Geo Information Systems (GPS/Galileo) state of the art and trends

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Abstract

Geo information systems, formally called Global Navigation Satellite Systems, represent the basis for services in the area of location and navigation. These systems are increasingly applied to improve many different fields, like military, transportation, mining, telecommunication, security, research, etc. Introducing a GNS System enables a variety of services. Some of them are completely new, while the others are converged with already existing ones. Nevertheless the development of GNS Systems and the introduction of even more accurate Differential GNSS entails many consequences worth investigating. This paper summarizes some basic GNSS mechanisms and investigates the consequences of implementing Differential GNSS. The prospect of using public IP networks in the distribution of differential signals is analyzed. Finally some aspects concerning the future convergence of GNSS services, level of user interaction and security are considered.

Keywords: GNSS, GPS, Galileo, GLONASS, DGNSS, positioning, navigation, public network

1. Introduction

1.1. Overview

Geo information systems play an ever increasing role in our everyday life. Their ability to exactly locate the receiver in any place of the world influences many fields of global economy. The satellite navigation, which was created for military purposes, proved itself useful for all kinds of civil applications. The most famous examples of current geo information applications are car navigation and electronic maps systems. However, as time passes even more domains will rely and depend on them.

The importance of geo information systems is increasingly growing and in some countries is considered as one of the key infrastructure elements. In the United States the GPS system has been recognized as the fifth utility – alongside water, electricity, gas and telephony [1]. It's key significance for the economy, security and transportation has been by that fully admitted.

Unexpected success of the American GPS impelled other developed countries to follow the same procedure and create other geo information systems. The European Galileo and Russian GLONASS are slowly being deployed and soon should be fully operable. The increase in new systems created the need for a general name. Therefore the name Global Navigation Satellite System (GNSS) was agreed upon.

Pursuit after improved accuracy drove the GNSS into the next phase of development - Differential GNSS (DGNSS). DGNSS offers more precise positioning, by minimizing the influence of weather conditions on the system. It introduces so-called position “markers” on the Earth. The position of each marker is exactly known, so it may be used as a reference point. However, a problem occurs when distributing the differential signals from the markers to the other receivers.

Increasing technological advancement and combining GNSS location services with other communication and data platforms like cellular and wireless networks introduces several new services. On one hand converging these services with popular Internet applications may aid the user in many ways. On the other hand, some questions concerning the influence of those new services on the security and privacy of the user arise.

1.2. Structure of the paper

This paper has been divided into three main parts. The first part introduces and investigates the structure, properties and mechanisms of GNSS, also the key elements and main technologies used are described.

The second part addresses the architectural challenges regarding services and quality of service. Details about the recent innovations in GNSS, like differential location are also described.

Last, but not least some considerations concerning various applications are presented, as well as the current evolution of service trends and the contemporary and future problems.

2. GNSS

2.1. Definition

Global Navigation Satellite System is a general name for the geographical information satellite systems like GPS or Galileo. It's main purpose is to provide navigation, positioning and timing services to end users. GNSS consists of three main, functional elements: satellites, ground stations and receivers. Additionally, application servers are used to build services on top of GNSS.

Satellites placed on the high Earth orbit (usually 20-30 thousand kilometers) broadcast signals used for time synchronization and to retrieve location of receivers. In order to provide sufficient precision 20-30 satellites, depending on the configuration, orbit and satellite type, have to be included in the system.

Ground stations are management centers of GNSS. Satellite positions on the orbit are monitored from these stations and corrected, if necessary. Any system malfunctions are also solved – including the replacement of corrupted satellites.

Receiver or end user equipment consists of a simple signal receiver and a graphical interface that prints out the computed coordinates and exact time. However, instead of using a simple Graphical User Interface (GUI), a more complicated one may be used – with additional functionalities like 3D maps for example. Very often the receiver is just a part of UE (User Equipment), encompassed into a mobile phone, PDA, watch, etc.

Application server is an additional part, which provides advanced services that require advanced UE. A proper functioning of the service always requires a close interaction between the user equipment and server. However, most of the system intelligence resides in the UE. For example the application server could contain information about the volatile geographical positions, while the graphical map representation would be already downloaded to and installed in the UE.

Figure 1 shows the structure of GNSS and the dependencies between the system elements.

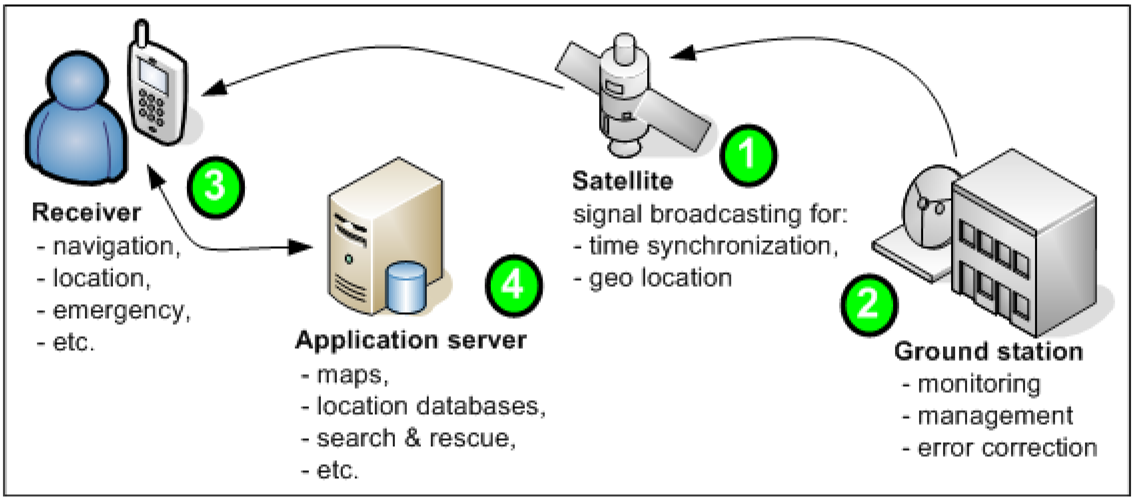

Figure 1: GNSS simplified structure

2.2. Functionality

Satellites broadcast the signal to the receivers. Using the signal's properties and some simple geometrical knowledge, the receivers may specify their position on the Earth in three dimensions and the exact time.

Marking the exact time and position may be divided into three main steps [2]:

- measuring distance to a satellite,
- triangulation from satellites,
- eliminating clock errors.

Measuring distance from a satellite is based on a simple fact that the broadcasted signal needs time to propagate. The radio signal, transmitted by the satellite, travels with the speed of light. As the distances between the satellite and the receiver is measured in thousands of kilometers (high orbit) the time it needs to reach the receiver is already detectable.

The receiver needs to know the configuration of the signal and the signal has to be repeated at equal time intervals. Possessing this information, the receiver is able to internally generate the same signal at the same time. The time needed to reach the receiver may be found, by comparing the delay between the received signal and the internally generated one.

Figure 2 shows the described mechanism. Knowing the time delay and the speed of light, the distance between the satellite and the receiver can be computed.

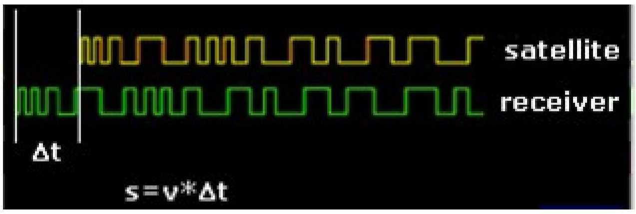

Figure 2: Computation of satellite-receiver distance

In order to triangulate the position of the receiver, signals from three satellites are needed. Knowing the distances between the satellites and the receiver, the position can be marked from simple geometrical properties.

In *Figure 3* it is shown, how information from subsequent satellites is added.

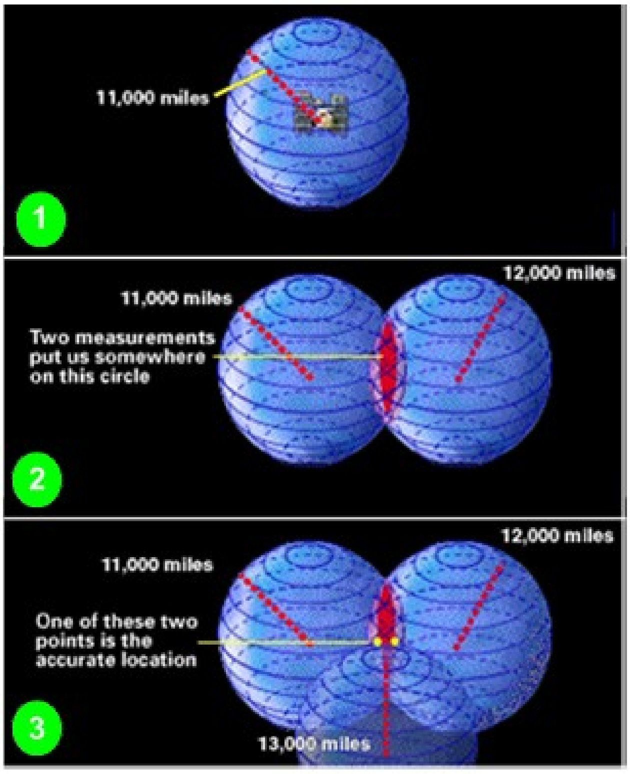

Figure 3: Triangulation from satellites [2]

(1) Knowing the distance from one satellite, one knows that the receiver is located somewhere on the surface of the sphere around this satellite.

(2) Adding the distance from the second satellite limits the possible locations to intersected points of the two spheres. The distance to both satellites is appropriate only there. Intersection of two spheres always forms a circle.

(3) Finally, the third sphere narrows the amount of possible locations to two points, where the circle from the second step intersects with the third sphere. One of the two points specifying the location of the receiver may be eliminated using a technical trick. It is usually located too far away from the Earth surface or is moving too fast and may be excluded. This way the possible locations are minimized to one point.

Measuring the delay between the signals has to be accurate. A mistake of one nanosecond translates into thirty centimeters misplacement during the position marking [3]. However, such accuracy may only be provided by an atomic clock that costs tens of thousands of dollars. Installing an atomic clock in each receiver and selling it for such a price would block the development of the technology. As a consequence another solution for retrieving the clock error has been developed.

Only a simple clock mechanism may be installed in the receiver. This implies that a relevant error will always occur. However, by adding a measurement from a fourth satellite, the clock error an be eliminated.

Figure 4 shows the GNSS solution for the clock error. It is represented in two space dimensions, as it is more visible and does not change the concept. A point to remember is that two satellites in two dimensions, are equivalent to three satellites in three dimensions.

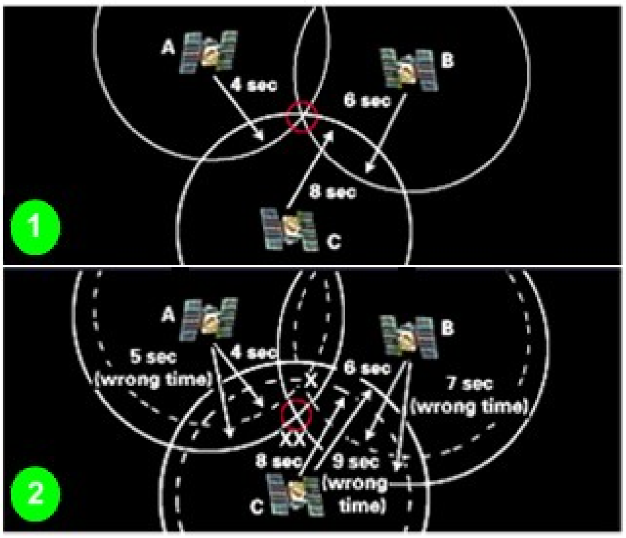

Figure 4: Clock error elimination [2]

(1) If one assumes that the receiver's clock is accurate, adding a third measurement (fourth in 3D) does not bring any additional information. The third circle (fourth sphere) intersects at the same point, where the two previous satellites specify the location (red circle in the figure).

(2) In reality however, the clock is inaccurate and the intersection of the two first circles (three spheres) shows a wrong location. By adding a third satellite (fourth in 3D) to the system one finds out that the circles do not intersect at a single point (XX on the illustration). All the circles are shifted because of the clock error. It is known however that all the satellites have an accurate clock. Thus the shift caused by the inaccurate clock in the receiver, should be the same for all the signals (circles). By computing a simple geometrical mean (middle of the triangle between the satellites), the correct location of the receiver (X) is found.

2.3. Existing systems

In reality, since the 1970s until today, the only fully operational GNSS has been the American GPS (Global Positioning System). It was mainly created for military purposes, but it has been offering a free-of-charge GNSS signal for any user for many years. Due to the great success of GPS and it's ever growing market demand, additional frequency signals are being offered. [1] [4]

Two additional systems are being developed at the moment. The first system is the Russian GLONASS (GLObal Navigation Satellite System) – also created and controlled by the army. The second one is the European Union Galileo that should be fully operable by the end of 2008. [1] [4]

From the engineering and architectural point of view all the systems are very similar and provide similar services. The only big difference is that Galileo is under civilian supervision and offers QoS (Quality of Service) on some encrypted frequencies aimed for industrial use. GPS and GLONASS, on the other hand, may theoretically be turned off at any moment without any consequences, if military commanders decide to do so. [1]

Neglecting these differences one has to emphasize that all geo information systems (at least GPS and Galileo so far) will compete only in some fields – like for example encrypted, limited access signals for industry. In concerns of publicly available, free GNSS signal, the US and EU agreed to cooperate and provide better and more reliable services. [5]

3. Geo Information Services

3.1. Services

A variety of services may be offered using application servers and encompassing GNSS receivers into different advanced platforms (GSM, UMTS, Internet, etc.). As a consequence many economy branches may be influenced by creating new capabilities in fields like: mapping, navigation, telecommunication, (maritime, land and aeronautical) transportation, tracking, location services, mining and welling, security, search and rescue, research and development, and many others. [6] [7]

From the architectural point of view however, it is not relevant what services are built on top of the system. The structure of the system will stay the same and only the implementation at the application server will change.

Whereas the architecture will remain the same, the signal might depend on the service. It's structure, properties and availability may differ for different scenarios. The newest ESA (European Space Agency) specifications define five categories of signals, for different services [5]:

- open access: free to air; mass market; simple positioning and timing,
- commercial: encrypted; high accuracy; guaranteed service (QoS),
- life safety: open service; integrity; authentication of signal,
- public regulated: encrypted; integrity; continuous availability,
- search and rescue: near real-time; precise; a feasible upload link.

3.2. Service limitations

GNSS as a system, consists of many complex, cooperating elements and as such leaves a lot of space for mistakes and errors. Some of them may be eliminated, by introducing technical solutions, while the others are inevitable.

In *Table 1* one can find an error budget of a GNSS system (DGNSS will be introduced later). The sources of these errors are the system elements and the signal propagation medium.

The signal transmitted from a satellite may already contain an error. Even though an atomic clock is very precise, it is still considered inaccurate to a certain extent. An inaccuracy of a few nanoseconds may cause a considerable error.

Second problem concerning the satellite is it's orbit position. So far it was assumed that a satellite is a reliable and certain reference point and it's position is always exactly known. Unfortunately it is not always the case. Even though, the position of each satellite is constantly monitored and any orbit shifts are constantly corrected, some inadequacy will always exist.

The environment, in which the signal propagates, influences it's properties. First the Ionosphere particles and then the Troposphere clouds and water vapor affect the signal. It's speed is changed by different environment densities and it's route is modified by the environment components.

Error source	***Standard GNSS***	***DGNSS***
Satellite clock drift	1,5 m	0,0 m
Orbit errors (ephemeris)	2,5 m	0,0 m
Ionosphere	5,0 m	0,4 m
Troposphere	0,5 m	0,2 m
Multi-path	0,6 m	0,6 m
Receiver noise	0,3 m	0,3 m
Total	~ 10,0 m	~ 1,5 m

Table 1: GNSS/DGNSS error budget, on GPS example [2]

The problems do not finish, when the signal reaches the ground. There are always many obstacles that may affect the propagation. This way the signal reaches the receiver with many different paths and the multi-path error has to be taken into consideration.

At last, the received signal might be incorrectly interpreted because of inaccurate receiver elements and the noise, they add to the signal.

Figure 5 shows the described propagation scenario. If the Ionosphere and Troposphere were as a homogeneous environment, as vacuum, the signal would reach the receiver without any problems (1). However in reality, there are all kinds of particles (magnetic, water vapor, etc.) in between. This modifies the route and speed of the signal, causing inaccuracy in marking the receiver's position (2). The receiver assumes that the signal travels in a homogeneous environment, without any obstacles (3) and misplaces its position. (the remaining signals will be discussed later)

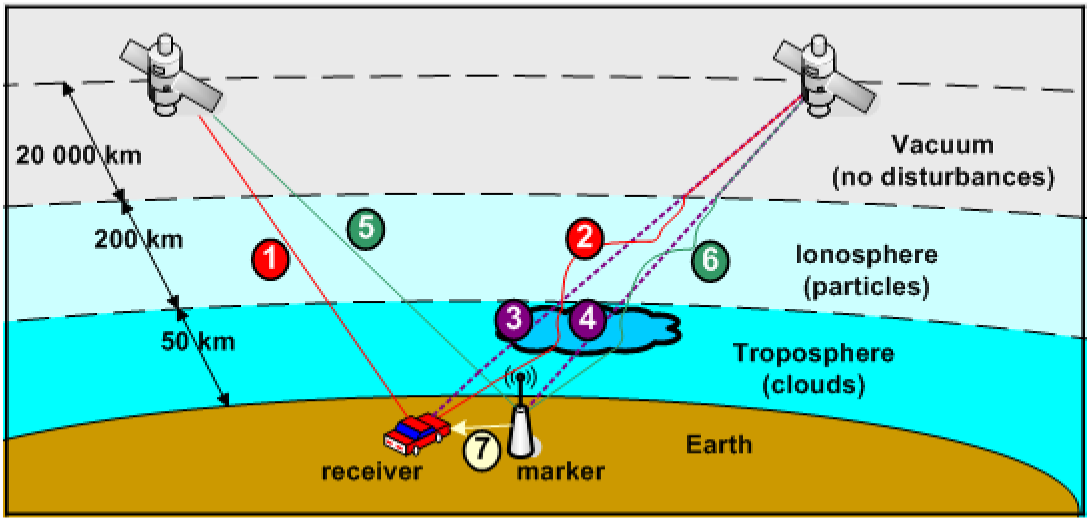

Figure 5: Atmospheric disturbances and Differential GNSS

There are some solutions dealing with constantly changing propagation environment and weather conditions. In one of the solutions – called modeling, the system tries to predict a typical delay on a typical day and simulates atmosphere model. Another solution implies sending two different signals and comparing them at the receiver. It is called dual-frequency technique. Both, modeling and dual-frequency limit the inaccuracy only to some extent, are complicated and expensive.

Eliminating the satellite clock shift and ephemeris error is even more complicated. Additionally it is limited by the used system elements and technologies and it can never be totally eliminated.

3.3. Differential GNSS

Since the beginning, GNSS (GPS) has been applied in many different fields. Positioning mechanism with an accuracy of ten meters was used for a long time and it performed well. However, with the huge success a demand for higher accuracy arose. Airports, harbors, oil platforms required much more, than the standard GNSS ten meters. Therefore, by the end of 1990s a new solution for the GNSS inaccuracies was introduced.

Differential Global Navigation Satellite System (DGNSS) is built on a simple fact that the distances that are traveled on the Earth, are relatively small in comparison to the Earth-satellite distance. A signal going from the satellite, to two different points (for example two hundred kilometers away) on the Earth, propagates through almost the same atmospheric environment. DGNSS uses this relation.

It is done by adding an additional receiver to the system (called marker). It's position and the delay to each satellite has to be exactly known. The marker monitors the signal broadcasted by the satellites and checks the delay. If the delay is different, than it should be (marker knows it exactly), then it is clear that there is some inaccuracy – caused by one of the mentioned factors.

Errors caused by the satellite clock shift, or ephemeris will affect all the receivers in the same way. The environment errors – weather conditions in Troposphere and Ionosphere will slightly differ. The difference, however, will be the smaller, the closer is the receivers to the marker. As already mentioned, DGNSS bases on this fact. Signal received by the marker is checked and if the delay is erogenous, then the error is transmitted to other receivers. If they are close enough, it will minimize the error just as it has been shown in *Table 1*, in the error budget.

Figure 5 shows how the mechanism exactly works. As already mentioned, the signal does not propagate in homogeneous environment (1). Sometimes the weather conditions affect the signal (2) and the receiver's assumption of the ideal medium is wrong (3).

The marker however, knows its position and the distance to the satellite. If the weather conditions are ideal, the delay known by the marker will not differ from the delay computed with the received signal (5). Else, the known delay (4) will not be the same with the computed one (6). The difference between these two delays is the system error that may be broadcasted to other receivers (7).

The receivers that are relatively close to the marker, may use the information about the system error and determine their position much better than in standard GNSS. There is an additional assumption that the receiver's and marker's error is identical. It is not totally true, but it allows minimizing the system error.

It takes a minimal amount of time, for the signal to travel from the marker, to the receiver. Atmospheric conditions in Ionosphere and Troposphere do not change rapidly. The time needed to send delay-information from the marker to the receiver will not affect the final result in any relevant way.

GNSS offers accuracy close to ten meters, whereas the accuracy of DGNSS is up to one meter. Such an increase of precision cannot be underestimated. For example, for the aeronautical transportation it means that the plane may not only find an airport, but it may be exactly put in the middle of the runway. By placing markers in critical places, like harbors, airports and oil-platforms or highly populated areas - one might provide significantly improved positioning services.

4. Trends

4.1. State of the art

In the modern world of high-tech three main trends can be observed. First of all, new technologies are constantly being developed. Instant messaging (IM), Voice over IP (VoIP), or Push-to-Talk are just a few examples from plenty of others. Some of these technologies offer completely new functionalities, while others simply replace generic technologies (transition of traditional telephony into VoIP).

Second, an even more important trend, is the convergence of already existing technologies. VoIP is merging with Instant Messaging, SMS is being incorporated into IM, television moves into the Internet (IPTv), etc. Merging different old technologies often results in completely new functionality.

Last, but not least, a search for a common platform is taking place. If two technologies, from two different platforms merge (TV and IP network create IPTv), a question arises – which of the two underlying platforms should be used for the converged technology (TV network, or the Internet)?

GNSS fits very well into this general picture. This is indeed an older technology, but the technology that is being constantly improved and developed. Transition to DGNSS is taking place, as even more markers are being installed. It is worth mentioning that it is not possible to improve the GNSS technology much more beyond the DGNSS capabilities. But it will should not be necessary, as a positioning accuracy around one meter will most probably satisfy the market demands.

In the convergence process, new applications are being found for GNSS, as it is encompassed in mobile phones, or car navigation systems. Most probably a pure GNSS receiver will soon cease to exist. Raw information about coordinates is not meaningful for somebody without cartographic and navigational knowledge. In order to be used by a mass user, it has to be included in some UE with a graphical interface that shows a map and a relative information (our relative position to other places). User Equipment and the technology that will converge with GNSS will not influence GNSS more, than application servers do.

The question of the underlying platform on the other hand has some relevant consequences for the system. Obviously the signal between the satellite and the receiver cannot be put on a different platform. It has to travel on the reserved radio frequencies, without any modifications. The problem lies in the distribution of the differential signal, from the marker to the receiver.

4.2. Platform

The main purpose of GNSS is to mark the geographical location of a moving receiver. Therefore, the problem of of distributing the differential signal concerns only the networks providing mobility. However, most of the Next Generation Networks that replace the generic public telephony (PSTN) provide mobility mechanisms. One may connect a VoIP phone in any place of the network and it should work with the same number, in exactly in the same way. Hence, the DGNSS problem, not only regards mobile and wireless networks, but also the fixed networks.

That is why the best solution for the differential signal distribution seems to be – the Internet. Most of the GNSS receivers are encompassed into cellular phones, PDAs, notebooks – i.e. the devices that already provide Internet connectivity. Information about the differential delay would be very small in comparison with voice or video contents, so transferring it via broadband or fixed networks would cause only minimal increase of the transfer rate. Additionally, recent development of wireless and cellular networks, enable the connection to the Internet from almost any place of the globe - with sufficient transfer capabilities (for example WiMax).

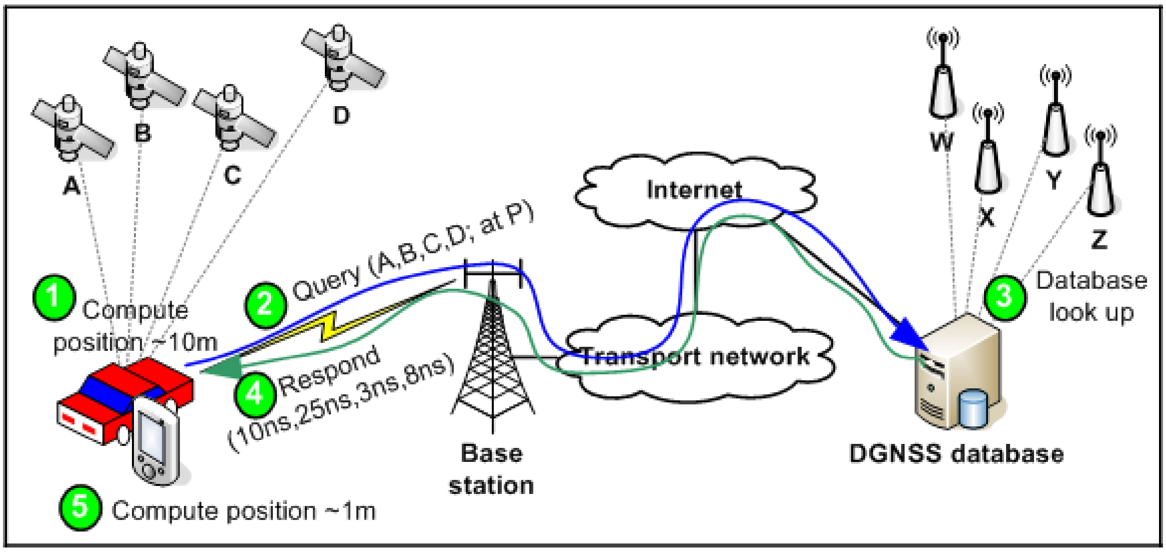

Figure 6: DGNSS on the example of cellular/Internet platform – simplified model

Figure 6 shows in a few steps, how DGNSS augmentation on a wireless device with a GNSS receiver could be performed. The access network may be GSM, UMTS, WiMax, or any other – the concept will remain the same.

(1) First of all an approximate position could be computed using standard GNSS. It's accuracy will be around ten meters.

(2) The approximate position in some point P may be transmitted via the transport network. The receiver sends the coordinates of point P and information about the four satellites that were used during position marking. A query may be now sent via an access network and then via the Internet to some DGNSS database.

(3) Basing on the position of point P the database server may determine the closest marker. For this marker a database look up may be performed, in order to check current signal delays between this marker and the satellites given by the receiver. Certainly the information from the markers has to be systematically collected and should always be available on the server.

(4) The information about the delays from the given satellites, to the closest marker, may then be transmitted back to the receiver.

(5) Compensating the delays to the used satellites, the receiver may now recompute an accurate (~1m) location.

One should emphasize that information about the receiver's speed, acceleration and movement direction are irrelevant here. Only the error information is used with some delay (propagation via transport network). The main positioning signal is directly taken from the satellite and used in real time. It means, the general position (ten meters accuracy) is constantly marked in real time and the most recent marker-satellite delay information is used (accuracy increased to one meter).

The simplified model from *Figure 6* shows how the problem of differential signal distribution may be solved. In reality there are already some standards and test implementations for this solution. Radio Technical Commission for Maritime Services (RTCM) defined (in 2003) a standard for distribution of DGNSS information over Internet Protocol, called Ntrip [8]. The standard has been tested in some of the European cities and so far fully meets the expectations [9].

4.3. Capabilities

In order to get a better insight into the capabilities of differential and standard GNSS one should investigate the services it currently offers and the services that it may offer in the future. The most important applications that were mentioned in the previous paragraphs regarded maps, navigation, location and timing. In all of these examples a user acquires some information from GNSS, while using a receiver. One could say that these are on-demand services. A user has to turn them on, or request them. They require user's interaction and the information flow is just one way - from the system to the end device, on the request of a user.

Most of the future GNSS capabilities lay in the background services. In such services the information about our location would be used by different applications, to make everyday life easier. A user would be no longer forced to request a GNSS service, but everything would happen without his involvement. Most of the system intelligence would be hidden and a typical, technologically unaware user would not even have to learn it. Information flow would be bi-directional from and to the receiver.

With the introduction of Voice over IP services and transition of telephony into the IP based world of the Internet, a process of converging traditional voice services with the Internet applications has begun. One of the examples is a merge of VoIP with Instant Messaging. It enables not only calling somebody from our contact list, but also sending him a message, if he or she is not available. One can notify his friends about the actual status – and inform if he is busy, or not.

Adding the GNSS positioning services, is the next step and offers even more capabilities. Busy/available information could be location based. Our IM client, while using our location information in background, could set a status and inform the other users, if it's user is home and available for social calls, or at work and busy.

Another IM-GNSS convergent function could be for example notifying us, if any of our friends is in the vicinity. This would naturally regard only the friends we approved to see our location and only if we decide to share it. The standard IM statuses “active”/”invisible” could be extended by notification (or not) about our geographical location.

Another developing, but very promising technology – intelligent home, could profit a lot on a merge with GNSS. Our UE equipped with a geo-receiver could notify, without even our knowledge (in background), where we are. Depending on our location some maintenance, or energy-sparing processes could be performed. Heating could be set to minimum, when we go away and then turned up, when we come back home. While we are away some automatic vacuum cleaning (such devices are already available on the market) could be likewise carried out.

Not only the future problems could be solved, with the usage of GNSS, but it could also resolve an already existing problem of the caller's location by emergency calls in VoIP systems. Traditional telephony works via fixed subscriber line. Each number is located at the end of a specific subscriber line. This connection line is fixed, so it is never a problem to locate the caller. A mechanism based on a simple telephone book can always locate the caller. In VoIP however, there is no subscriber line and no single and fixed point of connection. Localizing the caller in such a system is far more complicated. Moreover, as the VoIP networks provide mobility, the caller may constantly change his position. Including a GNSS receiver in UE and simply transferring the location information solves the problem and guarantees that it will be accurate the whole time.

The presented examples of background location services are just a drop in the ocean. Many more applications might be implemented and as new technologies are being constantly developed even more will appear in the future.

Unfortunately the background usage of our location is not only an advantage, but may also imply various problems.

4.4. Security

As soon as one starts implementing background location services a question appears. When, who and under what circumstances may get the information about our location? Privacy is one of the basic security expectations and a user should have a full control over location information.

Privacy problem in applications that work on top of GNSS, like Instant Messaging, or Intelligent Homes, should not be serious. Such an application is a software written on top of an underlying platform. If provided with necessary interfaces, might be controlled from the end device. It should allow the user to specify precisely what information should be shared, with whom and when. One only needs to ensure that the installed software is reliable.

The real problem lies in the emergency calls and emergency positioning. Such a solution would have to be implemented in the system, not on top of it and would have to be always active. Security issue of the emergency calls is a typical double-edged sword problem. On one hand it may increase security of any end user. While providing exact localization information in case of an emergency call, it may save lives and help protecting us. On the other hand, if the emergency infrastructure is misused in any way, then our privacy is compromised. A person with a GNSS receiver may be spied, controlled and monitored to an extent not possible earlier.

Not only the access to the emergency infrastructure should be considered, but also any transport networks that lie in between. Location information should not be accessible to anybody, who does not need it. In this case – access provider.

The bottom line of the security problem is that GNSS increases security, but may limit privacy. The real challenge of this technology is to maximize security and minimize probability of privacy breaches. From the engineering point of view, it is not a complicated issue. However, it should be particularly investigated, due to the extent it might compromise our privacy.

5. Conclusions

GNSS by itself creates rich positioning and navigational opportunities. Introduction of DGNSS augments the location accuracy to approximately one meter and allows it to be used in crucial and highly demanding environments, like airports, harbors, or oil platforms. Installing GNSS on top of the IP platform and advanced UE endpoints allows convergence of navigational services with other, already existing advanced applications, like Voice over IP, Instant Messaging, or Intelligent Homes.

All the hitherto developments and researches suggest that a future public platform for the distribution of differential DGNSS signal will be IP based. The Internet with it's vast accessibility and connectivity is a logical choice. However, the final solution will be chosen by the market users, depending on the technology price and simplicity.

There are some critical points regarding the reliability and security, but they may be solved by increasing the density of differential markers and strict supervision of the service providers.

Some economic and technological projections claim that GNSS will develop rapidly within next years. Just as it has been shown on *Figure 7*, in fifteen years' time there will be probably close to a million users, including people and vehicles. The analysis performed in this paper proofs that none of the concept or engineering problems should be serious enough to limit the development of GNSS. With this claim true, one can be sure that navigation and location services will be soon as popular, as mobile telephony today.

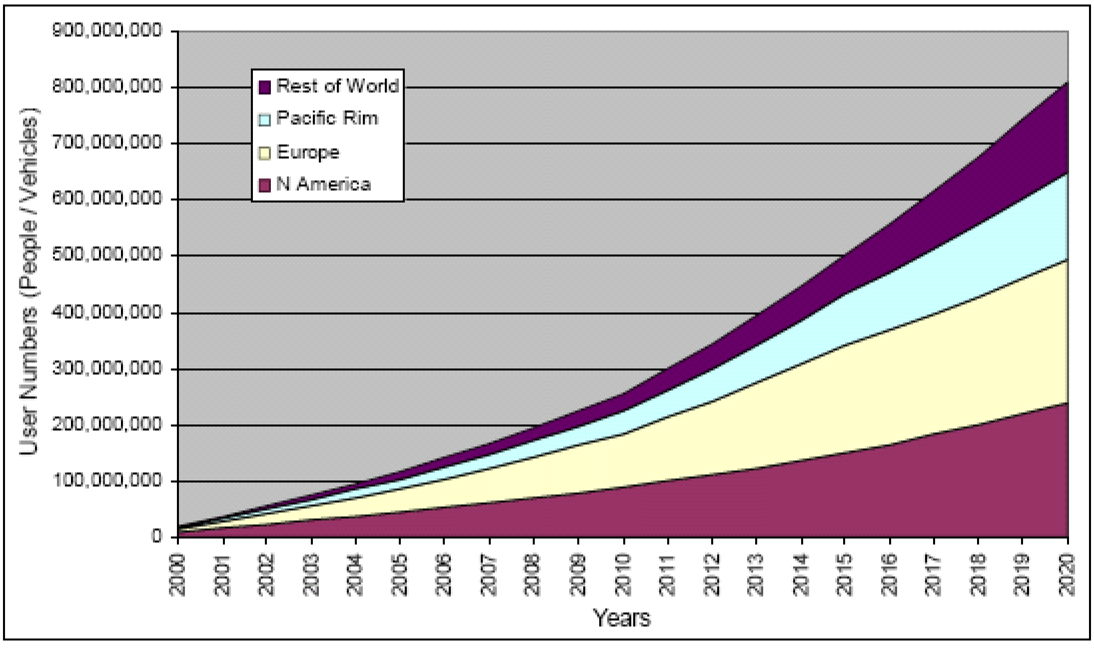

Figure 7: A prognosis of the GNSS market growth [1]

Abbreviations

3D	Three Dimensional
DGNSS	Differential Global Navigation Satellite System
ESA	European Space Agency
GLONASS	GLObal NAvigation Satellite System
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GUI	Graphical User Interface
IM	Instant Messaging
IP	Internet Protocol
IPTv	Internet Protocol Television
NGN	Next Generation Network
Ntrip	Networked Transport of RTCM via Internet Protocol
PDA	Personal Digital Assistant
PSTN	Public Switched Telephone Network
QoS	Quality of Service
RTCM	Radio Technical Commission for Maritime Services
SMS	Short Message Service
UE	User Equipment
UMTS	Universal Mobile Telecommunications System
VoIP	Voice over Internet Protocol

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