

Network Assisted GPS Positioning in WiMAX

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

Purpose: Discussion and Approval

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Network Assisted GPS Positioning in WiMAX

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Outline

- Positioning Requirement in 802.16m SRD
- Introduction to LBS
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Positioning Requirement 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 Coordination 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.

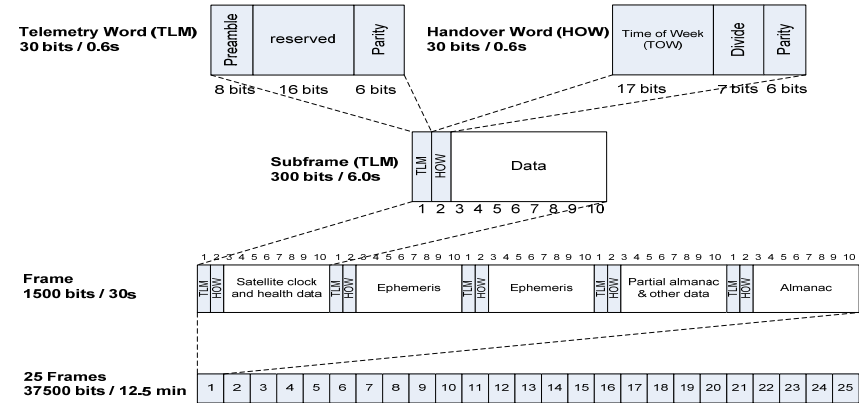
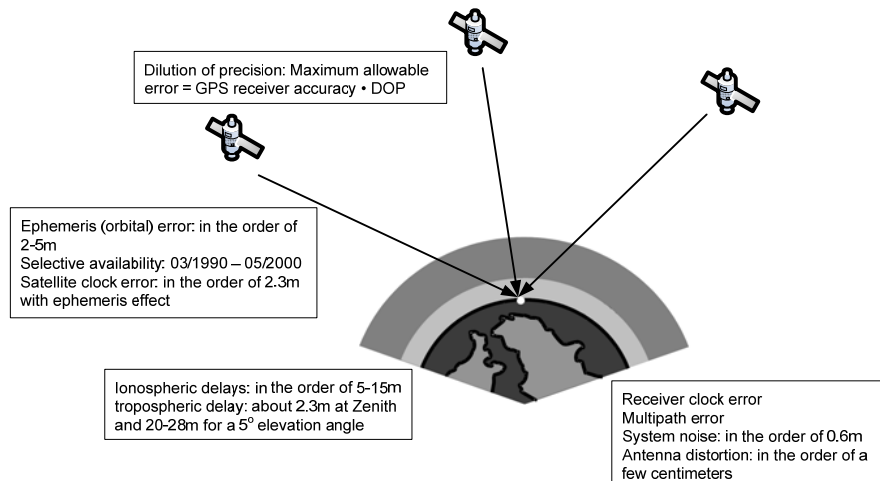
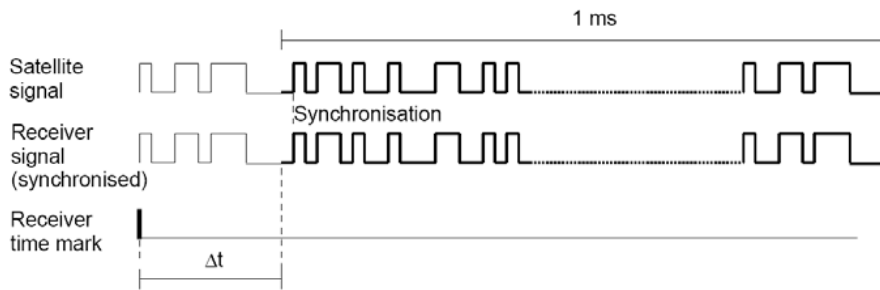
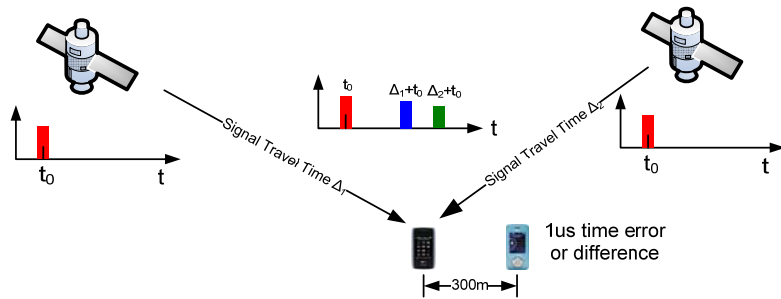
- **Mission Unaccomplished.**

- It is not easy to provide efficient and reliable positioning services.

Introduction (2/2): Existing Technologies Comparison

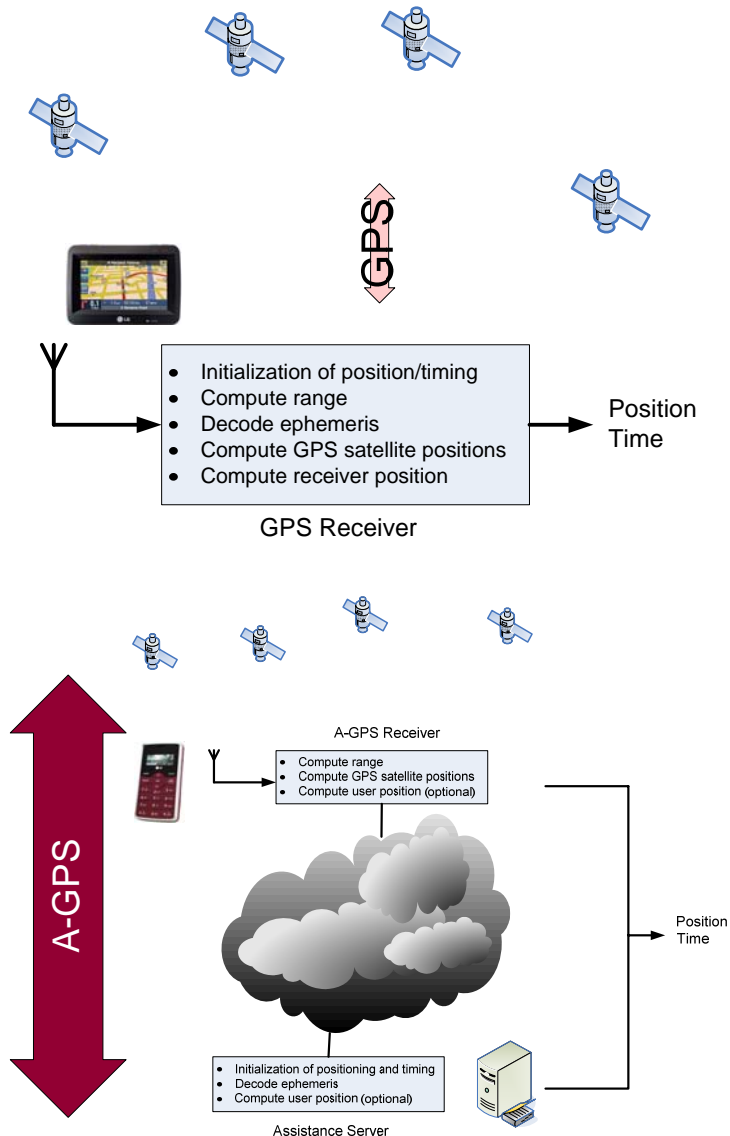
	Attributes	Network	Handset	Accuracy
Cell ID	obtains Cell ID based on pilot measurements	All	All	100m-3km. Depends on cell size and density
Cell ID + TA	combines Cell ID with time advance	GSM	All	Default is 500m. Depends on bandwidth
EFLT	measures the forward link pilot timing.	CDMA	All	250-350m
AOA	measures 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 – 100 m.
GPS/A-GPS	utilize the GPS receivers embedded in the handsets and network.	All	upgrade	5 - 30m

The Principles of GPS Based Positioning



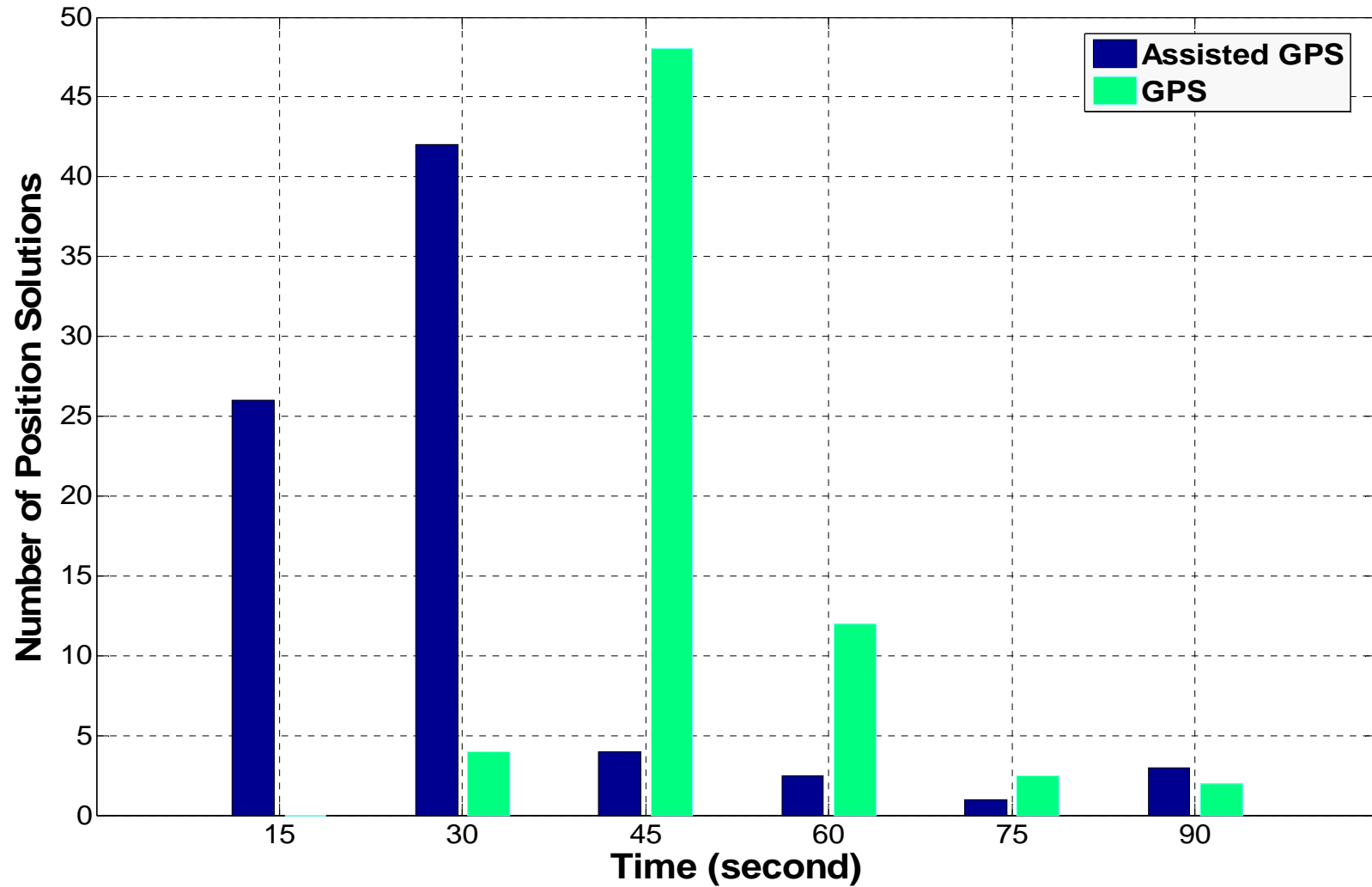
- **TLM – Telemetry:** 30 bits, sent at the beginning of each frame.
 - It is used for data synchronization and satellite maintenance.
 - They are usually constant for any one satellite for a long period of time.
- **HOW – Handover Word:** 30 bits, sent after TLM.
 - It indicates the time at the beginning 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.

Assisted GPS Positioning



- 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.

Assisted GPS: TTFF Gain



GPS World

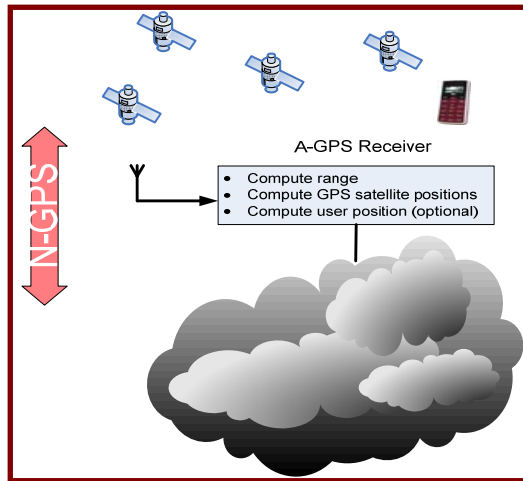
Existing Assistance in 16e

Field	Size	Description
GPS Second	12 bits	GPS second, modulo 2048
GPS Second fraction	28 bits	GPS second fraction
GPS time accuracy	8 bits	GPS Time Accuracy For unsigned integer values 0x00-0x3F: $\log_2(\text{Time error in pico seconds})$. For unknown accuracy in time error, 0xFF. Values 0x40-0xFE not allowed.

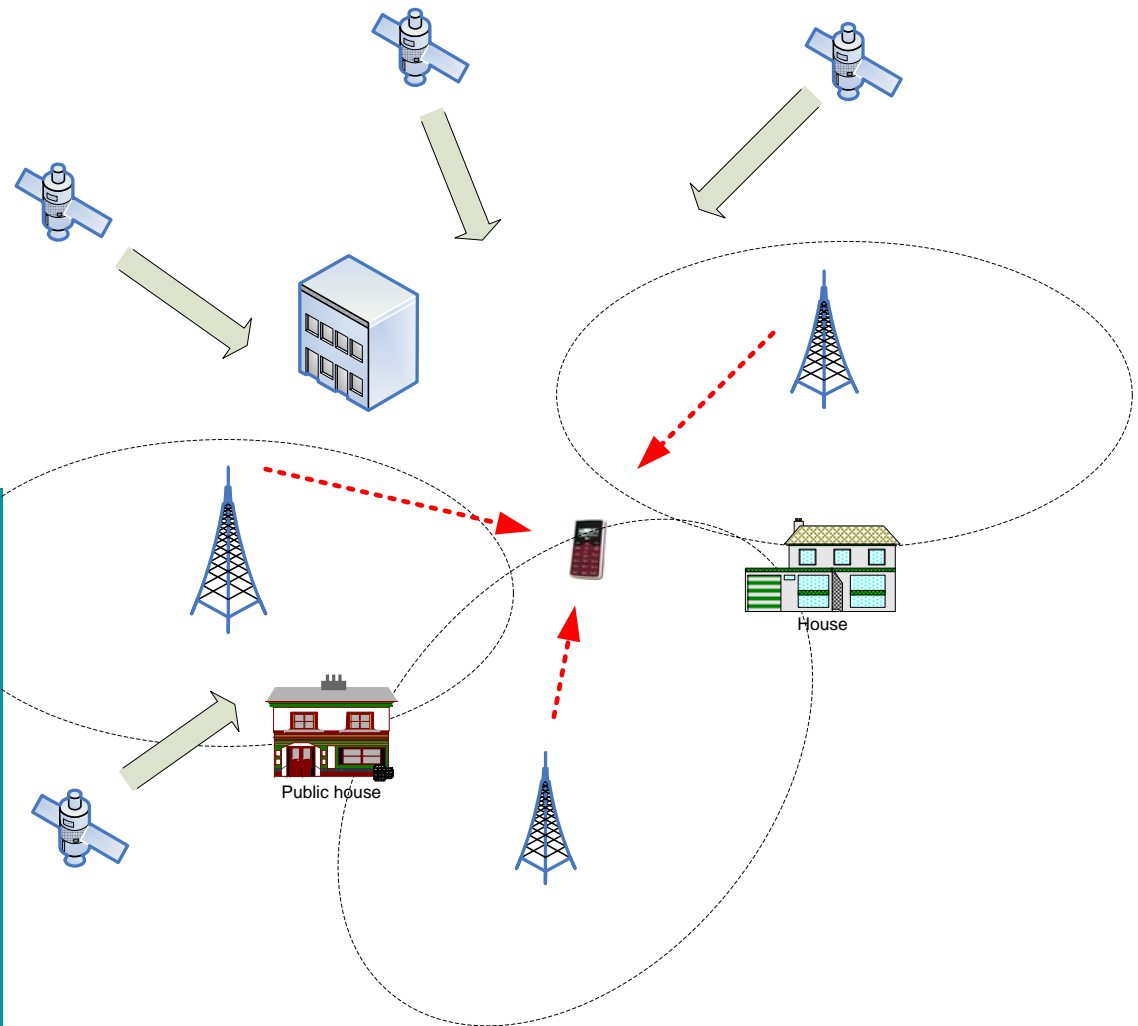
Name	Type	Length (bytes)	Value
Frequency information	5	1	BS transmit frequency accuracy in ppm. For values in range 0x00-0xFE, frequency root mean square error is $(\text{value}+1)*0.01$ ppm. For value 0xff, the MS shall interpret this as max frequency accuracy uncertainty for that profile, see subclause 12.

- The GPS Time TLV informs the receiving MS of the precise time at which the BS's First Frame of the current epoch has been transmitted, which the MS may use to calibrate its own internal clock in reference to the GPS time standard.
 - The GPS Time TLV is used if the BS's frame time is synchronized with the GPS clock. This may be particularly valuable for determining GPS satellite signal search windows in mobiles equipped to detect GPS satellites.
 - GPS second and second fraction allow the MS to use DL Frame arrival times as timing signals aligned with GPS time.
 - GPS Time Accuracy aids the MS in estimating how much error with respect to GPS time the BS may have when using this calibration.
- The GPS Frequency TLV shall be used to provide the frequency accuracy information.
 - BS transmit frequency accuracy in ppm.
 - For values in range 0x00-0xFE, frequency root mean square error is $(\text{value}+1)*0.01$ ppm.
 - For value 0xff, the MS shall interpret this as max frequency accuracy uncertainty for that profile.

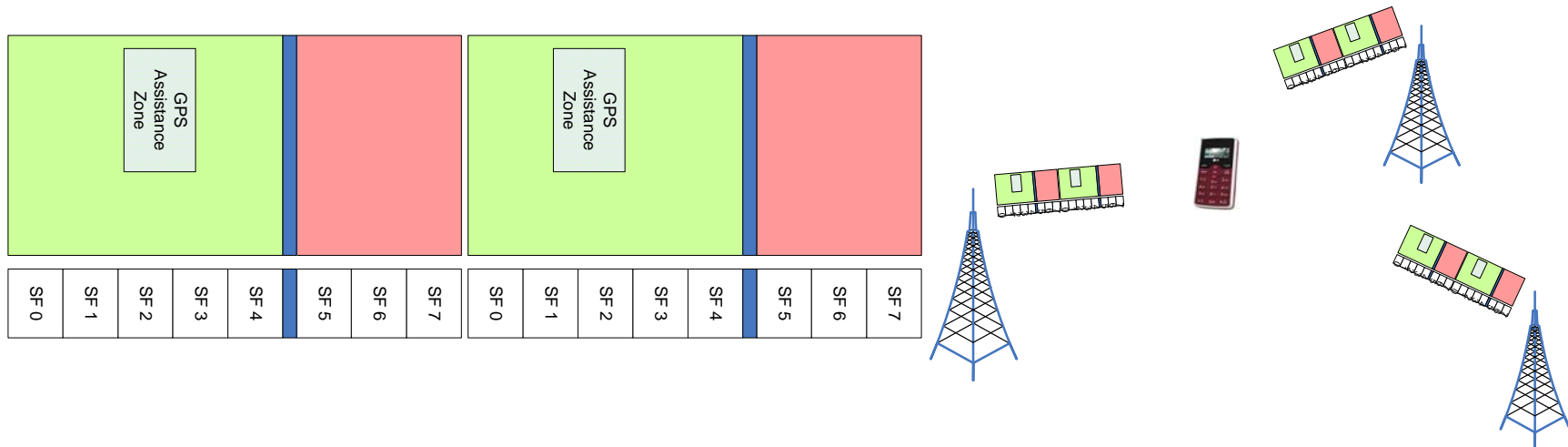
Network-Assisted GPS: It is the network.



- GPS assistance data is sent through control plan instead of user plan.
- No additional data channel setup overhead.
- Easy authentication or access control.
- More reliable than layer-3 A-GPS approaches.
- More efficient if broadcast message is used for delivering assistance data.



Network Assisted GPS (1/3): GPS Assistance Zone



- With the assistance of GPS assistance zone and SFN broadcasting, it is easy for a GPS-capable mobile to receive the assistance from WiMAX network.
- The important assistance information for GPS positioning includes
 - 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.
 - The detailed explanation of GPS Almanac data is in the next two slides.
 - Ephemeris: It is sent in each frame by each satellite.
 - It may take the GPS receiver up to 30 seconds to acquire Ephemeris.
- The information of Ephemeris and Almanac can be broadcast by capable base station within LBS zone.

Network Assisted GPS (1/3): GPS Assistance Zone (Con'd)

Type	Length	Value	Comment
XXX	1	0: No available LBS Zone. 1: LBS Zone in Serving BS only 2: LBS Zone in a multiple BS zone	

- This TLV indicates whether the LBS Zone service is being requested or provided for the connection that is being setup.
 - A value of 1 indicates that an MBS service limited to the serving BS is being requested
 - and a value of 2 indicates multi-BS-MBS is being requested.
- If MS or BS wants to initiate MBS service, DSA-REQ with MBS service TLV shall be used. The DSA-RSP message shall contain the acceptance or rejection of request and if there is no available LBS, LBS service value shall be set to 0.

Network Assisted GPS (2/3): Enhanced GPS TLV

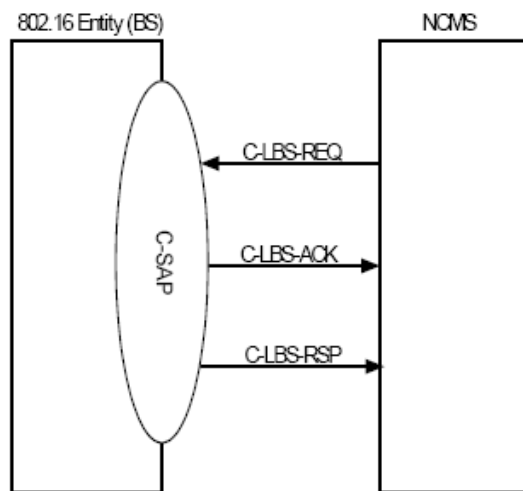
Name	Type	Length (Byte)	Value
GPS Almanac TLV	XXX	Variable	GPS Almanac Data
Field Bit-Map	XXX.0	2	It signaling which field of GPS Almanac is available.
GPS Satellite ID	XXX.1	1	PRN of the SVN, Range: 0 to 32; Accuracy: 1
Satellite Health	XXX.2	1	000=usable; Range: 0 to 63; Accuracy: None
Eccentricity	XXX.3	3	This shows the amount of the orbit deviation from circular (orbit). It is the distance between the foci divided by the length of the semi-major axis (our orbits are very circular). Range: 0.0 to 0.03; Accuracy: 4.7E-7
Time of Applicability (s)	XXX.4	3	The number of seconds in the orbit when the almanac was generated. Kind of a time tag. Range: 0 to 602112; Accuracy: 1
Orbital Inclination (rad)	XXX.5	3	The angle to which the SV orbit meets the equator (GPS is at approx. 55 degrees). Roughly, the SV's orbit will not rise above approx. 55 degrees latitude. The number is part of an equation: $\# = \pi/180 =$ the true inclination Range: -9.999999E-2 to +9.999999E-2; Accuracy: 1.91E-6
Rate of Right Ascen (r/s)	XXX.6	4	Rate of change in the measurement of the angle of right ascension as defined in the Right Ascension mnemonic. Range: -9.999999E-7 to +9.999999E-7; Accuracy: 3.6E- 12
SQRT(A) (m ^{1/2})	XXX.7	2	This is defined as the measurement from the center of the orbit to either the point of apogee or the point of perigee. Range: 79.0 to 9999.99999; Accuracy: 4.8E-4

Network Assisted GPS (2/3): Enhanced GPS TLV (Con'd)

Name	Type	Length (Byte)	Value
Right Ascen at Week(rad)	XXX.8	3	Geographic Longitude of the Ascending Node of the Orbit Plane at the Weekly Epoch Range: -9.999999E-7 to +9.999999E-7; Accuracy: 3.6E- 12
Argument of Perigee(rad)	XXX.9	3	An angular measurement along the orbital path measured from the ascending node to the point of perigee, measured in the direction of the SV's motion. Range: -1.0 to +1.0; Accuracy: 1.1E-7
Mean Anom(rad)	XXX.10	3	Angle (arc) traveled past the longitude of ascending node (value= 0-180 degrees or 0-negative 180 degrees). If the value exceeds 180 degrees, subtract 360 degrees to find the mean anomaly. When the SV has passed perigee and heading towards apogee, the mean anomaly is positive. After the point of apogee, the mean anomaly value will be negative to the point of perigee. Range: -1.0 to +1.0; Accuracy: 1.1E-7
Af0(s)	XXX.11	3	SV clock bias in seconds Range: -9.9999E-4 to +9.9999E-4; Accuracy: 9.5E-7
Af1(s/s)	XXX.12	3	SV clock Drift in seconds per seconds Range: -9.9999E-9 to +9.9999E-9; Accuracy: 3.6E- 12
GPS Week Number:	XXX.13	2	GPS week (0000-1024), every 7 days since 22 Aug 1999 Range: 0 to 1023; Accuracy: 1
Reserved	XXX.14 – XXX.16	N/A	N/A

- The including of the field, "Field Bit-Map", is for providing a mechanism for delivering only necessary Almanac data fields.
 - The length of "Field Bit-Map" is 2 bytes and 16 bits.
 - Each bit is mapped to each Almanac data field. For example, the 13th MSB of "Field Bit-Map" is mapped to XXX.13, GPS Week Number.
 - If the bit field is "0", it means this field is not included. If it is "1", it is included in the delivery.

Network Assisted GPS (3/3): Enhanced LBS Management



- **C-LBS-REQ** (
 - Operation_Type: Get,
 - Destination: BS,
 - Attribute_List:
 - MS MAC Address,
 - LBS Parameter Types)
- **C-LBS-RSP** (
 - Operation_Type: Get,
 - Destination: NCMS,
 - Attribute_List:
 - MS MAC Address,
 - Requested LBS Parameters[]
 - BSID,
 - CINR mean,
 - RSSI mean,
 - D-TDOA,
 - U-TDOA,
 - GPS Orbital Data)
- GPS Orbital Data, which may include Almanac data, Ephemeris data or other assisting data.

Comparison of GPS, N-GPS and A-GPS

Feature	GPS	N-GPS	A-GPS
Accuracy	Good	Better	Best
Yield	Good	Better	Best
TTFB	Slow	Fast	Faster
Additional Carrier Investment	None	None	Yes.
Protocols	Open	Open	Propriety
Access to Network	No Control Channel Access	Control Channel Access Only	Control Channel Access
	No Traffic Channel Access	No Traffic Channel Access	Traffic Channel Access

Other Assistance Topics

- The GPS information can be any of
 - 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

Proposed ToC

- **XX. Support for Location Based Services**
 - XX.1. Location Based Services Overview and Protocol Structure
 - XX.3. MAC Layer Support for Location Based Services
 - XX.3.1. Location Based Services (LBS-ADV) message
 - XX.3.2. GPS and Galileo Positioning Assistance
 - XX.3.1. GPS Zone
 - XX.3.2. GPS Almanac TLV
 - XX.3.3. GPS Ephemeris TLV
- **XXX LBS Management**

Proposed SDD Text

- The orbital description data of GPS satellites is important for GPS-capable mobile to performance GPS based positioning. In addition, the GPS almanac data is generally usable for months. With making GPS almanac data easily available to mobiles from the network, it can enhance the existing support of LBS.
- The delivery of GPS orbital description data, such as Almanac and Ephemeris, to mobiles can be realized by the implementation of GPS zone and GPS TLV.
 - The GPS zone is a special broadcast zone for broadcasting GPS orbital description data.
 - GPS TLV, including GPS Almanac TLV and GPS Ephemeris TLV, is another mechanism assisting mobile to do GPS based positioning.
 - LBS management, where a mobile can request GPS assistance data for LBS.

Reference

- IEEE 802.16 Broadband Wireless Access Working Group IEEE 802.16m System Requirements. http://wirelessman.org/tgm/docs/80216m-07_002r4.pdf
- P802.16Rev2/D4 (April 2008), Part 16: Air Interface for Broadband Wireless Access Systems
- 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.
- Shu Wang, Jungwon Min, Li-Hsiang Sun, “Enhanced Location Based Support in cdma2000”, 3GPP2 TSG-C NTAH, Osaka, Japan, May 2008.

Appendix – GPS Almanac Data

Definition of A SEM Almanac

- **GPS Week Number:** The almanac reference week (VINA) for all almanacs in this *.AL3 file per [ICD-GPS-200](#)
- **GPS Time of Applicability:** The almanac reference time (TOA) for all almanacs in this *.AL3 file per [ICD-GPS-200](#)
- **PRN Number:** The satellite PRN number per [ICD-GPS-200](#). This is a required data item as it is the GPS user's primary means of identifying GPS satellites. It is equivalent to the space vehicle identification (SVID) number of the satellite.
- **SVN Number:** The satellite "SVN" reference number. This is not a required data item and is normally included only for cross-reference with the operational control system (OCS).
- **Average URA Number:** The satellite "average" URA number, with URA number as defined in [ICD-GPS-200](#). This is not an item in the raw almanac file but is based on the average URA value transmitted by this satellite in its subframe 1 data sets.
- **Eccentricity:** The satellite almanac orbital "eccentricity" (e) as defined in [ICD-GPS-200](#).
- **Inclination Offset:** The satellite almanac orbital "inclination angle offset" (8i) as defined in [ICD-GPS-200](#). This is an item in the raw almanac file and does not include the 0.30 semicircle reference value. This should not be confused with the "Io" term in the satellite ephemeris files.
- **Rate of Right Ascension:** The satellite almanac orbital "rate of right ascension" (OMFGADOT) as defined in [ICD-GPS-200](#).
- **Square Root of Semi-Major Axis:** The satellite almanac orbital "square root of the semi-major axis" (A1/2 as defined in [ICD-GPS-200](#).
- **Longitude of Orbital Plane:** The satellite almanac orbital "geographic longitude of the orbital plane at the weekly epoch" (OMEEGAO) as defined in [ICD-GPS-200](#).
- **Argument of Perigee:** The satellite almanac orbital "argument of perigee" ("small omega") as defined in [ICD-GPS-200](#).
- **Mean Anomaly:** The satellite @ac orbital "mean anomaly" (MO) as defined in [ICD-GPS-200](#).
- **Zeroth Order Clock Correction:** The satellite almanac zeroth order clock correction term (afo) as defined in [ICD-GPS-200](#).
- **First Order Clock Correction:** The satellite almanac first order clock correction term (afl) as defined in [ICD-GPS-200](#).
- **Satellite Health:** The satellite subframe 4 and 5, page 25 six-bit health code as defined in [ICD-GPS-200](#) expressed in integer form.
- **Satellite Configuration:** The satellite subframe 4, page 25 four-bit configuration code as defined in [ICD-GPS-200](#) expressed in integer form.

<http://www.navcen.uscg.gov/GPS/almanacs.htm>

SEM Almanac Data of all 32 Satellites for the Week of 09/05/2008

• 2 61 0 8.74471664428711E-03 4.00543212890625E-05 -2.53203324973583E-09
5.15371582031250E+03 -6.52886986732483E-01 8.39504957199097E-01 -
2.04112529754639E-02 1.88827514648438E-04 -3.63797880709171E-12 0 9 3 33 0
1.11255645751953E-02 -5.11550903320312E-03 -2.58660293184221E-09
5.15363378906250E+03 9.82764959335327E-01 2.69010663032532E-01 -
1.26006960868835E-01 2.80380249023438E-04 3.63797880709171E-12 0 9 4 34 0
8.27074050903320E-03 -1.92642211914062E-04 -2.53567122854292E-09
5.15352392578125E+03 -6.46926403045654E-01 1.25461101531982E-01
8.72251152992249E-01 -1.64985656738281E-04 -1.09139364212751E-11 0 9 5 35
2 9.27305221557617E-03 3.03268432617188E-04 -2.53567122854292E-09
5.15364257812500E+03 6.54263496398926E-01 4.04299974441528E-01
7.43140816688538E-01 9.05990600585938E-05 -2.18278728425503E-10 63 9 6 36
0 5.75113296508789E-03 -2.71415710449219E-03 -2.56477505899966E-09
5.15365576171875E+03 -9.96409058570862E-01 -5.03825664520264E-01
7.01984047889709E-01 1.66893005371094E-04 0.00000000000000E+00 0 9 7 48 0
2.18057632446289E-03 6.72149658203125E-03 -2.51384335570037E-09
5.15364990234375E+03 3.50370764732361E-01 8.62732648849487E-01 -
5.41878104209900E-01 1.52587890625000E-05 3.63797880709171E-12 0 10 8 38
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9.07628059387207E-01 1.33514404296875E-05 3.63797880709171E-12 0 9 10 40
1 8.00514221191406E-03 6.21414184570312E-03 -2.51020537689328E-09
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2.72096872329712E-01 -4.76837158203125E-06 0.00000000000000E+00 0 9 11 46
0 8.44144821166992E-03 -1.65119171142578E-02 -2.68846633844078E-09
5.15357568359375E+03 -7.12397813796997E-01 1.93965554237366E-01 -
6.48602962493896E-01 2.00271606445312E-05 0.00000000000000E+00 0 9 12 58
0 3.15809249877930E-03 7.05528259277344E-03 -2.47018761001527E-09
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43 0 3.72505187988281E-03 1.69544219970703E-02 -2.44108377955854E-09
5.15354101562500E+03 3.29654216766357E-02 4.92298841476440E-01
1.58925175666809E-01 2.69889831542969E-04 0.00000000000000E+00 0 9 14 41
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8.97552967071533E-02 -2.22206115722656E-04 3.63797880709171E-12 0 9 15 55
0 8.47816467285156E-04 4.84657287597656E-02 -2.56477505899966E-09
5.15364794921875E+03 1.31870508193970E-03 -3.80673170089722E-01
3.67426156997681E-01 -1.73568725585938E-04 -7.27595761418343E-12 0 10 16
56 0 4.72450256347656E-03 7.57598876953125E-03 -2.46291165240109E-09
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6.63194179534912E-01 1.07765197753906E-04 -3.63797880709171E-12 0 9 17 53
0 3.80325317382812E-03 5.58471679687500E-03 -2.47382558882236E-09
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• 18 54 0 9.84668731689453E-03 1.14822387695312E-03 -2.55749910138547E-09
5.15366455078125E+03 -3.05157423019409E-01 -7.85651087760925E-01
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1.24397873878479E-01 3.52859497070312E-05 0.00000000000000E+00 0 9 20 51 0
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5.15364892578125E+03 3.20120573043823E-01 -3.978123664859596E-01
8.30402493476868E-01 -2.01225280761719E-04 5.09317032992840E-11 63 9 26 26 0
1.91502571105957E-02 1.62906646728516E-02 -2.45199771597981E-09
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2.54565715789795E-01 3.22341918945312E-04 7.27595761418343E-12 0 9 27 27 0
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5.15368798828125E+03 3.31313014030457E-01 -5.37585854530334E-01
8.21136236190796E-01 2.15530395507812E-04 3.63797880709171E-12 0 9 28 44 1
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5.15358544921875E+03 6.92729949951172E-01 -6.66249394416809E-01
4.31116223335266E-01 -2.19345092773438E-05 0.00000000000000E+00 0 9 29 57 0
3.51715087890625E-03 5.63049316406250E-03 -2.47018761001527E-09
5.15354785156250E+03 -9.75986361503601E-01 -4.37855601310730E-01 -
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1.10654830932617E-02 2.23350524902344E-03 -2.51384335570037E-09
5.15363867187500E+03 6.70903921127319E-01 4.44796085357666E-01
5.72311401367188E-01 9.53674316406250E-05 3.63797880709171E-12 0 9 31 52 0
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1.39498710632324E-02 7.99369812011719E-03 -2.48837750405073E-09
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3.26437711715698E-01 3.15666198730469E-04 0.00000000000000E+00 0 9

In reality, the data of 4 GPS satellites may be enough.