control.
- LBS Zone and LBS Pilot.
  - Base stations shall be able to transmit LBS pilots inside LBS zone for enhancing downlink positioning.

Proposed Text (3/3)

- LBS Zone
  - LBS Zone is a special block of time and frequency resource assigned for help the served mobiles to performance positioning operation.
  - Each base station can have its own LBS zone independently. Or there are multiple base station share the same LBS zone during their transmission.
  - The assignment of LBS zone can be dynamic or periodic.
  - The position and size of LBS zone are informed and available to each served subscribe station.
- LBS Pilots
  - LBS pilots are a set of orthogonal pilots transmitted from base stations to subscribe stations for positioning purposes.
  - LBS pilots are transmitted inside LBS zone.
  - Each involved base stations has its own unique LBS pilot, which is transmitted through a different set of symbol periods or frequency subcarriers from other LBS pilots. Therefore there is no collision between any pair LBS pilots.

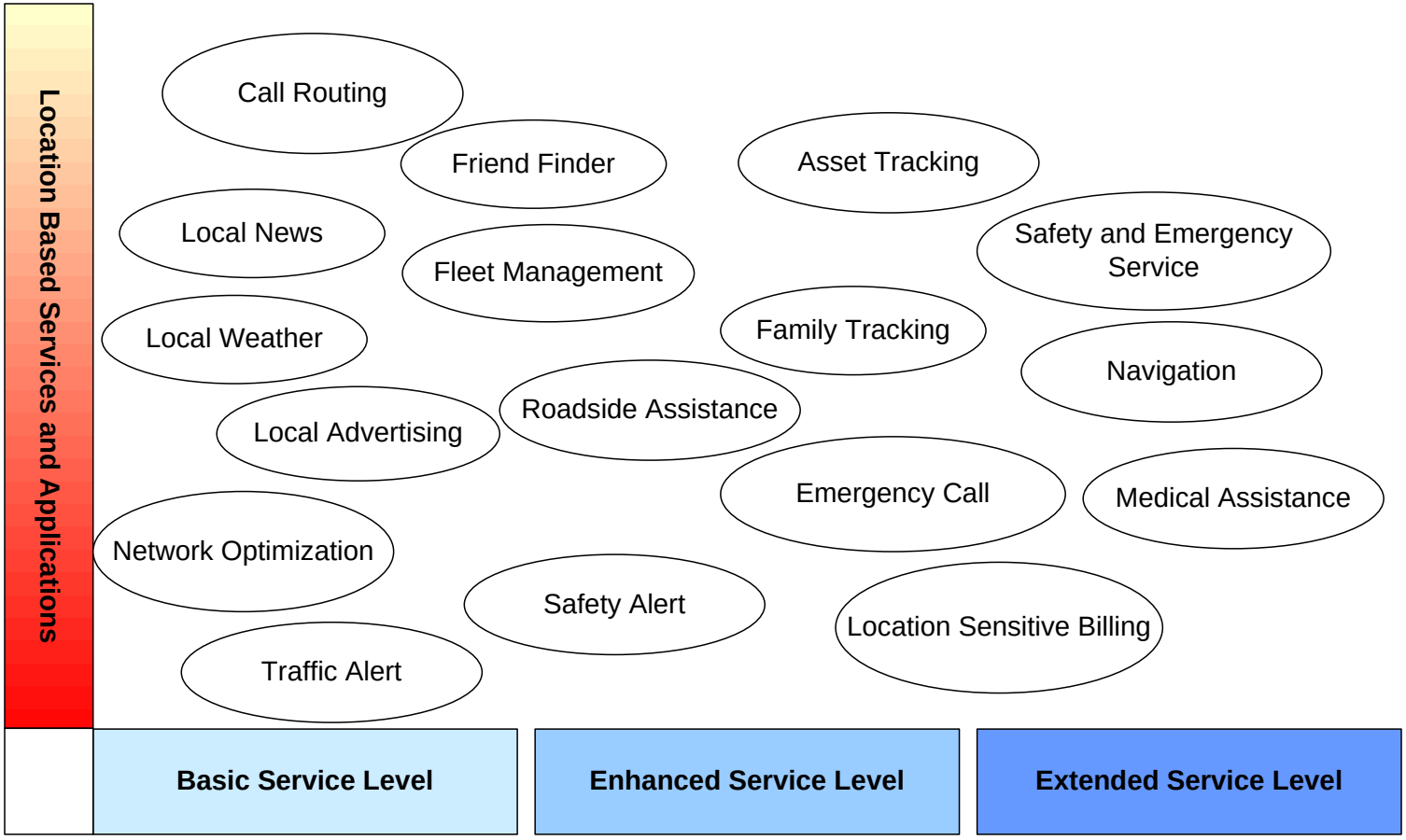
Reference

1) IEEE 802.16 Broadband Wireless Access Working Group IEEE 802.16m System Requirements. http://wirelessman.org/tgm/docs/80216m-07_002r4.pdf
2) P802.16Rev2/D4 (April 2008), Part 16: Air Interface for Broadband Wireless Access Systems
3) Shu Wang, Jungwon Min and Byung K Yi, “Location Based Services for Mobiles: Technologies and Standards”, Tutorial#25, IEEE International Conference on Communication (ICC), May 23, 2008, Beijing, China.
4) Shu Wang, Jungwon Min, Li-Hsiang Sun, “Enhanced Location Based Support in cdma2000”, 3GPP2 TSG-C NTAH, Osaka, Japan, May 2008.

Appendix

LBS Service Levels

- Applications usually require different service levels. [Source: Location Interoperability Forum (LIF), now a part of Open Mobile Alliance (OMA)]
  - Basic service level: 400-1500m
  - Enhanced service level: 40-150m
  - Extended service level: less than 40m.



Introduction (2/2): Existing Technologies Comparison

	Attributes	Network	Handset	Accuracy/Performance
Cell ID	obtains Cell ID based on pilot measurements	All	All	100m-3km. Depends on cell size and density
Cell ID + TA	combines Cell ID with time advance	GSM	All	Default is 500m. Depends on bandwidth
EFLT	measures the forward link pilot timing.	CDMA	All	250-350m
AOA	measures the angle of arrival by base stations	All	All	100-200m
EOTD	measures time difference by network and mbiles.	GSM	upgrade	50-200m
AFLT	measures the forward link pilot timing.	CDMA	upgrade	50-200m
U-TDOA	Network measures the timing difference	All	All	50 – 200 m.
GPS/A-GPS	utilize the GPS receivers embedded in the handsets and network.	All	upgrade	5 - 30m

***The rough accuracy data are compiled from the claims of various technology providers.**