INDOOR POSITIONING IN THE LOCATED BASED SERVICES

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Commission Ⅳ, WG-IV-6

KEY WORDS: LBS, GPS, HSGPS, Positioning

ABSTRACT:

In this paper the Topography Section of the University of Cagliari (Italy) presents the results of the research carried out on the Location Based Services. These are services which use the knowledge of a mobile device's position (e. g. a mobile phone or PDA) in order to send to the user information and news.The research had the purpose of investigating some critical issues linked to the Location Based Services, particularly related to the location component. In fact to determine the mobile device's position should is very difficult cause to the environment where the mobile device moves. In these cases the positioning is improved by using a high sensitivity receiver such as a HSGPS. Particularly, we examined the behaviour of such receivers in conditions of weak signal or critical satellite coverage, such as urban canyons or indoor.The achieved results proved that the type of receivers tested offer high values of sensitivity, but to the detriment of accuracy and consistency.

1. INTRODUCTION

The term "Location Based Services" (LBS) denotes those value-added services which use the knowledge of an user's geographic location to dynamically provide to him the answers to specific requests, such as tourist-receptional information or the route to a certain destination. All these services are usually based upon a mobile communications network and one or more location technologies (GPS or the mobile network itself), combined with geographic information systems (GIS) managing the collected information and distributing it to the final user.

Among the more widespread LBS systems are the automotive navigation systems, which can calculate routes for the mobile users, integrating the optimal routing calculation with real-time traffic information in order to recalculate the route in case of heavy traffic. Other LBS systems have informative or tourist purposes (e. g. yellow pages or multimedia travel guides) and answer the question "Where is the service or item nearest to my location?", or provide news about a site of interest. Particularly significant are the emergency services, like the E911 in the U. S. or 118 in Europe, which must follow standards about the location technologies to be used and the required precision. But the list could go on with tracking and management services, or community services such as "people finding" (answering requests like "find my friend" or "where is my dog now").

The structure of an LBS is composed by 5 elements (Figure 1): a mobile device (e. g. a cell phone or PDA), a mobile communications network, a location component (e. g. a GPS receiver), a service provider, and lastly a data provider.

Mobile devices are categorized as single-purpose or multi purpose devices. Single-purpose devices are built for a specific function and cannot be used for different purposes; automotive navigation systems fall into this category. Multi-purpose devices, on the other hand, can be used for other applications than LBS, such as cell phones, notebook PCs, PDAs etc.

The communications network has the task of transmitting the user's requests from the mobile device to the service provider, and carrying the responses back to the user. The network can be a Wireless Wide Area Network (WWAN) such as the GSM and UMTS networks, a Wireless Local Area Network (WLAN) such as IEEE 802.11, or a Wireless Personal Area Network (WPAN) such as Bluetooth.

The location component has the purpose of determining the location of the mobile device. This can be obtained through the mobile communications network (cell triangulation), or with a GPS receiver (Figure 2).

The service provider is the component offering the Location Based Services to the user. It is responsible for the entire data processing operation, and can be either owner of the data or make use of another provider of data.

The data types involved in an LBS application are geographic as maps or georeferenced satellite images, textual/numeric as html pages, or audio video streaming files.

The minimal characteristics for an LBS service are:

- High performance: the response time to the user's requests should be short
- Scalable architecture: ability to manage up to thousands of users and terabytes of data without changing the system architecture
- Reliability: ability to successfully transmit 99.9% of data
- Up to date: support for real-time and dynamic information
- Availability: the LBS service should be available from any mobile device
- Open: the system should support the most common standards and protocols (HTTP, WAP – Wireless Application Protocol, WML – Wireless Markup Language, XML – Extensible Markup Language, MML – Multimedia Markup Language)
- Secure: the system should ensure a secure and protected data management

- Interoperability: the service should be able to integrate with other applications such as e-Business, VoIP, etc.

Regarding compliance and interoperability, the International Standards Organization (ISO) and the Open Geospatial Consortium (OGC) issued several standards related and/or dedicated to LBS. Among them, ISO 19119 describes a generic service model, and ISO 19101 offer a categorization of geographic services. The OGC, on its own, released the OpenLS (Open Location Services) Specification (2005), where the basic services, the access modes and the data types forming an open "GeoMobility Server" structure are defined. The server works as an application server, answering to the service requests; such requests can come to the GeoMobility Server from mobile users, Intenet users or even other application servers (see Figure 3).

The basic services defined in the OpenLS 1.1 specification are divided in five types. These are the core services that can be implemented by the providers and are categorized as follows:

- Directory Services (locational yellow pages): this service provides the user with an online directory where a specific (or the nearest) place, product or service may be found.
- Gateway Service: this is the interface between the GeoMobility Server and the Location Server owned by the mobile network provider, through which the OpenLS services can get the location data of the mobile devices. It is used to request the current position of a mobile device in various modes (e. g. single or multiple terminals, immediate or periodic location).
- Location Utility Service (Geocode / Reverse Geocode): this service performs a "geocoding" operation, that is, given an address, place name, or zip code, it produces a geographic position. It can also perform the reverse operation, producing a complete address (or just a place name or zip code) from a geographic position.
- Presentation Service: this service converts the geographic information into a graphical representation that can be displayed on a mobile device. An OpenLS application can call this service in order to get a map of an area, with or without overlaying the geometries of streets, points and areas of interests, locations, positions, and/or addresses.
- Route Service: this service calculates a route for the user. The client must specify the starting point (usually the position acquired through the Gateway Service, but it can also be a user-supplied position, such as the user's home when planning a travel) and the destination (any location, even a place known only as a phone number or address, or found with a research in a Directory Service. The user can optionally specify intermediate waypoints, the preferred route type (faster, shorter, less traffic, more panoramic, etc.) The returned information can be in text form with a description of turns and distances) or geometric (displayable on a map).

The Open Mobile Alliance (OMA) issued the Secure User Plane Location (SUPL) standard for A-GPS receivers. The standard is based on the User Plane and uses the packet switching network (TCP/IP).

The main purpose of the SUPL specification is to make the A-GPS capabilities available without having to modify the existing communication networks and terminals. In addition, the specifications were developed such as to use existing standards when possible, and to allow their use with other positioning techniques (Enhanced Cell-ID, E-OTD/OTDOA, AFLT et.).

The standard is composed by the following specifications:

- SUPL Architecture (OMA-AD-SUPL-V1_0-20070122-C). This is the main document, describing the general system architecture. It introduces the different components and depicts the most common use cases through UML activity diagrams.
- Enabler Release Definition for SUPL (OMA-ERELD-SUPL-V1_0-20070122-C). This document describes the minimum requisites of a SUPL system, both on the infrastructure (SLP) and terminal (SET) sides.
- SUPL Requirements (OMA-RD-SUPL-V1_0-20050616-C). This document describes several use cases for the SUPL infrastructure, and the respective quality requirements that the infrastructure must fulfil.
- OMA Management Object for SUPL (OMA-TS-SUPL_MO-V1_0-20070122-C). This document describes the OMA Management Object, a software module which manages the configuration of a SUPL infrastructure.
- UserPlane Location Protocol (OMA-TS-ULP-V1_0-20070122-C). This document describes the detail of the communication protocol between the SUPL infrastructure and the mobile terminal.

The SUPL platform is composed by a SUPL Location Centre (SLC) and one or more SUPL Positioning Centres (SPC). The SPC provides the A-GPS data and/or calculates the position of the mobile terminal; the SLC coordinates the SPCs and manages the communication with the mobile terminals (SETs), and also the SUPL service in general. SLC and SPC can be integrated in a single system.

The mobile terminal (SET, SUPL Enabled Terminal) supports the procedures defined in the SUPL standard for communicating with the SLC through the TCP/IP network. The position calculation can be performed directly by the SET, or it can be requested to a SLP. The SET can also store and run LBS applications.

In this work we present our recent studies on Location Based Services. Starting from generic LBS applications such as tourist assistance, we planned to explore some critical issues related to:

- the LBS architecture itself, which at present does not allow the portability of applications between mobile phone and PCs, or between mobile networks and fixed networks, or even between two different terminals (e. g. a car navigation mobile to mobile phone);
- the location component, particularly in areas where the GPS signal is weak or corrupted;
- the standards, which very few applications actually strictly follow it

Figure 1: LBS Components

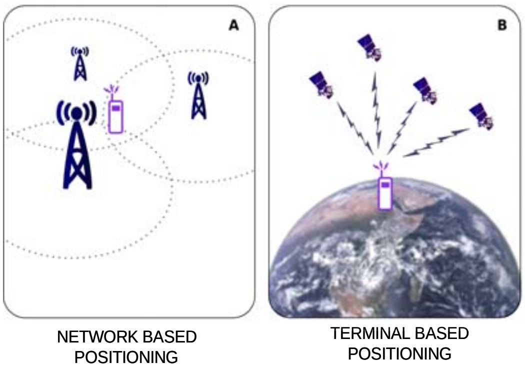

Figure 2:Types of mobile positioning

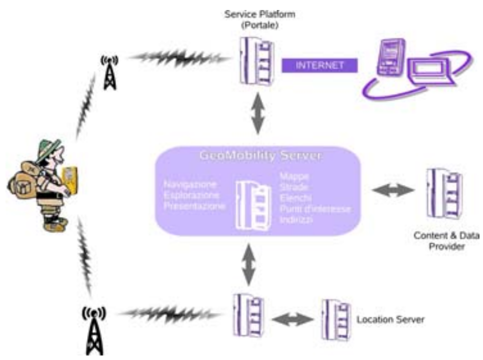

Figure 3: GeoMobility Server

2. POSITIONING COMPONENT

In the present work, we looked at the location component, focusing on the positioning accuracy, on the location techniques, and on the terminal types.

Regarding accuracy, current scientific literature show that the error position in the LBS change between some centimetres and several tens of meters. The highest accuracy is required for services such as Route Guidance for the Blind or In-Building Survey; an intermediate, metric or sub-metric accuracy is sufficient for foot or car navigation applications; lastly, local information and advertising services require accuracies of roughly tens of meters.
This range of accuracies is covered by different positioning techniques. The most precise positioning technique requires double frequency GPS receivers in RTK (Real Time Kinematik) mode, while sub-metric and metric accuracies can be achieved using L1 receivers in DGPS (Differential GPS) or stand-alone modes respectively. Other techniques like l'Enhanced Observed Time Difference (E-OTD) allow accuracies of the order of hundreds of meters.

Figure 4 shows a graphic of the accuracies required by the most common LBS applications (from GPS World April 2008).

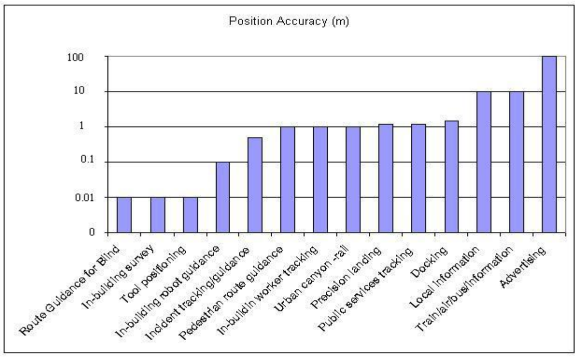

Figure 4: Positioning accuracy requirement by LBS

Several positioning techniques are used in LBS; these differ from each other in positioning accuracy, Time To First Fix (TTFF), service coverage, or costs, and are so classified:

- Network-based positioning; if the position is calculated by the GSM/GPRS/UMTS network infrastructure
- Terminal-based positioning (also known as Handset-based) if the position is calculated by the terminal using information from external sources (e g, the GPS, GLONASS satellite systems)
- Hybrid: a combination of the other two, including (among others) the A-GPS (Assisted GPS) receivers.

The choice of a positioning depends essentially on two factors: required accuracy, and expected operating conditions, such as outdoors (sea, open fields) or indoor (buildings, heavily built areas, forests etc.).

Regarding the types of GPS receivers, numerous international studies discuss the problem of indoor GPS. These studies are mostly carried out by the manufacturers of the chipsets used in terminals such as cell phones, cameras etc. Such studies have brought an improvement of the receivers' performance in two ways: better performance of the stand-alone receivers with the HSGPS (for High Sensitivity) and another that used information from service providers, e.g. the A-GPS (Assisted GPS).

An HSGPS is a very sensitive GPS receiver operating in stand-alone mode, it belongs to the "terminal-based positioning" techniques. The receiver implements special algorithms in order to correctly decode the incoming signal, even if it is heavily degraded by the environmental conditions.

A-GPS receivers, "hybrid" technique, have the ability to fix the position faster than stand-alone receivers in conditions of low satellite visibility, thanks to the data received from a different infrastructure than the satellite constellation. These data enable the receiver to avoid the so-called "cold start", that is the time that a conventional GPS receiver needs to fix the position at power-up, without having any information on the satellite network. This time is generally about 2-5 minutes. By integrating the satellite system with a service providing auxiliary data one can improve both the TTFF and the real-time positioning accuracy, which varies between 4 m outdoors and 50 m in dense urban areas.

According to a classification by Syrjarinne (2006), the transmitted assistance data can be divided in two categories, based on whether they are specific to the GPS positioning system or not.

In the first category we have:

- Differential code corrections
- Real-time integrity information
- Navigation data frame or subframe, in order to help the receiver decoding the signal
- Real or virtual reference station observations for high-accuracy positioning
- Almanac models
- Ephemerids and satellite clock models.

Further data originating from other systems can include:

- Time reference coordinated by the wireless network
- Initial reference position of the receiver
- Ionospheric and tropospheric models, in order to correct the respective delays
- Earth orientation parameters.

In order to study the critical issues of the receivers used in LBS systems, we performed various tests with different types of receivers, including also HSGPS. The tests have been carried out in critical conditions recreating the operating conditions of LBS terminals, such as cities (urban canyons), shopping centres (indoors), under trees, etc. These conditions bring forth either an absence or a degradation of the GPS signals, which reflects in the positioning determining the following situations:

- The receiver cannot fix the position;
- The receiver dos not fix the position with an accuracy adequate to the application;
- The waiting time for calculating the position is too long.

In particular, the following parameters have been examined:

- Time to First Fix (TTFF), that is the time needed to obtain the coordinates of the point where the receiver is;
- Accuracy, intended as the root mean square (RMS) error of the horizontal coordinates (the elevation usually is not considered), corresponding to a 96% position circle;
- Sensitivity, intended as a measure of the receiver's ability to track the satellites in conditions where the signal is heavily degraded. Usually, two aspects are evaluated: the ability to perform the pseudorange measurement, and the ability to decode the message in order to obtain the position independently;
- Consistency, intended as the chipset's ability to obtain a consistent positioning in every environmental condition, so as to be useful in any condition.

The receivers used in the tests are the following:

- HP iPAQ hw6915: incorporates a Global Locate Gl-20000 GPS Baseband Processor IC Chipset and Gl-In22 GPS Integrated Face End Inc with 12 channels. It is a HSGPS whose chipset contains 20000 correlators, which process in parallel the calculations required to obtain the satellites' C/A code. The terminal is also A-GPS enabled and can connect to the Broadcom servers to download the LTO (Long Term Orbits), calculated from the observations of the WWRS worldwide network of permanent stations built and managed by the same company. LTOs have a 48 hours validity, and are calculated from the satellite ephemerids through proprietary algorithms. The software controlling the AGPS is named "Quick GPS Connection"; it downloads to the terminal several files, among them "lto.dat" containing the orbit data. This file has been used or removed in different tests, in order to evaluate the effect of AGPS on the terminal.
- GeoXT, with 12-channels Trimble L1 GPS receiver.
- Juno, with L1 single-frequency Trimble receiver.

3. TEST

The tests carried out concerned the accuracy, sensitivity and consistency of the examined receivers. Many tests have been performed in conditions of degraded and/or weakened signal. Among these, a test performed during the survey of a mountain trail, characterized by a sequence of open areas and woods where the satellite visibility was alternately free and blocked, was deemed particularly significant. In this scenario, the satellites had to be tracked in conditions of weak signal (under the foliage) alternated to short stretches where the receiver had to quickly acquire the visible satellites and fix the position. In this experiment the Trimble Juno, Trimble GeoXT and HP iPAQ hw6915 were used. The receiver in the iPaq hw6915 is a A-GPS, but we used it without A-GPS.

In this test we surveyed a mountain trail about 9 km in length, in the "Sette Fratelli" mountains (municipality of Sinnai, about 30 km from Cagliari). The path is characterized in some traits by low bushes, where the GPS receiver has full visibility, and in others by tall trees with thick foliage, attenuating or blocking completely the GPS signal.

The trail was surveyed with a sampling rate of 1 Hz.

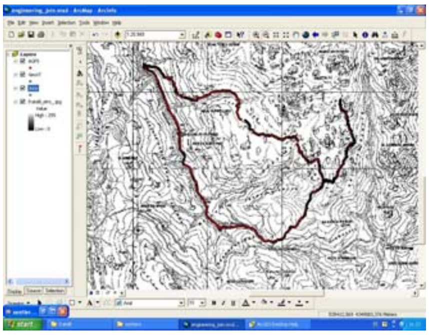

Figure 5: Mountain trail

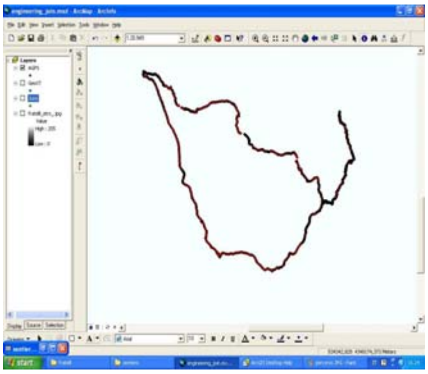

Figure 6: Path with Ipaq hw6915

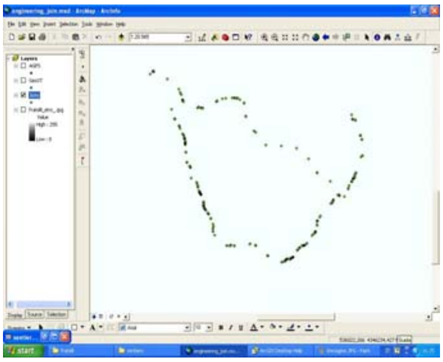

Figure 7: Path with Juno Trimble

In order to assess the geometric accuracy of the positions calculated by the three receivers, it was necessary to use the digital map of the area at the scale 1:10000. The positioning accuracy, in fact, can be assessed only by comparison with a survey of the same path with greater accuracy. The absolute positioning provided by a GPS receiver, in the best visibility conditions, has an RMS error of about 5 m in the horizontal directions and 25 m in vertical. The 1:10000 digital map has a 3 m accuracy in all directions, sufficient for a first comparison. Taking the path extracted from the digital map as accurate, for each sampled position its distance from the path line was calculated, and used as the receiver error. The absolute distances between each surveyed point and the path were determined Table 1 reports the accuracy calculated from these results.

Receiver	RMS (m)
JUNO Trimble	11.02
GeoXT Trimble	6.61
Ipaq hw6915	10.32

Table 1: Receiver accuracy

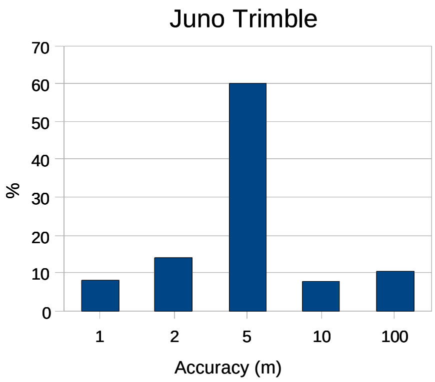

Figure 8: percentage of points for every precision interval

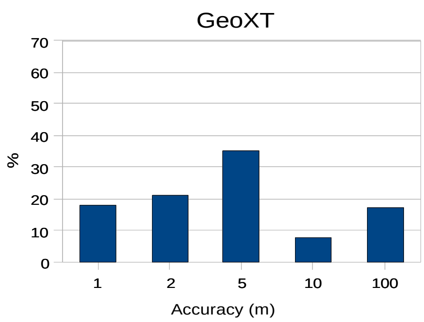

Figure 9: percentage of points for every precision interval

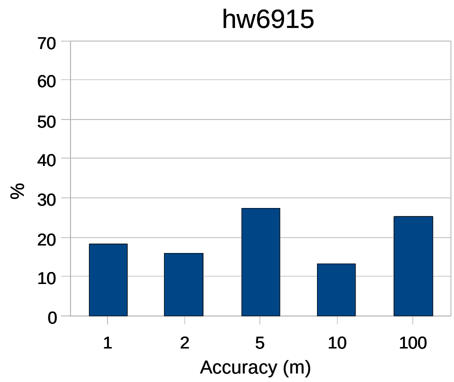

Figure 10: percentage of points for every precision interval

Figures 8, 9 and 10 show the frequency histograms, where the ordinates correspond to the percent of acquired GPS position within the following accuracy ranges:

- Under 1 m;
- Between 1 and 2 m;
- Between 2 and 5 m;
- Between 5 and 10 m;
- Over 10 m (and up to a maximum of 100 m).

As one can see, the receiver with the best accuracy is the Juno, with 85% positions within a 5 m accuracy; the GeoXT is very close with 75% of positions, while the iPAQ has only a 61%. However, these data must be compared to the receiver's sensitivity, that is the receiver's ability to track the satellites in environment where the signal is highly degraded, thus being able to perform the pseudorange measurement and obtain the position independently.

Considering the receivers' acquisition epochs, that is the time the receivers have been switched on, and the corresponding GPS position we could extract the data reported in Table 2, showing the expected position values (one per second) and those actually acquired by the receivers.

Receiver	expected positions	acquired positions	%
JUNO	18310	926	5
GeoXT	10303	3160	30.7
iPAQ hw6915	20714	12526	60.5

Table 2: Receiver sensitivity

By comparing the accuracy and sensitivity data we can see that in operating conditions of heavy cover and highly degraded signal the iPAQ hw6915 (HSGPS) had a better performance than the two Trimble GPS receivers, acquiring a number of positions double than theirs. We must assess the consistency of the positions acquired by the HSGPS receiver by comparing it with that of the others, which by filtering the "cleaned" signals determine more correctly the pseudoranges. In order to study this aspect we analyzed the percentages of positions acquired with an accuracy better than 10 m (maximum allowable error for stand-alone positioning in these conditions). Table 3 reports the results of this comparison.

Receiver	% of distances < 10m
JUNO	90
GeoXT	96.4
iPAQ hw6915	74.5

Table 3: Consistency receiver

By comparing the data shown in the tables 1, 2 and 3 we can conclude that, if on one side the number of positions acquired by the HSGPS receiver is much higher than that obtained from the common GPS receivers, on the other hand we cannot obtain a comparable accuracy and consistency.

4. FUTURE DEVELOPMENT AND CONCLUSIONS

The tests carried out on the LBS positioning component and especially on the high-sensitivity receivers brought forth some interesting results. Particularly, they emphasized that, in order to significantly improve the performance of the terminals indoor or in conditions of weak signal, it is necessary to provide the terminal with auxiliary data.

A more exhaustive understanding should get to analyse the pdop value, especially for the high value, wich is of no less importance in particular conditions.

The study will carry on with other tests make use a A-GPS receivers.

REFERENCES

Aiga, Y, K. Washizo, M. Nakamura, M. Shoji, Y. Ogasa and M. Hada (2003), *Standalone High Sensitivity GPS Receiver*, Proceedings of ION GPS-2003, September 9-12, Portland, OR, pp 1158 –1163B

Bryant, R, S. Dougan and E. Glennon (2001), *GPS Receiver Algorithms and Systems for Weak Signal Operation*, Proceedings of ION GPS-2001 , September 11-14, Salt Lake, UT, pp 1500-1510

Chansarkar, M and L. Garin (2000), *Acquisition of GPS Signals at Very Low Signal TO Noise Ratio,* Proceedings of ION NTM 2000, Anaheim CA January 26-28, pp. 731-737.

Chiang, T. C (2005), *Location Based Services and the Future of Wireless Communication,*

Dru, M-A., Saada, S., (2001), *Location-based mobile services: The essentials.* Alcatel Telecommunications Review, first quarter, 71-76.

Edwardes, A., Steiniger, S., Neun, M., (2006), *Foundations of Location Based Services*, CartouCHe1 - Lecture Notes on LBS, V. 1.0

Eerola, V (2000), *Rapid Parallel GPS Signal Acquisition*, Proceedings of ION GPS-2000 , September 19-22, Salt Lake, UT, pp 810 –816

Eisfeller, B. D. Gänsch, S. Müller, and A. Teuber (2004),, *Indoor Positioning using Wireless LAN Radio Signals*, Proceedings of ION GPS-2004 September 21-24, Long Beach, CA, pp. 1936-1947.

El-Natour, H. A, A. Escher, C. Macablau, M. Bouchrest (2005), *Impact of Multipath and Cross-Correlation on GPS acquisition in Indoor Environments,),* Proceedings of ION NTM 2005, San Diego, CA, January 24-26, pp. 1062 – 1070

J. B. Schleppe, G. Lachapelle, (2008) *Tracking performance of a HSGPS receiver under avalanche deposited snow* GPS Solution vol. 12 n. 1 pp 13-21

Karunanayake, M. D M.E Cannon, G. Lachapelle and G. Cox (2004), *Evaluation of Assisted GPS (AGPS) in Weak Signal Environments Using a Hardware Simulator*, Proceedings of ION GPS-2004 September 21-24, Long Beach, CA, pp. 2416-2426.

Lopez, X., (2004), *Location-Based Services*. In: Karimi, H. A., Hammad, A., ed. Telegeoinformatics. CRC Press, 171-188.

MacGougan, G. (2003), *High-Sensitivity GPS Performance Analysis in Degraded Signal Environments*, M.Sc. Thesis, University of Calgary, UCGE Report 20176

Nardi, B. A., (1996), *Context and consciousness: activitytheory and human-computer interaction*. Cambridge, MA: MIT Press.

Nivala, A.-M., Sarjakoski, L. T., (2003), *Need for context-aware topographic maps in mobile devices.* In: Proceedings of ScanGIS 2003, Espoo, FI. , 15-29.

O'Driscoll, C., M.G. Petovello and G. Lachapelle (2008), *Software Receiver Strategies for the Acquisition and Re-Acquisition of Weak GPS Signals.* Proceedings of ION NTM08 (San Diego, 28-30 Jan, Session B4). The Institute of Navigation, 12 pages.

Singh, S. (2006) *Comparison of Assisted GPS and High Sensitivity GPS in Weak Signal Conditions*. MSc Thesis, Department of Geomatics Engineering, The University of Calgary.

Syrjärinne J, Wirola L (2006) *Setting a new standard. Assisting NGSS receivers that use wireless networks*. Inside GNSS 1(7)

www.broadcom.com/products/GPS/locationed-based-services/AGPS-wwrn

www.opengeospatial.org

www.wocc.org/wocc2004/2004program_doc/930308P-W2.pdf