



AGNSS Standardization

The Path to Success in Location-Based Services

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After a faltering start in the early 2000s, growth in mass-market LBS applications appears ready to explode, driven by implementation of GNSS capabilities on mobile handsets. Customer expectations and technological advances are contributing to the growing demand, but standardization has long been needed to provide a common framework as a real technological and market enabler. Success appeared first in the assisted GPS standard, an effort that has now progressed within the Third Generation Partnership Project to address assisted GNSS techniques in which Europe's EGNOS and Galileo system already play and will continue to play a key part.

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Location technology is entering ever more deeply into our day-to-day lives. Growing market demand for location-based services (LBS) revolves the single premise: "Location everywhere, any time." The requirement for seamless, ubiquitous positioning includes, of course, urban and indoor environments.

Meeting this requirement will provide the cornerstone for a real "boom" in the location market. To realize the capability, location technology seems to evolve naturally towards the aggregation of several systems used in combination to provide accurate information to users.

Already today one can see the pre-eminent place of assisted GPS or AGPS, which is no more than a way of combin-

ing telecommunication signals with GPS signals in order to improve real-time positioning capabilities. Many mobile handsets equipped with AGPS are now available and standardization played a great role in this beginning success story.

With the arrival of Galileo and the near-term prospect for implementation of assisted GNSS (AGNSS) receivers, the market is about to pass through a new technological gap in the location solutions offered by mobile communication systems.

For the last several years, the advance of the Galileo program has stimulated very important efforts to allow this technological passage to take shape and, therefore, to enable Galileo to play a central role among the location solutions offered to the mass market. This market,

stimulated by technological innovation, can already be experienced through the recent adoption of the European Geostationary Navigation Overlay Service or EGNOS, which prefigures the great advance that Galileo will offer.

One of the core conditions for marketplace success rests in creation of a solid framework to enable development and interoperability among location technologies and applications. This framework is embodied by standardization that enables a straightforward usage of the full capabilities of Galileo within the AGNSS concept.

Within the last year, a great step has been achieved through the implementation of AGNSS standards in mobile telecommunications. Indeed, a stable version of AGNSS standards for the Global

System for Mobile communications (GSM) and Universal Mobile Telecommunications System (UMTS) standards arrived in late 2007 with the so-called Release 7 of the 3rd Generation Partnership Project (3GPP) specifications.

These standards provide for the full normalization of assisted Galileo and, even more significantly, of assisted GNSS. This achievement opens a new era in the performance and potential for mass market LBS applications.

This article chronicles the process and some of the key steps that led to publication of the 3GPP AGNSS standard. In order to give a useful context to that achievement, we will first discuss some of the market drivers, technical challenges of meeting location performance requirements, and the role of standardization in rationalizing and supporting market growth.

LBS: A Market in Need of a Catalyst

Location-based services are steadily gaining importance for telecommunication applications as our society is more and more influenced by the emerging, technology-driven mobility culture.

The first impetus was probably given by regulatory initiatives in the United States and Europe, but increasingly consumer demand and technological advances are behind the growth in LBS markets. Beginning in the middle 1990s, the U.S. Federal Communications Commission (FCC) began developing a requirement for enhanced 911 (E911) capability that would provide public safety organizations with the location of mobile callers in emergencies.

Under the FCC mandatory guideline eventually implemented, mobile communications operators who chose to provide handset-based solutions (typically GPS-based) for E911 needed to be able to locate distress calls with an accuracy of 50 meters for 67 percent of the calls and 150 meters for 95 percent of the calls. In Europe, the E112 and related eCall initiatives impose a best-effort approach for the location of the distress callers.

As location technology is implemented on portable devices, the LBS market is

expected to undergo explosive growth. LBS market projections drawn from a 2006 study by ABI Research and reproduced in **Figure 1** forecast that annual worldwide LBS revenue will reach up to \$5.5 billion in 2009.

The ABI forecast suggests that the main part of the 2009 revenue will occur in North America with \$3 billion and in Western Europe with \$1.5 billion. A huge potential is also underlined in Asia-

Pacific region where the predicted number of subscribers exceeds 60 million.

However, this promising situation needs two key conditions before LBS market success can be achieved:

- A *solid technical framework* that will favor and bring together the elements needed for an economically vigorous location ecosystem by clearly segmenting the entire value chain, and
- an appropriate and *efficient technical solution* to the stringent location demand of the mass market, particularly in terms of position/location availability in deep urban canyons and indoor environments.

Standardization: Framework for Market Success

As clearly seen in the Figure 1 graphs, an inflection in the LBS growth slope appeared between the end of 2005 and mid-2006, after operators and customers had substantially abandoned the LBS marketplace earlier in the decade.

The SK Telecom (South Korean telecom operator) story presented during the Mobile Location Services 2006 conference exemplifies the first success in the LBS market. In his presentation there, Kihak Shim with SKT's Research and

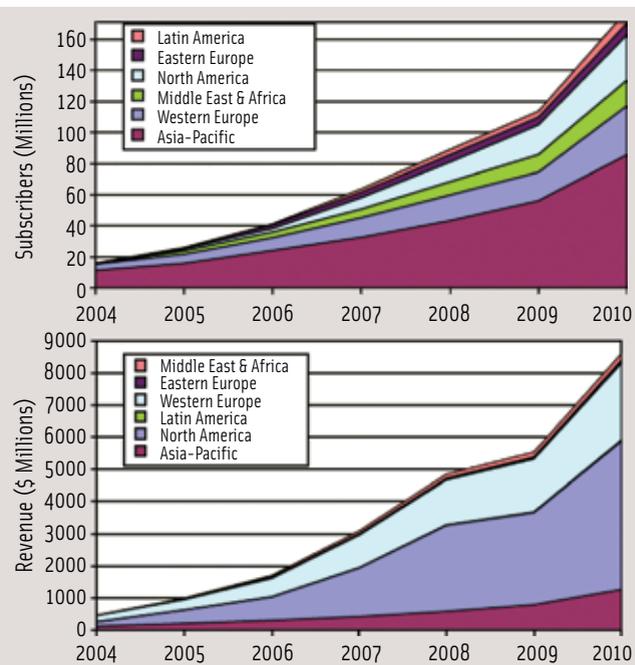


FIGURE 1 LBS market forecast (source ABI research 2006)

Business Development Team, reported that LBS already stood third in revenue among all the data services provided by SKT, behind music and gaming.

Certainly, part of the reasons for this inflection in LBS growth rates can be found in the naturally evolving demand of telecom subscribers as they become familiar and comfortable with LBS applications.

But the success is also largely underlain by the convergence of two other factors. On the one hand, a new technological capability — AGPS — appeared that responded to market expectations. On the other hand, a strong and stable standard emerged — namely Version 1 of the Open Mobile Alliance Secure User Plane Location specification (OMA SUPL V1) based on 3GPP's Radio Resource LCS Protocol (RRLP) and Radio Resource Control (RRC) specifications.

These developments insured the interoperability of the service offerings and cleaned up the interfaces in the whole value chain. As a result, GPS chipset providers and mobile device manufacturers could converge with network vendors to offer an appropriate technological answer to the marketplace through a clear and economically feasible framework: location standards.

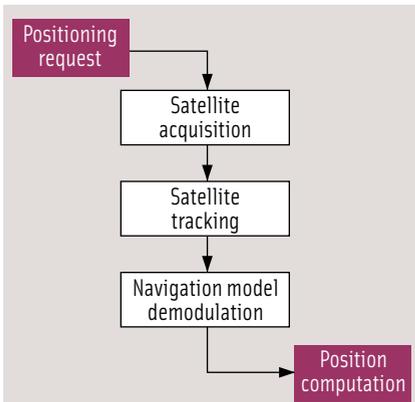


FIGURE 2 Standard SPS receiver processing

This historical turn demonstrated how the LBS standardization is about to play the same key role in LBS applications as GSM standards did in boosting the success of mobile telecommunications.

But the history is just beginning. Having turned this first important corner for LBS, we cannot overlook the important challenges that still must be met before the market forecast can turn into reality. These challenges are mostly technical ones that aim at answering ever more stringent performance demands for location technologies in urban environments and indoor location.

Here, Galileo surely has a key role to play in overcoming the technical gap that the emerging market faces. Moreover, to meet the demand for indoor location capability, hybridization techniques incorporating other positioning technologies will obviously need to be made available for equipping mass-market customers. This again underlines the importance of advancing the standardization framework.

AGPS: Only a First Step

As previously indicated, the take-off point in the LBS market is correlated with the first appearance of an assisted GPS technology sustained by a strong standardization commitment. It is particularly interesting to understand why such assistance techniques could answer to the market demand in a better way than autonomous GPS.

The objectives of network-aided techniques in which cellular phone infrastruc-

ture is combined with GPS signal processing are twofold: first, to improve the sensitivity of a GPS receiver and, second, to decrease the time to first fix (TTFF) while improving positioning accuracy.

Of course, achieving these two objectives brings an improvement of the location service availability and a decrease of the receiver complexity for a given level of sensitivity.

In order to provide LBS capability, a GPS receiver is implemented within a mobile phone —with the accompanying strong constraints on bulk and power consumption. To help understand how assistance can improve the functioning of a receiver (sensitivity, accuracy, power consumption), Figure 2 illustrates the classical receiver processing steps.

The Limits of Autonomy

The limitation of stand-alone or autonomous receiver sensitivity comes primarily from the first processing step, signal acquisition, and secondarily from demodulation of the navigation message.

The limitations of the acquisition process (see Figure 3) for an autonomous receiver are set forth in the paper by M. Monnerat *et alia* as cited in the Additional Resources section at the end

of this article. The paper shows how the complexity of the process depends upon the total frequency uncertainty Δf , the time uncertainty l_c , the coherent integration duration T_c , and the total accumulation duration T_a , as follows:

$$C_{\text{compl}} \# 16(f_s T_c)^2 l_c \Delta F * (T_c / T_a)$$

The discussion in the paper also demonstrates that, despite its efficiency, the coherent integration for an autonomous GPS L1C/A receiver is limited to 1 millisecond for two main reasons:

- the computation capacity of the chip-set versus the complexity linked with frequency uncertainty
- the bit-transition position unknown (even if 10 millisecond integration can be achieved at the expense of the overall complexity).

In that case, the sensitivity versus the total integration time is represented in Figure 4. For a total integration of one second, the acquisition threshold is limited to approximately 23 dBHz.

Tracking Limitation of Autonomous GPS. The ION paper describes how carrier phase tracking (absolutely necessary for bit demodulation) limits the tracking sensitivity to approximately 25 dBHz for a rather low dynamic user (typically moving at 100km/h), as reflected in Figure 5.

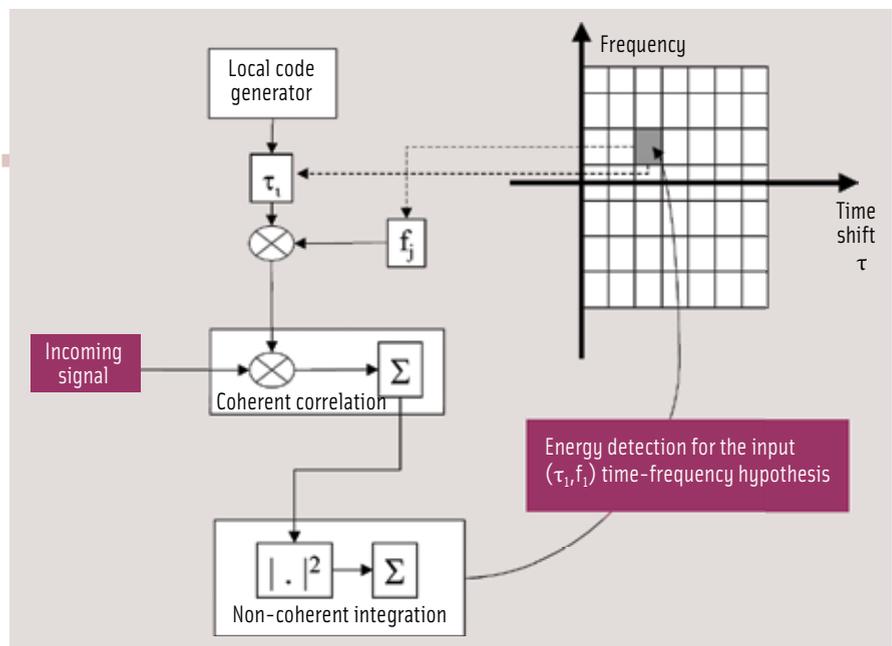


FIGURE 3 Signal acquisition

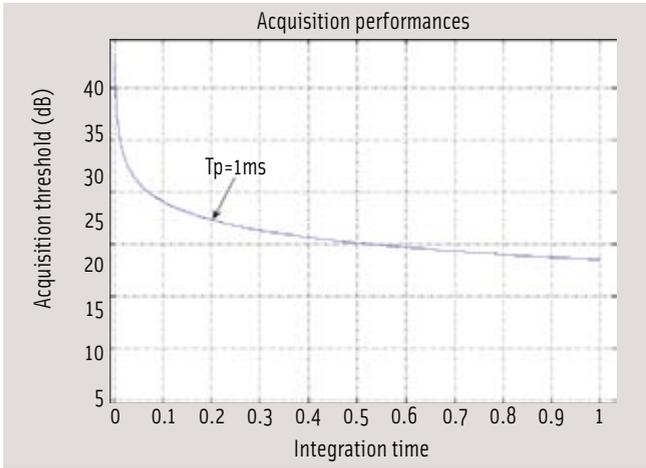


FIGURE 4 Acquisition threshold for coherent integration of 1ms, pfa = 10⁻³, Pd = 0.99

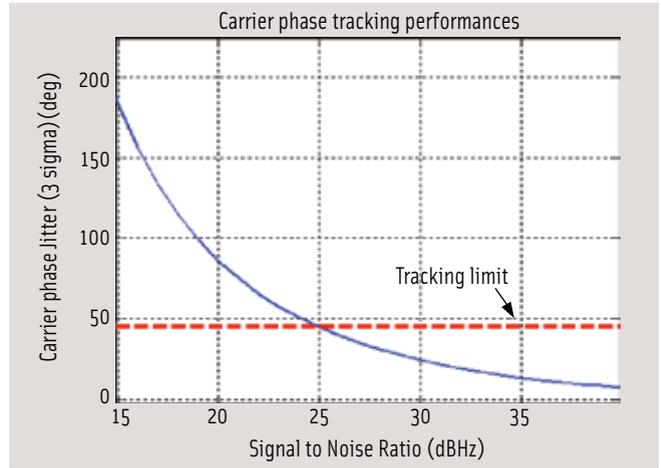


FIGURE 5 Carrier phase tracking limitation

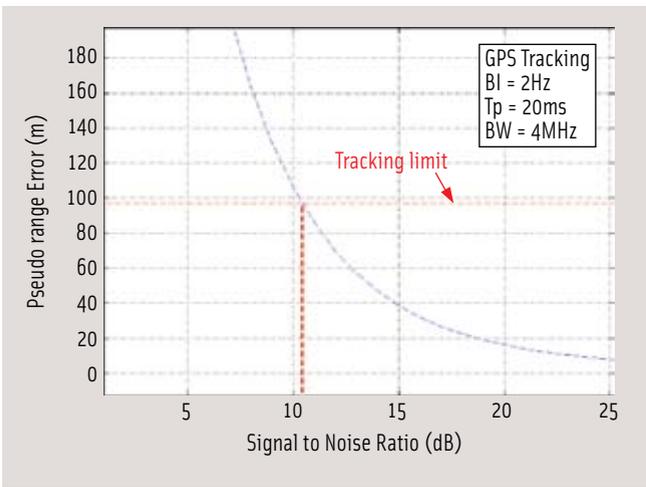


FIGURE 6 DLL tracking limitation; BI = 2 Hz, Tp = 20 ms

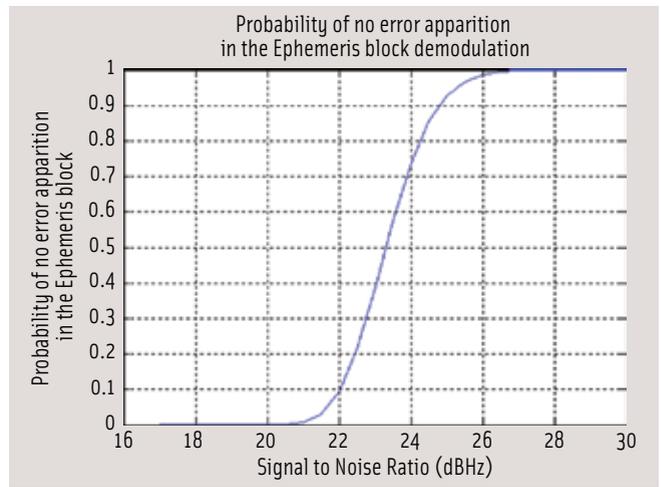


FIGURE 7 Probability of non-error on the ephemeris/clock block (white Gaussian noise channel)

In comparison, the delay lock loop (DLL) threshold is much lower — around 11 dBHz (see Figure 6). This low DLL threshold shows how it is all the more important to enable the receiver to achieve a position fix relying on this code-only threshold alone, which is exactly the goal of the network-assisted approach.

Data Demodulation Limitation of Autonomous GPS. As noted earlier, the carrier phase tracking loop allows demodulation of the BPSKmodulated GPS signal (to extract ephemeris, clock correction, hand-over word, and so forth). Consequently, a dual limitation appears:

1. First, in terms of sensitivity, to reach the point of better than 0.99 probability of making no error on the demodulation of the ephemeris/clock

block requires a minimum signal-to-noise ratio (SNR) of 27 dBHz (Figure 7).

2. Second, because the essential data (typically the first three frames) are repeated every 30 seconds, the minimum time to first fix is at least 30

seconds. Table 1 presents a summary of the limits of autonomous GPS receiver performance.

Assistance Techniques: an Overview

The basic principle of AGNSS consists

Acquisition	Acquisition Threshold		23 dBHz
	Complexity	Coherent integration length	1ms
		Frquency slots	14,000/500=28
		Time slots	2*Rc=2046
		2046*28 slots	
Tracking	Data demodulation`		28dBHz
	PLL Threshold		25dBHz
	DLL Threshold		11dBHz
TFFF	Minimum Time to demodulate forst 3 frames		30s

TABLE 1. Summary of the order of magnitude of autonomous GPS receiver limitations

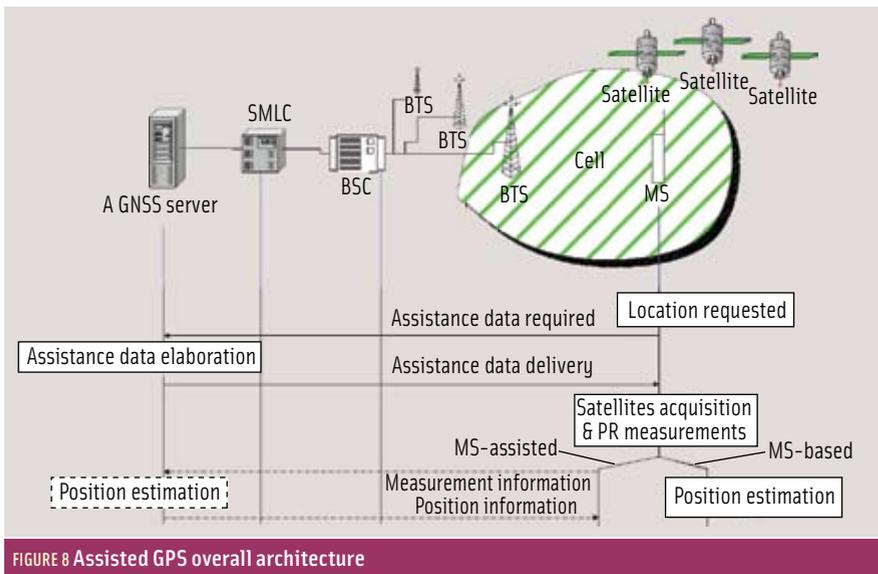


FIGURE 8 Assisted GPS overall architecture

of hybridizing mobile communication capabilities with a GNSS receiver (Figure 8). The mobile communication network is used to assist the working modes of the GNSS receivers through the dissemination of several types of assistance data. The assistance data that can be delivered to the GPS receiver are summarized in Table 2.

Let us return to the subject of how standardization has played a great role in the expansion of the technology. Today, two methods of conveying assistance data are standardized:

Control plane implementation. This method uses the signaling layers of the communication network to convey the assistance data to the mobile phone and to retrieve position information from the

handset. The main protocol definition can be found in the TS44.031 (RRLP) for GSM and the TS25.331 (RRC) for UMTS. The advantage of the control plane implementation is precisely that it uses the lower layers of the communication system, which are particularly adapted to emergency (E112, E911) services. This approach ensures delivery of service even if a mobile user's subscription has expired.

Secure user plane (SUPL) implementation. This method uses the high-level layers of the communication network, i.e., the application layers. The OMA standardization group (to which the activities of the former ETSI Location Interoperability Forum have been transferred) now deals with this subject. While 3GPP has been defining the core protocols and physical layers, OMA has been focusing their work on

- the protocols used by external applications to access the telecom networks' location servers, namely, the MLP protocol,
- the protocols using the IP architecture to connect the terminals and the location servers together in view of assistance session implementation. The data are exchanged through IP but are enclosed in 3GPP RRLP or RRC containers.

Benefits of Assisted GPS

As the first implementation of assisted GNSS, AGPS has demonstrated a variety

of benefits that improve location capability for mobile users. We will outline these here briefly. Further details are available in the previously cited paper by Monnerat *et alia*.

Acquisition. AGPS improves signal acquisition mainly as the result of the availability of a "pre-location" with a coarse accuracy bounded by the maximum cell size, for example, 35 kilometers; the reference time, and the ephemerides of visible satellites. With this information, the receiver is capable of quickly computing the satellite doppler and dramatically reducing the frequency uncertainty Δf .

Moreover, in the case of a synchronized cellular network, the reference network time can be consistent with GPS time, which reduces the time uncertainty. (See Figure 9.)

This reduced complexity can be used to augment coherent integration, effectively improving receiver sensitivity. Indeed the pre-location, coupled with the navigation model and the reference time, enables the receiver to get an approximate knowledge of the satellite-receiver pseudoranges and, therefore, the knowledge of the bit transition. The acquisition threshold is then automatically improved by 5 to 6 dB as shown in Figure 10.

If the pre-synchronization provided by the network is not sufficiently precise, the receiver can use the first acquired satellite signal to refine this synchronization information and then use a 20-millisecond coherent integration on the other satellite signals.

Tracking Threshold. Assistance techniques benefit tracking in two ways.

First, availability of the navigation model from the network eliminates the need for data demodulation. This removes the limit of 30 seconds corresponding to the update rate of the navigation model derived from the signal in space, thus mechanically reducing the TTFF. Eliminating the need for data demodulation also removes the SNR limitation associated with the demodulation threshold.

Second, network assistance allows use of code-only techniques so that the

Reference Location	Cell Size <35 km (typ. Urban: 1 km)
Reference Time	GPS Time Tag, BTS clock Stability: 10 ⁻⁹
Navigation Model	Ephemeris + Clock Correction (Frame 1-3 GPS message)
Ionosphere Corrections	Klobuchar model
Differential Corrections	DGPS
Real Time Integrity	Real Time Alerts
Almanacs	Constellation Almanacs
UTC Model	UTC Parameters
Acquisition Assistance	List of Visible Satellites, Code phase, Doppler

TABLE 2. Types of assistance data available via telecom networks

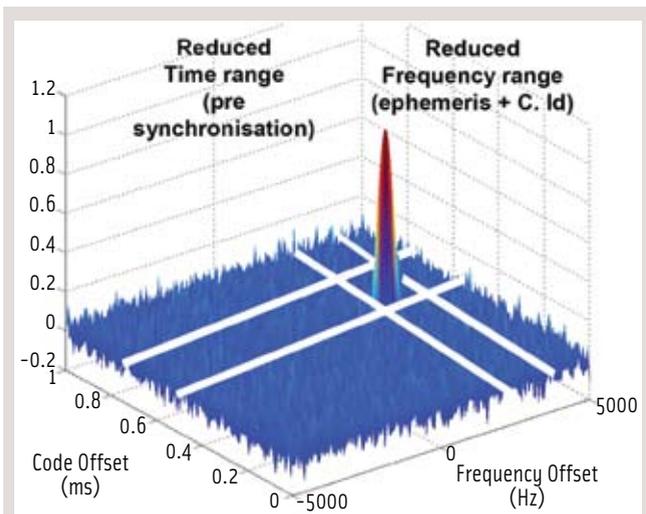


FIGURE 9 Reduction of acquisition complexity. By constraining the time and frequency unknowns, network assistance data reduces the size and number of the search "slots."

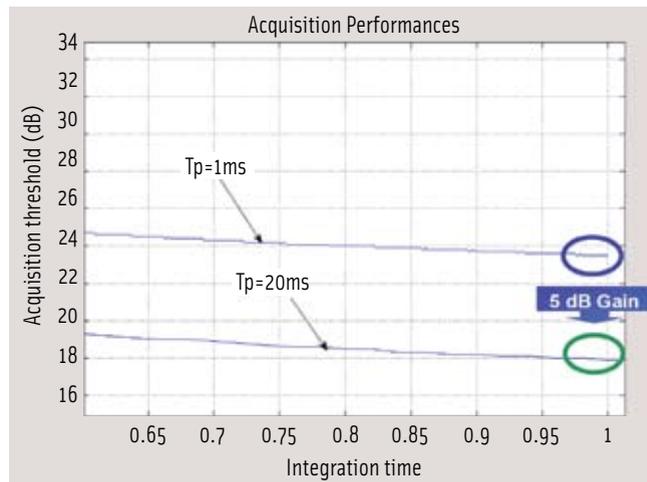


FIGURE 10 Increased sensitivity due to coherent integration of 20 milliseconds

tracking sensitivity then is based on the DLL threshold, as discussed earlier.

Accuracy. In addition to the tracking sensitivity improvements, assistance techniques can produce a great improvement in positioning accuracy.

First, the assistance data set can include local differential or satellite-based augmentation system (SBAS) corrections, such as those available from EGNOS or the U.S. Wide Area Augmentation System (WAAS). These increase the accuracy of pseudorange measurements.

Second, increased receiver sensitivity can play a dramatic role in improving positioning accuracy in difficult environments such as urban canyons (Figure 11). In those situations, the number of tracked satellites is much higher than an autonomous receiver can track in such environments. As a result, the satellites' geometrical dilution of precision (DOP) factor improves, which usually has a positive effect on the position accuracy of end users.

In summary, then, AGPS/AGNSS provides distinct benefits that can help grow LBS mass markets: better sensitivity, which responds to the requirements of typical LBS operating environments, improved time to first fix, which matches service expectations, and better accuracy, which is in line with the initial applications expectations.

To illustrate these benefits quantitatively, Figure 12 provides an estimation of TTFF improvement with AGPS (12a) in several use cases (12b), assuming operation of a GPS receiver with 16,000 physical correlators. The use cases include:

- autonomous GPS with C/N_0 of received signals at 25 dBHz
- A-GPS with C/N_0 of received signals at 25 dBHz
- A-GPS with C/N_0 of received signals at 18 dBHz and one satellite at 23 dBHz

This example clearly illustrates the benefits of the assistance techniques for time to first fix as well as sensitivity because TTFF is affected only slightly by the diminished SNR (18 dBHz).

Standalone GPS			AGPS w/o Wipe-off
Acquisition	Complexity	Acquisition Threshold	23 dBHz
		Coherent Integration length	1ms
		Frequency Slots	14,000/500=28
		Time Slots	2*Rc=2046
			2046*28 slots
Tracking	Data demodulation threshold	27 dBHz	-
	PLL Threshold	25 dBHz	-
	DLL Threshold	11 dBHz	11 dBHz

FIGURE 11 AGPS sensitivity improvement

Assisted Galileo: A Market Advantage

AGPS provided the first technological response to meet LBS market expectations. This response has spectacularly pushed the market during the past two years.

However, location market growth still must tackle technological challenges, mainly related to an ever more critical need for positioning capability in difficult environments. The arrival of Galileo will surely catalyze the location market, provided that the same avenue is followed as with AGPS, that is to say, a standards-based approach.

The potential benefit incorporating Galileo into the assisted GNSS concept was recognized early in a 2002 feasibility study by a 3GPP Technical Specification Group, "Study into Applicability of GALILEO in LCS [Location Services]."

Availability Benefit. The evolution of AGPS into AGNSS means using two or more constellations of GNSS satellites instead of one. Nominally, access to two complete GNSS constellations would about double the number of available satellites and ranging signals. This could have a dramatic effect on the availability of LBS services especially within locales that have high masking angles for receiver operation, as is the case in urban canyons.

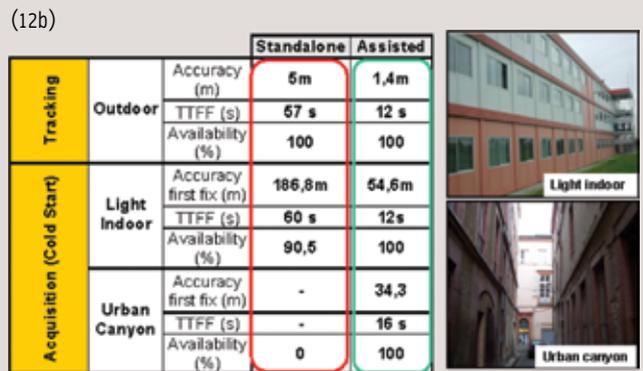
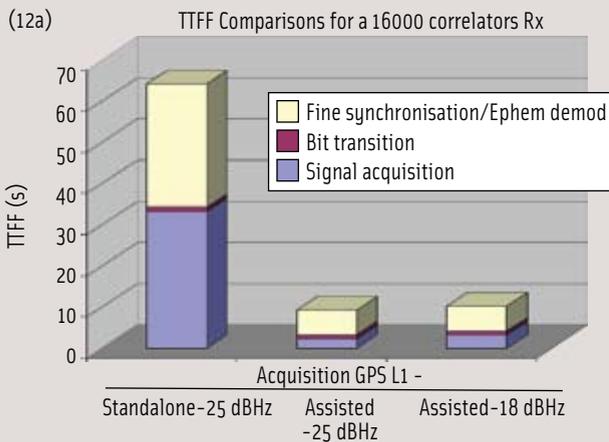


FIGURE 12 (a) Estimation of TTFF for a GPS receiver with and without assistance. (b) Time to first fix in various use cases

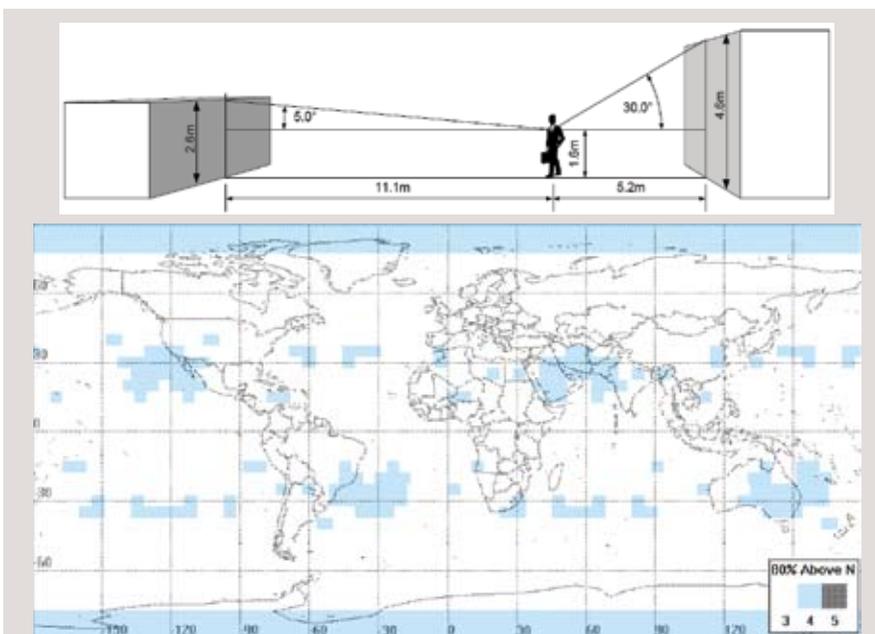


FIGURE 13 GPS constellation availability with a masking angle of 30°, number of satellites visible at least 80% of the time

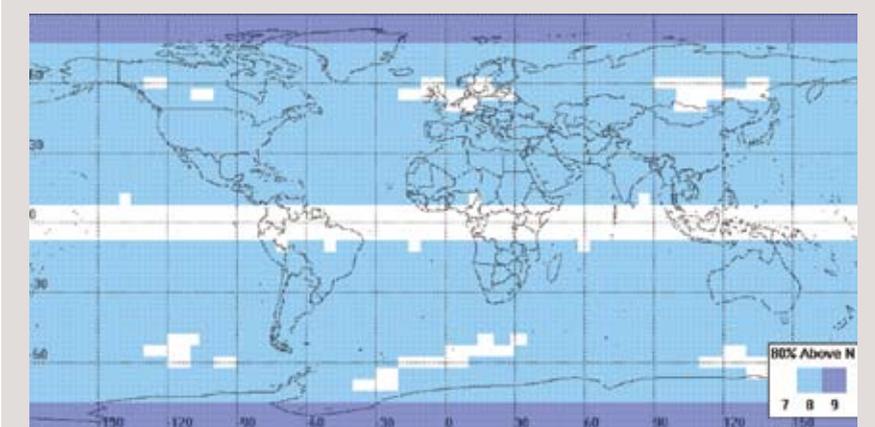


FIGURE 14 GPS+Galileo constellations availability with a masking angle of 30°, number of satellites visible at least 80% of the time

Figures 13 and 14 demonstrate the increased availability of satellites with two constellations compared to GPS alone. In this case, more than eight satellites are visible over nearly all the globe 80 percent of the time using GPS+Galileo.

The second lever acting on location availability under challenging conditions rests on the question of indoor penetration of the GNSS signals in space. The main advantage brought by Galileo rests on the signal in space design itself and more particularly on the dataless pilot channel.

As shown in the Monnerat *et alia* paper, coherent integration of up to one second can be anticipated with the Galileo L1 Open Service signal (BOC 1,1), leading to a sensitivity improvement of approximately 5 dB compared to the current GPS L1 C/A-code signal. (See Figure 15.) All the benefits pointed out for the Galileo signals will also be applicable for the modernized GPS signal. Indeed, under the terms of the 2004 EU/US cooperation agreement establishing a common Galileo-GPS signal waveform, the future GPS L1 civil signal will have the same design —and, therefore, properties — as the Galileo signal.

We must underline the fact that the Galileo pilot tone offers a *reserve* of performance improvement that can be activated only if used with time reference data, which can be disseminated through the telecom network.

Accuracy Benefit. Figure 16 compares the performance of the Galileo and GPS code-tracking loops versus the attenua-

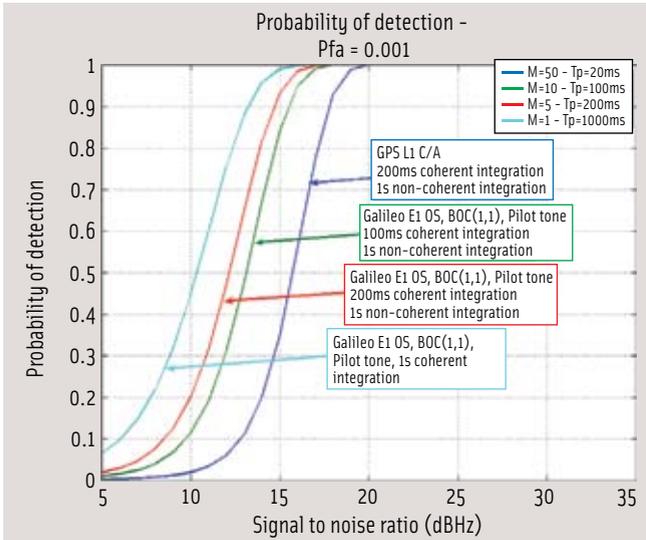


FIGURE 15 Comparison of GPS-Galileo sensitivity in signal acquisition simulation, assuming pre-synchronization of receiver with assistance data

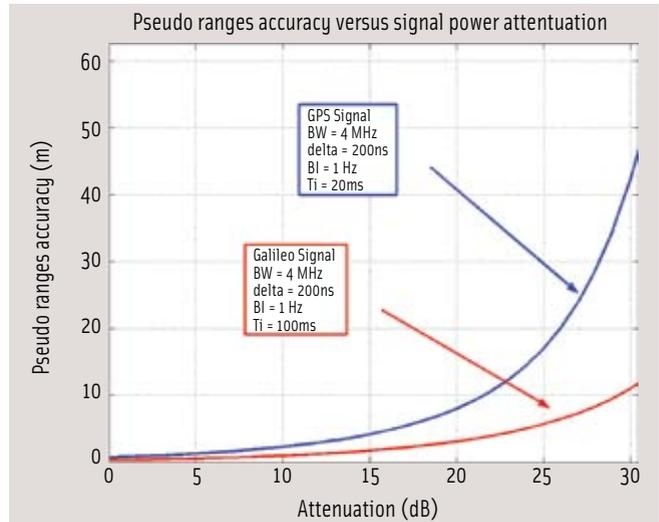


FIGURE 16 GPS and Galileo code-tracking accuracy versus signal power attenuation

tion of the signal, e.g., as occurs in indoor environments. The increase in performance primarily results from the advantages of the pilot tone and the BOC(1,1) waveform.

The second main factor of accuracy degradation in signal-challenged environments stems from the presence of reflected signals or *multipath*. Figure 17 compares the effects of multipath on Galileo and GPS signals. It shows the multipath envelope obtained with the Galileo L1 signal and the GPS C/A signal, taking into account a narrow correlator with the same spacing, consistent with a bandwidth of 4 MHz. The multipath signal strength is assumed to be 6 dB lower than the direct path.

AGNSS Standardization

As we mentioned at the outset of this article, following a period of hesitation, the years 2005 and 2006 marked a real turn in the LBS market. The reason for the first successes was a conjunction of two key points:

- the emergence of a new technology that met market expectations
- the introduction of stable standards that could provide a sound framework for the LBS ecosystem.

Indeed, the first marketplace successes of LBS applications exactly coincide with the publication of the SUPL V1 standard, which allows implementation of AGPS over IP. The standard set forth a clear technical architecture and, therefore, a clear market segmentation.

This economic inflection recalls the huge development of GSM telecommunication systems, mainly due to a strong standardization initiative. So, no doubt exists that standardization has played and will continue to play a central role of market enabler for advanced technologies.

Without this essential economical framework, real market growth cannot be possible for sophisticated technology-dependent applications such as LBS. This principle was understood

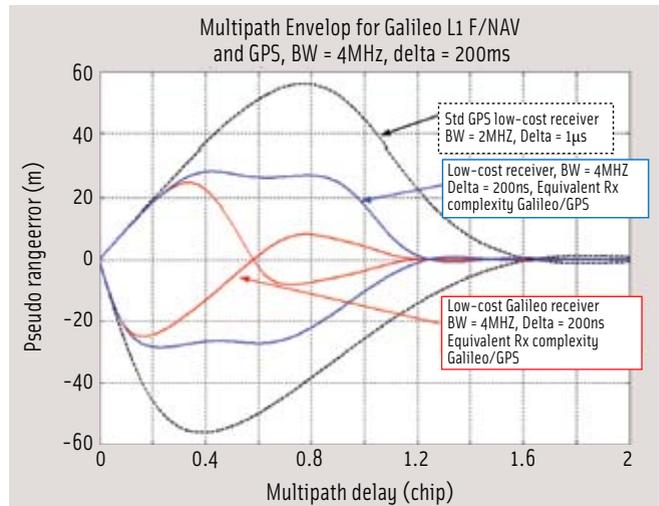


FIGURE 17 Multipath mitigation capability, GPS & Galileo signals

by the Galileo programmatic team, who from a very early time pushed to build mass-market AGNSS standards, targeting first the GSM and UMTS systems.

3GPP, OMA & AGNSS: A Long Story

GSM and UMTS standards are established by the 3GPP, created in December 1998 and based on a participatory discussion forum including telecommunication actors. The group's rules and the process for defining and ratifying 3GPP technical specifications are described at the group's website <www.3gpp.org>.

3GPP is organized into four working groups themselves subdivided in technical working groups, as shown in Figure 18.

The Technical Specification Group for Service and System Aspects (TSG SA) defines high-level requirements for GSM and UMTS. For instance, specification TS22.071 defines the requirements for location services. This specification was written and is maintained by TSG SA Working Group 1. Any

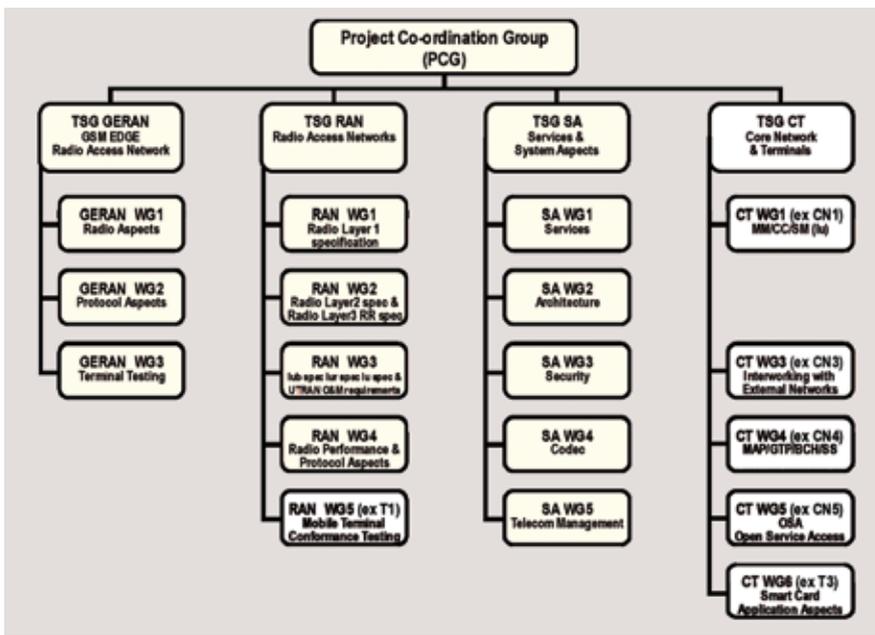


FIGURE 18 3GPP Organization overview

requirement to support a new location service must be first initiated under this specification.

Other technical working groups then define technical standards to meet the requirements defined by TSG SA. The core network and terminals group (TSG CT) is in charge of the technical specifications of the mobile network and of the mobile handset. The GSM EDGE Radio Access Network (GERAN) group is in charge of the radio access technical specifications for GSM/EDGE whereas the RAN is in charge of the radio access for UMTS.

The main protocols that transport the assistance data and that enable any hybridization among locations techniques are maintained by GERAN for RRLP (TS44.031) and RAN for RRC (TS 25.331).

In parallel with the 3GPP, since 2002 the OMA (Open Mobile alliance) has been in charge of developing mobile services and insuring interoperability across devices, countries, and operators. Briefly, the OMA standardizes high-level applications and services. It complements the 3GPP for the applications layer of GSM/UMTS, whereas the 3GPP focuses mainly on the internal low layers of GSM/UMTS specifications.

Building the AGNSS Specification. The first work to integrate Galileo into the

location methods for GSM/UMTS was performed between mid-2002 the end of 2003 by Alcatel-SA group of Alcatel Space (now Thales Alenia Space) under a 3GPP study item realized under the SA WG2 group for architecture. The aim of this feasibility study — which resulted in the previously mentioned report on the applicability of Galileo in LCS, was twofold: to demonstrate the added value of Galileo for location services and, more generally, the added value of GNSS and to analyze the effects on the GSM/UMTS networks of including a new AGNSS capability in the LCS group of features.

A work item to develop the AGNSS location technique was then proposed by Alcatel-SA in SA1. The strong support of France Telecom, Qualcomm, and Ericsson revealed the key importance of Galileo and GNSS to providers of location services and led to TSG SA1's approval of this work item followed by endorsement of the SA plenary group in June 2004. These actions opened up the possibility of introducing work items into the GERAN and RAN groups for optimizing implementation of AGNSS architecture and protocols.

The process consisted in concentrating the technical researches in GERAN and then in transposing the results in the TSG RAN group. In August 2004

the GERAN WG rapporteur from Alcatel Space-SA — supported by Ericsson, Motorola, Orange, and Qualcomm — opened a work item on AGNSS.

In March 2005, Alcatel-SA then proposed the first technical solution of creating a complete GNSS concept, "Introduction of GNSS" (3GPP document G2-050074). This document provided a first draft proposal to unify the GNSS systems within a generic AGNSS formulation.

After a long period of technical maturation involving the joint active efforts of many industrial participants — in particular Alcatel-Lucent, Ericsson, Global Locate (later Broadcom), Nokia (decisively pushing the GNSS generic approach), Nokia Siemens Networks, Orange, Qualcomm, SiRF Technology, and Thales, — a technical consensus was reached in November 2006 during the 32nd meeting of TSG GERAN. The resulting technical solution gave birth to the first generic implementation of the AGNSS concept, under the name of Assisted Galileo and Additional Satellite Systems — A-GANSS.

This consensus laid the groundwork for progress in the technical integration of the solution within the GSM architecture and also opened the way for replicating the solution in TSG RAN (for UMTS) while insuring the coherence of end-to-end protocols, including those in TSG CT.

The decisive progress made in 3GPP allowed standardization of this generic GNSS concept within the OMA – SUPL V2 protocol. As mentioned earlier, this protocol encapsulates the 3GPP protocols over an IP connection, providing more flexibility for the physical deployment of solutions. The same companies involved in 3GPP decided to define the SUPL V2 standards with the addition of the strong support of RITT (China's Research Institute of Telecommunications Transmission) and CGI (Chinese Galileo Industries).

The overall process is roughly recalled in **Figure 19**. Many of the key 3GPP AGNSS proposals and research documents are cited in the Additional Resources section.

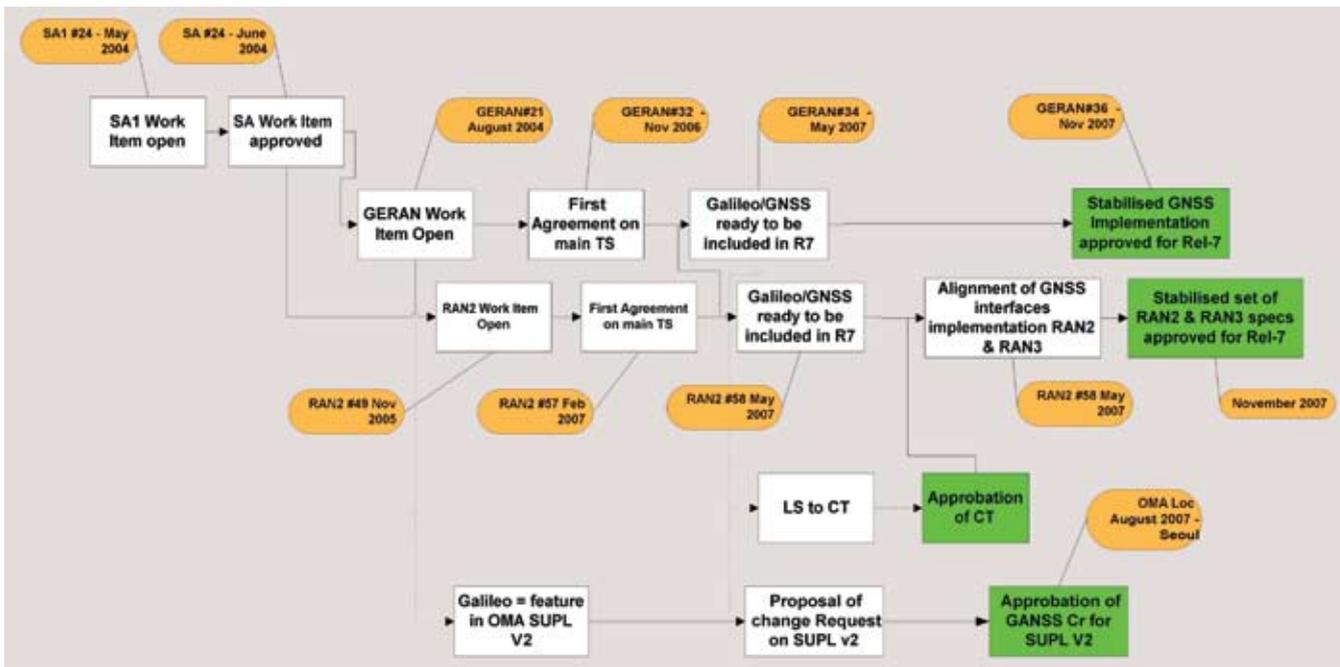


FIGURE 19 Overview of the AGNSS standardization process

Improvements Driven by Standardization

The AGNSS standardization process (or to use 3GPP’s terminology, A-GANSS) brought to the fore many improvements in location features, including the following:

- The GNSS concept can include up to nine GNSS constellations.
- The standard is fully open to the integration of new GNSSes, that is to say, the protocol containers can include new data formats adapted to any new GNSS.
- The GNSS concept is, in particular, embodied by the capability for the network to disseminate time scale offsets between the various constellations and the possibility to include reference frame transformations if necessary.
- The mobile handset is allowed to report heterogeneous measurements from several constellations in order to obtain in return a position estimation computed by the network, e.g., the serving mobile location center (SMLC), radio network controller (RNC), stand-alone SMLC (SAS), or for SUPL, the service provider center (SPC).
- The navigation data and format can be unified for all the constellations (same navigation model format for

all the constellations, which can be different from the satellites’ broadcast format).

- Any constellation, or any combination can be used as reference for the synchronization of the networks.
- The network has the capability to disseminate ephemeris with an extended validity period (up to seven days). Two encoding schemes were proposed and deeply analyzed: one that consists of encoding slices of polynomials parameters representing the corrections to apply to the almanacs and a second approach that disseminates slices of Keplerian parameters, encoding only the variations in parameters from one slice to the other slices, which allows dramatic improvements in data compression.

Thales performed an intensive trade-off study of both methods to determine which provided the best rendering of satellite orbits during several days versus the amount of bits that needed to be transmitted to describe those orbits. The Thales analysis showed that the second method had the best performance. This method was then included in the specifications and is now standardized.

Figure 20 shows the achievable performance of this method. It represents the RMS error caused on the end user

position due to orbit encoding errors (and only due to the encoding scheme, that is to say, not taking into account the orbit propagation error).

The heavy technical work led to final 3GPP approval of the entire AGNSS standard in November 2007. More than 26 technical specifications have been modified or defined to allow the feature to become available.

The assisted Galileo system is now included in a broad AGNSS concept fully standardized in the 3GPP Release 7 standards and SUPL V2. The key points can be summarized as follows:

- Compatibility with all the Galileo signals: E1, E6, E5a, E5b, E5a+E5b
- Possibility of broadcasting ephemeris assistance identical to the signal-in-space ephemeris or that can be reconstructed ones
- Capability of reporting carrier phase measurement from the handset to the network to insure three carrier ambiguity resolution (TCAR) computations
- Capability of sending a posteriori slices of bits of the message, to ensure data wipe-off, and therefore to improve working thresholds
- Full GNSS concept: capability of sending to a mobile station the time differences among all the GNSS systems; ready to support up to seven

new GNSSes in addition to GPS and Galileo

- Possibility to change the navigation model representation, including the capability for the navigation model to evolve and ephemeris extensions to allow longer periods in which the ephemeris data is valid.

Conclusion

The central place that standardization could play in the development of the location market was recognized very early in the Galileo program. This was strongly relayed by the industrial participants that merged their competencies and energy to build a new, very efficient location standard around AGNSS.

This industrial cooperation — tangibly achieved within 3GPP and OMA — brought Galileo and the GNSS concept into the heart of the location market. Even more, the achievement by all the private companies involved in the process gave birth to what we could call the first real and tangible AGNSS concept, gathering and standardizing the use of several constellations together to improve location performance, a concept in which EGNOS is already demonstrating great advantage.

The work continues to add attractive features to the AGNSS standard that ensure even higher performance in mass-market LBS applications. On the one hand, the companies and organizations involved in this process will have to follow the development of communication technologies and, on the other hand, to support the growth of the GNSS concept with the interoperable integration of the future satellites navigation systems. Additionally, an even deeper hybridization of Galileo and GNSS with other technologies will have to be standardized in order to tackle the next challenge: providing accurate locations deep indoors.

In parallel, standardization bodies will also have to tackle the challenge of developing test procedures of new AGNSS (or A-GNSS) location technologies, e.g. minimum performance standards, in order to make the feature really usable.

Nonetheless, the success already achieved in 3GPP and OMA has established an ideal basis and framework for the development of the mass market for location services, starting from the mobile communications domain but also certainly providing an ideal technological basis for other domains such as intelligent transport systems.

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Additional Resources

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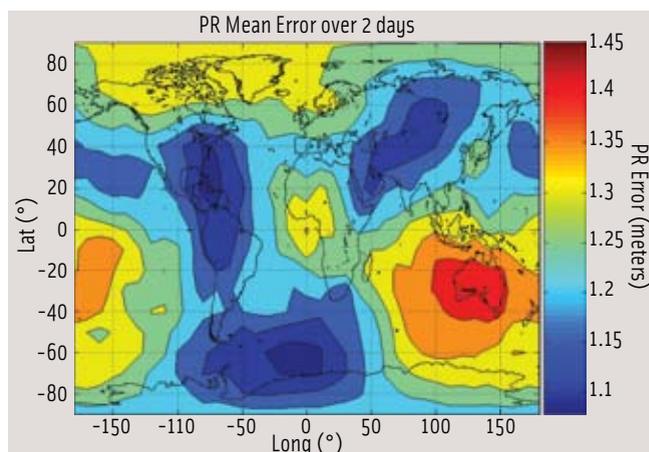


FIGURE 20 Effect of ephemeris extension encoding scheme on the end user accuracy

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