Global Navigation Satellite Systems (GNSS): An Overview

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Abstract: Global Navigation Satellite Systems (GNSS), including the United Stated (US) Global Positioning System (GPS), the Russian Glonass System and the future European Galileo System, are capable of providing time, position and velocity information to users all over the world. The GPS was firstly announced for a full operational capacity in 1995 and currently is the only fully operational satellite navigation system globally for both military and civilian users. The Russian Glonass System is not currently at its fully operational stage. In 2010, the Galileo system operated independently from the GPS system is expected to be in services with a great focus for civilian applications. The GPS alone could provide position solutions with an accuracy ranging from approximately a hundred metres up to few millimetres, depending on various parameters such as hardware, software algorithms, atmospheric activities and tracking conditions, assuming good measurement availability. In the near future, the combination of a completed Galileo and the modernized GPS (GPS IIF and GPS III) promises users to more available, more accurate and more reliable navigation solutions.

The paper aims to briefly review the current and developing global navigation satellite systems, including their system structures, capabilities and existing challenges. Various current and merging applications are described for the market world-wide as well as in Vietnam. This overview could become beneficial for fast merging GNSS users.
Keywords: GNSS, Technology, Capability, Applications, Challenges, Future

1. Introduction

Since 1995 when the Global Positioning System (GPS) operated by the United States (US) Department of Defense was firstly announced for its fully operational capacity, users world while are amazed by its state-of-art technologies and contributions to the positioning and navigation history of human beings on Earth. Our history of positioning and navigation started a long time in the past, heavily depended on astronomy and absolutely limited on the availability of the stars until the twentieth century. The success of GPS, nowadays, brings us the capability, under a clear view of the sky, to position and navigate globally, regardless of time and weather conditions. Especially since the year 2000 when the GPS Selective Availability limiting GPS performance achievable by unregistered users was turned off, GPS has become more accessible for civilian applications than ever and contributed in many different fields requiring high accurate positioning and navigation solutions such as aviation, marine, civil, deformation control and geodetics to name a few. Moreover, driven by the demands for emergency call positioning, namely the E-911 mandate set by the US Federal Communications Commission and the E-112 directive set by the European Commission, satellite navigation technologies are very popular for location-based services in entertainment industry, transportation guides, wireless networking and communication and security, promising billions of dollars in revenue. Consequently, there is an ever-increasing demand for more available, more accurate and, especially, more reliable GPS positioning and navigation solutions. This has partly led to the fascinating plan of modernizing GPS, modernizing GLONASS and developing Galileo system letting the second generation of GNSS to begin.

In order to provide readers with an overview of global navigation satellite systems, this paper endeavors to firstly describe in brief GNSS technologies and systems, including the existing GPS, GLONASS and the future GALILEO. Continuously, GNSS capabilities focused on GPS achievements will be presented and followed by a short review of GNSS applications worldwide and in Vietnam. Various challenges and the coming future of GNSS are then discussed. Conclusions are drawn at the end.

2. Global Navigation Satellite Systems

Global Positioning System (GPS)

Global Positioning System is a Navigation System by Timing And Ranging (NAVSTAR) operated by United States (US) Department of Defense (DoD). The system is initially designed for military purpose in the 1970's. However, civilian applications quickly become apparent and the system now is truly dual-use. With the first satellite launched in 1973 and the fully operational capacity declared in 1995, GPS is a line-of-sight, all weather, world-wide continuously available satellite-based radio frequency system that is capable of providing three-dimensional position, velocity and time to users with an appropriate receiving equipment. The GPS specified constellation consists of 24 satellites (although the number of current satellites available is up to 29 at the time of writing), operated in 6 orbital planes, 60 degrees apart, nominally inclined at 55 degrees to the equator as shown in Figure 1 [9]. Each orbital plane thus contains four satellites equally placed orbiting at an altitude of 20183 km from the mean surface of the Earth, with a period 11 hours and 58 minutes [2]. A world-wide network of six ground control stations are facilitated to monitor satellites health and status as well as to maintain the GPS system time base which follows, within the limit of 1 μs, the Coordinated Universal Time reference kept at the US Naval Observatory (UTC (USNO)) [9]. The system uses the Earth-Center-Earth-Fixed World Geodetic System 1984 (WGS84) coordinate frame.

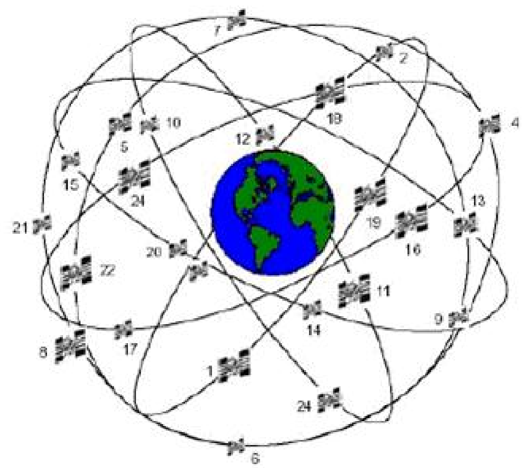


Figure 1: Global Positioning System (GPS) Constellation

GPS system applies the concept of one-way Time of Arrival (TOA) ranging. The satellite signal transmissions are referenced to highly stable atomic time standards installed onboard the satellites and ideally synchronized with an internal GPS system time. This requires the receiver to install a clock. The system currently uses two navigation carrier signal frequencies in the L band, called L1 (1575.42 MHz) and L2 (1227.6 MHz), which are modulated using Binary Phase Shift Keying (BPSK) technique by Spread Spectrum (SS) codes with a unique Pseudorandom Noise (PRN) sequence associated with each satellite and by the navigation data message. Each GPS satellite transmits signal with two modulation codes: Coarse/Acquisition (C/A) for free civilian uses on L1 frequency, and Precision (encrypted) (P(Y)) for authorized military users on both L1 and L2 frequencies. The unique nature of the PRN codes allows GPS signals of different satellites transmitted using the same frequencies without interference. This technique is called Code Division Multiple Access (CDMA). The PRN codes are selected due to their cross-correlation properties allowing one to be distinguished easily from others. In addition, it allows the receiver to determine the signal propagation time, which theoretically is the time necessary to align the coming satellite code with the receiver generated replica. As a result, the satellite-to-user range can be determined by multiplying the propagation time with the known speed of light. This requires an absolute synchronization between the two clocks for an error-free estimation. However, in reality, this is hard to achieve causing an error in the estimated ranges; the ranges are so called pseudoranges. In addition to these pseudorange measurements (also called code measurements), the carrier-phase measurements are a different type of GPS measurements. They are measured value of the phase difference between the coming satellite signal and the receiver generated replica. In comparison with code measurements, carrier-phase measurements are less affected by noise and some other GNSS errors (e.g. multipath). However, they are bias by an unknown integer number of wavelength differently for each satellite-to-user range measurement. These unknown integers are referred to as ambiguities and they must be resolved before the precise carrier-phase measurements can be used to provide accurate positioning solutions. The navigation data messages provide necessary information for the receiver to determine satellite position at the time of signal transmitting in addition with satellite clock marks and information of other satellites (almanac).

GPS satellite signals obtained at receiving antennas are extremely weak, specified to be -160dBW for C/A codes; -163 dBW for P(Y) codes on L1 frequency and -166 dBW for P(Y) on L2 frequency [9]. This signal power is well below the noise level. GPS signal extraction, fortunately, can be easily performed due to the cross-correlation properties of the PRN codes given good tracking conditions. However, under degraded signal environments, signal acquisition faces a lot of difficulties. More details on GPS signal structures as well as signal acquisition and tracking are, unfortunately, too complicated to be discussed fully herein; readers are thus recommended to other more technical readings (e.g. [2][9]). GPS autonomously provides two types of services: (i) Standard Positioning Services (SPS) and (ii) Precise Positioning Services (PPS). The SPS is designed for civil community while the PPS is specified for US military and special government agency users. Civilian users of PPS are permitted but only upon special US DoD approval. In order to prevent and limit civil access to GPS high-class performance, two functions called Anti-Sproofing (AS) and Selective Availability (SA) were developed. AS function helps to prevent the P code from sproofers and jammer by encrypting the P code by a secure Y code, resulting in the Precision (encrypted) (P(Y)) code. SA differently is a purposeful degradation of GPS signal operated the US government by dithering the GPS satellite clocks in a pseudorandom manner in order to limit GPS performance achievable by non authorized military users. This function has officially turned off on 1 May 2000.

GLObal'naya NAvigatsionnaya Sputknikkovaya Sistema or GLObal NAvigation Satellite System (GLONASS)

GLONASS is a navigation satellite system operated by Russia's Ministry of Defense. The system consists of a 21 active satellites and 3 spares constellation, operated in 3 orbital planes, 120 degrees apart, nominally inclined at 64.8 degrees to the equator [2]. Each orbital plane thus contains eight satellites placed orbiting at an altitude of 25500 km from the mean surface of the Earth, with a period of approximately 11 hours and 15 minutes [2]. The full operational constellation was achieved in 1995 as shown in Figure 2.

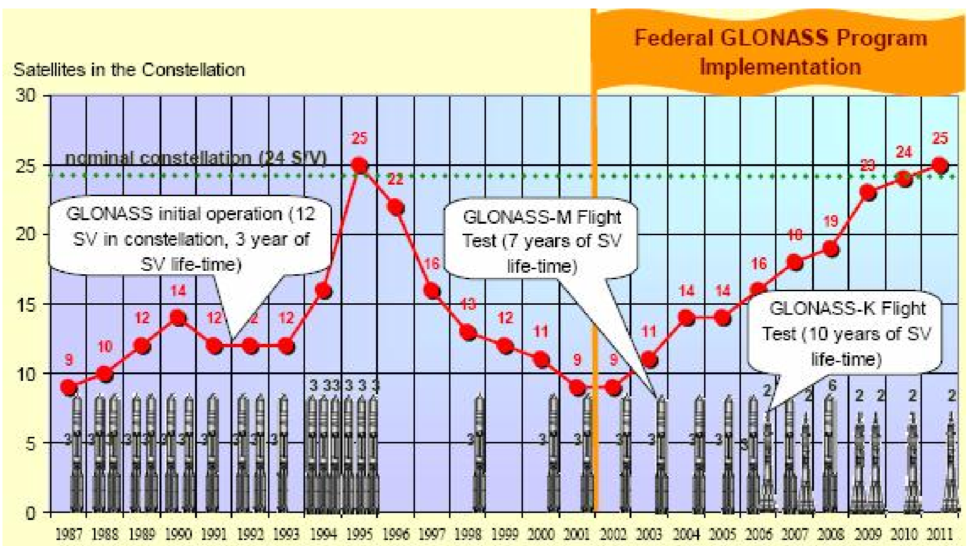


Figure 2: GLONASS Implementation plan [12]

GLONASS in many ways is very similar to GPS. It is also initially designed for military uses but quickly becomes military and authorized civilian dual use. GLONASS positioning, velocity and time determination is also performed using PRN ranging signals. However, in contrast with the Code Division Multiple Access (CDMA) technique used by GPS, GLONASS uses Frequency Division Multiple Access (FDMA), in which satellites transmit the same ranging code on different frequencies. The GLONASS codes are totally different from the GPS codes. The GLONASS time base is referenced to the Coordinated Universal Time, Soviet Union (UTC(SU)) and GLONASS satellite navigation parameters are framed in the PZ-90 geocentric reference system. Similar to the GPS navigation data, the GLONASS navigation messages include the broadcast ephemeredes reporting the transmitting satellite position, the time scale shifts of the satellites relative to the GLONASS System Time and UTC(SU), signal transmitting time marks, and the GLONASS almanac reporting information on other satellites' position. Due to insufficient funding for system maintenance following the dissolution of Soviet Union, only thirteen GLONASS satellites remain at the time of writing as shown in Figure 2. In addition, being dominated by the success of GPS, GLONASS observations, over the past few years, are mainly used for strengthen GPS positioning and navigation solutions. The GLONASS program however is undergoing modernization which aims to improve the system services and the space segment. GLONASS modernizing plan is shown in Figure 2 and expected to be accomplished by 2010. However, Russian government is facing financial difficulties for such a big project and calling supports from others. This in fact is not very well going due to the parallel development of European system and some agreements required on GLONASS development policies. Technically, the use of GLONASSS FDMA technique unfortunately causes interoperable issues for GLONASS to be developed popularly for open and commercial users. So far, GLONASS receivers are still not commercially available. GLONASS system is thus not a strong focus of the discussion herein.

European Galileo

Aiming to satisfy the European market demand for an independent positioning and navigation capability from US, Europeans are urged to develop their own global satellite navigation system, named Galileo. The development of Galileo is responsible by the European Union (EU) and the European Space Agency (ESA) and well attracted funding from various other non-European countries such as Canada, China, India and Israel to name just a few. Its first stage for commercial services is expected to be completed by 2010. The designed Galileo constellation consists of 30 satellites, placed in three circular orbits inclined at 56 degrees at an altitude of 23616 km above the Earth surface [3] as shown in Figure 3. Therefore, there will be 10 satellites on each plane and orbiting period of each satellite is 14 hours. Similarly to GPS and GLONASS, Galileo satellites are also monitored and controlled by a worldwide network of ground stations (ground segment). Differently from other GNSSs', Galileo ground segments is further facilitated with satellite uploading links for regional integrity data provided by regional integrity monitoring components. It is specified a guarantee that a user will always be able to receive integrity data through at least two satellite with elevations angle of higher than 25 degree [3][6]. The Galileo capability of providing integrity information will be obviously helpful to further extend positioning and navigation services especially for indoors.

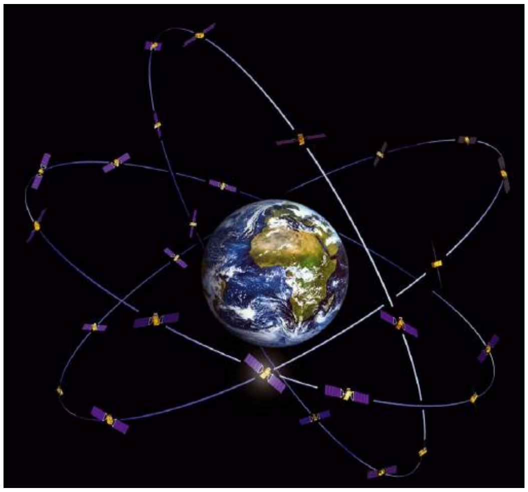


Figure 3: European Galileo constellation

Galileo navigation parameters are expressed in the Galileo Terrestrial Reference Frame (GTRF) which is almost coincident with the GPS WGS84. For timing reference, Galileo will use International Atomic time (IAT) which is different to Universally Coordinated Time used by GPS. It is aimed to keep Galileo System Time to be within 50 ns of TAI [7]. The Galileo system will transmit ten navigation signals among which six are for open and safety-of-life services, two serve commercial services and two aim for public regulated services [3]. These signals will be transmitted at three different frequency bands: (i) E5a-E5b (1164-1215 MHz); (ii) E6 (1260-1300 MHz; and (iii) E2-L1-E1 (1559-1591 MHz). An overview of GNSS current frequency reservation is presented in Figure 4. The Galileo E2-L1-E1 is already used by GPS, thus, a joint frequency transmittance will be done to avoid interference while allow the simultaneous accessibility to both systems. Galileo satellites also utilize the use of CDMA technique for comparability with the GPS approach. The Galileo signal design and construction is not yet finalized at the time of writing. The Galileo system is being scheduled for implementation in three stages. The development and in-orbit validation stage is planning for 2001 to 2005 consisting of the consolidation of the mission requirements and the development of 2 to 4 satellites to validate ground-based components and the system in orbit. The deployment stage is scheduled for 2006 to 2007, consists of the construction and launch of the remaining satellites as well as the completion of the ground segment. The third stage is for commencing commercial operations starting in 2008. However, due to a delay during the first stage, the completion of Galileo system is rescheduled for 2010.

Opposing to the GPS objective mainly to serve military and special governmental purposes, Galileo is designed mainly for civilian applications that can be divided into five groups: (i) the Open Service (OS) which is free of charge timing and positioning service opened to mass-market applications with a limited level of integrity data and without guaranteed level of accuracy; (ii) the Safety-of-Life (SoL) service that provides the same level of accuracy, but guaranteed, as the OS but with higher level of integrity information; (iii) the Commercial Service (CS) aims to satisfying commercial market requiring higher performance compared to the OS by providing, on payment of fee, value-added services such as two more signals, high data-rate broadcasting, service guarantees, precise timing services, the provision of ionosphere delay models, and local differential correction signals for extreme-precision position determination; (iv) Public Regulated Service (PRS) which is designed to serve special groups such as police and customs with the most priory services and (v) Search And Rescue (SAR) service that will endeavor to improve existing humanitarian search and rescue services by the capability to precisely locate emergency alerts using not only the 30 satellite space segment but also the additional four low earth orbit and the three geostationary satellites.

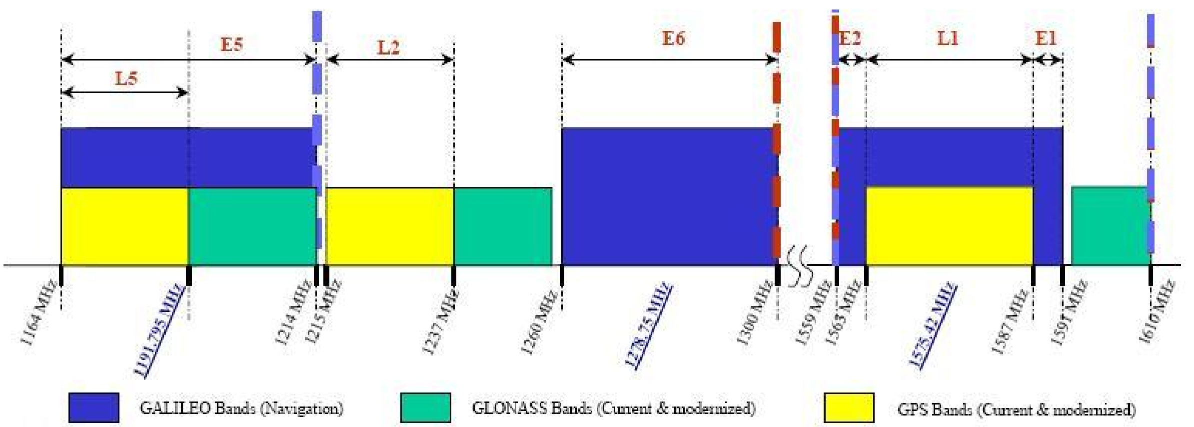


Figure 4: GNSS frequency reservation

3. GNSS Current Capabilities and Impacting Factors

GNSS is capable of providing position, velocity and time (PVT) to users providing one can obtain at least four satellite signals. TOA ranging measurements made for three satellites can be used to determine three-dimensional receiver's location as demonstrated in Figure 5. Due to the satellite's and receiver's clocks are not synchronized, the fourth TOA ranging measurement is required to determine the time bias between them. User's velocity can be determined similarly to position but using Doppler measurements, which basically are instantaneous phase rate of the tracked satellite signals caused by the relative movement of satellites and users. Given the resolved receiver time bias, user can synchronize his/her time with the system reference time (GPS Time for example in case of GPS) which is usually very precise to world-wide standard time bases (for example GPS Time is only 1µs apart from the UTC (USNO)). Therefore, GNSS is also considered to have the world-wide timing synchronization capability.

There are many different factors affecting GNSS performance. The satellite positioning and navigation errors come from four main sources: satellite-based (e.g. satellite clock error, satellite perturbation), control-segment based (e.g. satellite orbit prediction error), propagation-based (ionospheric error, tropospheric error, multipath) and receiver-based (e.g. receiver noise, receiver clock error). Typical code-based pseudorange error budgets for GPS are summarized in Table 1 [2] as an example. In order to reduce the effect of errors on positioning solutions, many different special measurement processing techniques have been developed. Among which, the technique differencing measurements obtained between two receivers and two satellites (so called differencing technique, e.g. DGPS) significantly helps to eliminate common errors such as satellite clock error, receiver clock error and to significantly reduce the spatial correlated errors such as satellite orbit error and atmospheric errors. The reduction in spatial correlated errors can be performed efficiently only in the present of a high error correlation usually achievable with relatively short inter-receiver distance under quite or normal atmospheric activities. In addition, the use of different type of ranging measurements, e.g. code measurements or carrier-phase measurements, noticeably affects positioning results. This is because the code measurements are usually less precise than the phase measurements. For instance, the typical noise and multipath error in code measurements reaches 0.5 – 1 m (rms) while this is only 0.5-1 cm for carrier-phase measurements [9]. As discussed earlier, however, the use of these more precise observations requires ambiguities to be resolved. There has been many different ambiguities resolution techniques presented among which LABMDA is the most popular (e.g. [11][5]). However, due to its ambiguous nature and the uncertainties during the resolving process, ambiguity resolution still remains as hard topic for very accurate positioning, especially under abnormal conditions (e.g. high error magnitude and/or a lot of cycle slips). For GPS, after the SA is turned off, propagation error caused by the ionosphere is generally the biggest. This ionospheric error becomes more critical under active conditions due to solar phenomena. The rapid decorrelation of the ionospheric error both temporally and spatially caused by highly localizing activities of electrons disaffects differencing approaches. Fortunately, ionospheric error is frequency dispersive and therefore can be modeled and mostly eliminated by using dual frequency measurements. Nevertheless, the problem remains in the case of very active ionosphere which severely affect GNSS measurement quality due to dangerous scintillation effects and cycle slips that could make satellite positioning becomes impossible, even with the use of dual frequency observations. Another important error source is multipath, which is the phenomenon of a signal reaching an antenna via two or more path as a result of signal reflection. Multipath can be a big challenge for satellite positioning because it is highly localized and cannot reduce by differencing technique. It often becomes dominant source of differential errors for indoor GNSS.

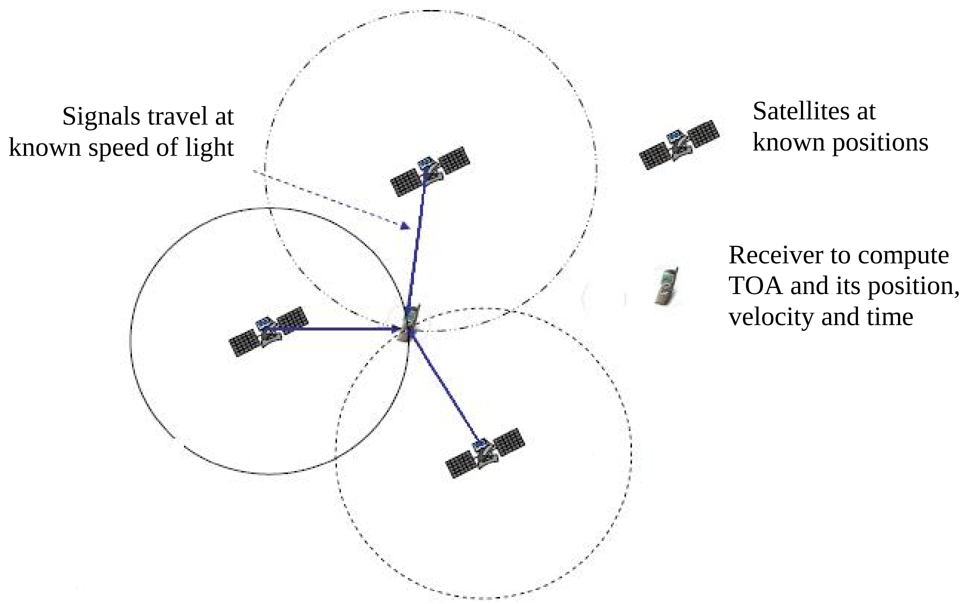


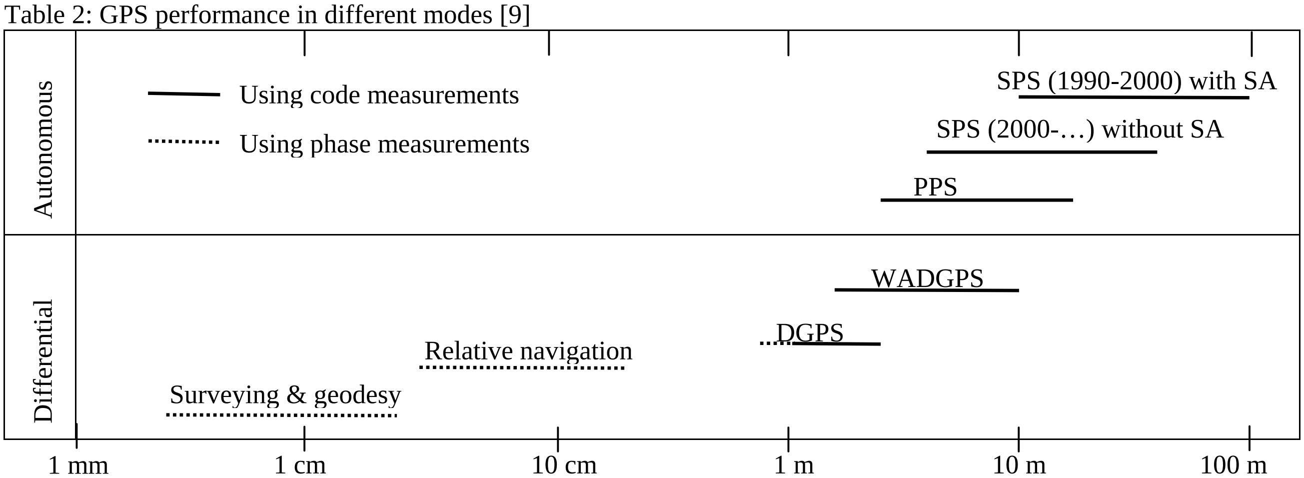
Figure 5: User position determination using three TOA ranging measurements

Table 1: GPS Error Budgets (m) [2]

Error sources		SPS (1σ)	PPS (1σ)	DGPS (1σ)
Satellite-based	Satellite clock	3.0	3.0	0
	Satellite perturbations	1.0	1.0	0
	Selective availability	32.3	-	0
	Other (thermal radiation, etc)	0.5	0.5	0
Control segment-based	Satellite orbit prediction error (broadcast)	4.2	4.2	0
	Other control segment error	0.9	0.9	0
Propagation-based	Ionospheric error	5.0	2.3	0 *(assuming ideal conditions)*
	Tropospheric error	1.5	2.0	0 *(assuming ideal conditions)*
	Multipath	2.5	1.2	2.5
Receiver-based	Receiver noise	1.5	1.5	2.1
	Others (inter-channel bias, etc)	0.5	0.5	0.5

Since its full completion in 1995, GPS system has obtained undeniable achievements. GPS performance in reality has been better compared to the specified 100 m (95%) horizontal positioning accuracy with the Selective Availability (SA) for SPS using single receiver code measurements under open sky tracking conditions [2]. Without SA, the SPS accuracy has been increased significantly to approximately 22.5 m (95%) [10] to 19.1 m [8] to as good as 10 m [9]. Depending on many factors as described above, GPS performance varies from metre-level to millimetre-level of accuracy, as shown in Table 2.

Table 2: GPS performance in different modes [9]



4. GNSS Applications world-wide and in Vietnam

Although initially designed for military uses, both GPS and GLONASS have quickly become popular in various different professionals and civilian services. GNSS market rapidly grows leaded to annual revenue of more than seven billions USD in total world-wide in 2001 [1] as shown in Figure 6. Various applications have been formed and developed. They are listed in Table 3.

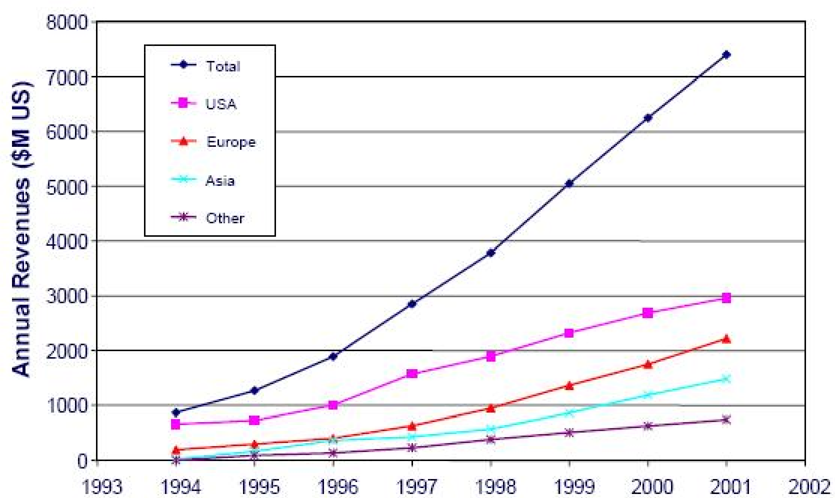
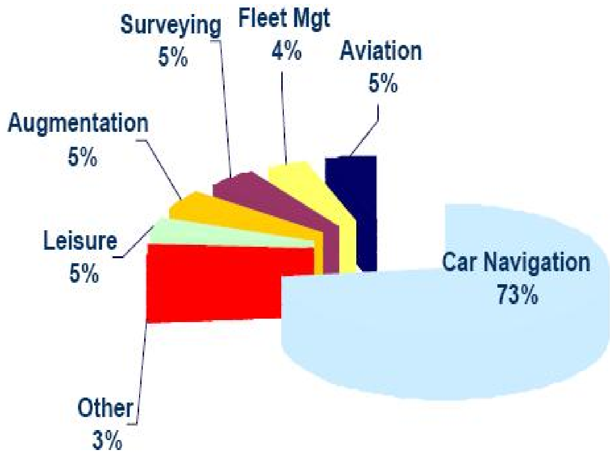


Figure 6: GNSS market evaluation up to 2001 [1]

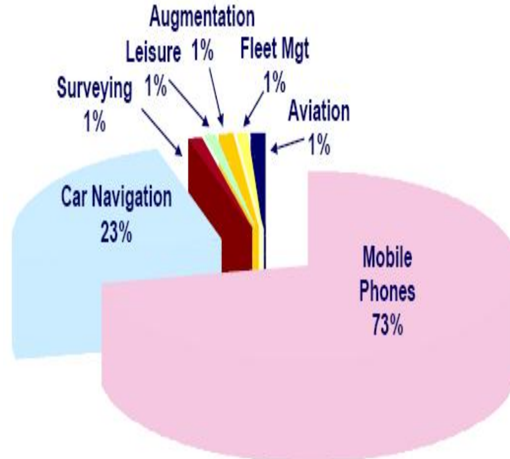
Table 3: GNSS world-wide current and merging applications [1][13]

Fields	**Descriptions**
Military	– Positioning and navigating objects – Aiming targets
Professional applications	– Geodesy, geology, seismology – Timing metrology – Civil engineering (structure deformation monitoring) – Environmental monitoring and weather predictions
Transportation	– Air (route navigation, airport approach, landing, ground guidance) – Road (electronic charging, real time traffic information, emergency calls, route guidance, fleet management) – Rail (train control & supervision, fleet management, track survey, passenger information) – Maritime (ocean and coastal navigation, port approach and manoeuvres)
Agriculture and Fisheries	– Monitoring and spraying of fertilizers and chemicals – Yield monitoring, monitor fish resources – Certified proof of non-invasion of national water boundaries
Energy (electricity, gas, oil)	– Power network synchronization for generation and distribution – Oil and gas marine seismic exploration, positioning of the rig and its anchor-handling vessel
Crisis Management Search and Rescue	– Location of mobile phone (US E-911/ European E-112)
Telecommunications	– Location based services (LBS) and telematics
Recreation	– Sport training for athletics
Finance, Banking and Insurance	– Certified timing for electronic signature, time-stamping – Certified time stamping on transactions (e-commerce) – Data encryption – Control and monitoring of valuable or dangerous goods – Services related to car and property insurance

Figure 7 shows the European GNSS market distribution for 1999 and 2005 in comparison [1]. In 1999, the main GNSS revenue generating sector occupying 73% was car navigation while all others including surveying, aviation, fleet managements and augmentations in total counted for 27%. However, in 2005, driven by the requirement to locate US emergency call E-911 from mobile phones, GNSS becomes one obvious solution for the mobile phone positioning demand and telecommunication carriers was successful in initially turning the costly government-mandated technology into profit-generating services called Location-based Services (LBS). Location-based services, which are able to provide targeted spatial information to mobile workers and consumers, have been talked about more than ever. These include utility location information, personal or asset tracking, concierge and route-guidance information, to name just a few of the possible LBS. In 2005, 73% of the positioning market is taken for mobile phones and their services while other contributions are relatively decreased compared to 1999. Figure 8 demonstrates the GNSS European market prediction for 2015. In the future, personal navigation will become dominant. Regardless of privacy issue, the information-based convenience and safely it brings along keeps promising big profits. This consequently results in an integration of personal navigation and communications which will expectedly occupy 33% of the market in 2015. Car navigation and car security remains as an important sector with 41%. Applications for creation and safety-of-life services will be in focus.



(a)



(b)

Figure 7: European GNSS market distribution in (a) 1999 and (b) 2005

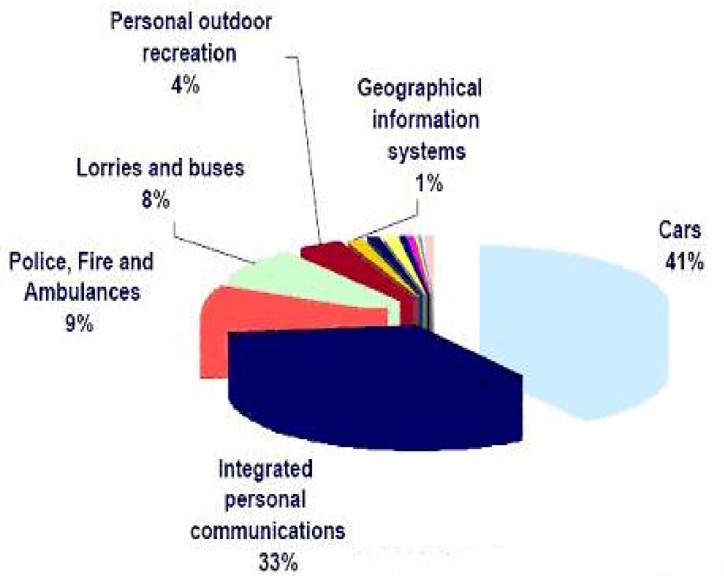


Figure 8: Expected European GNSS market distribution in 2015 [1]

Nowadays, on world-wide market, there are hundreds of different GPS receivers and GPS-based application interfaces developed around the world while just some of them are shown in Figure 9 for demonstration. GPS receiver costs vary greatly from couple of hundreds to tens of thousands of US dollars, depending on quality and functions.

(a) (b) (c) (d)

Figure 9: Examples of GPS receivers and GPS-based application interfaces: (a) High performance NovAtel DL-4 plus GPS receiver costing approximately few thousands USD, (b) Garmin GPS handheld costing approximately USD200; (c) GPS-based LBS on mobile phones and PDAs; (d) Car navigation

In Vietnam, GNSS technology has been fast popularized over the last 5 years. Courses are being taught at various Universities around the country (e.g. Hanoi University of Mining and Geology, Hanoi University of Technology, Hanoi University of Civil Engineering and HoChiMinh University of Technology) and GPS-based applications are found commonly in many professionals and everyday activities. For geodesy and mapping, high accurate GPS has been used for estimating reference station network and/or reference coordinate maintenance at centimetre-level of accuracy. Similarly, GPS is used on a regular basis to maintain Vietnam-China boundary over the last few years. The GPS's capability to detect movements at millimetre level has also been applied to monitor significant manmade structures such as Hoa Binh Hydro-Electronic station. Low-cost GPS receivers (handhelds) are usually used to coordinate registered locations during field visits in remote sensing. To call for more GPS applications in Vietnam, location-based services also can possibly find a promising future. The fast developing economy brings along a significant increase in living standards of Vietnamese which encourage the security, convenience and creation that technology-based information brings. Moreover, the developed tourism will open significant chances for Vietnamese LBS market. However, one cannot overlook the serious issue of lacking a Vietnamese mature digitized spatial information facility (is referred to as GIS herein), which is essential component of any location-base service. This is extremely important in spatial information science and technology because "position" information of an object is meaningless unless it could be transferred into "location" information in relation with the surroundings on the Earth surface prior to decision-making processes. Some works have been carried out in order to build the GIS database for main cities in Vietnam and GPS appears to be an important mean to set up way points. In parallel, plans to equip cars, taxies and buses with GPS are discussed. As an example, a GPS-based automatic train speed control and supervision technology was successfully designed and deployed for many long-distance Vietnamese rail trains.

5. Current Challenges and the Coming Future

Merging into many important applications, the first generation of GNSS including GPS and GLONASS faces an upgrading requirement to satisfy the continuously increasing demand of civilian users. In 2001, it has been counted for 6 million users of GNSS and the number is predicted to be dramatically increased up to 250 millions [1]. The market for GNSS civilian applications, especially personal navigation, telecommunications, transportation, search & rescue and recreations, has been formed with huge equipment and service developments, promising billions in revenue. The mature development of system-on-chip technology opens up an ever-easier opportunity for GPS technology to be integrated into all different devices.

Currently responding to the demand, however, GPS is the only fully operational global navigation satellite system. In addition, although its achievements for outdoor applications with good signal tracking conditions are undeniable, various issues surface when performing GNSS positioning and navigation under degraded signal tracking conditions such as urban canyons, forested areas and indoors where location-based service demand is dense. Under such conditions, GPS alone provides poor performance in all measures of accuracy, availability, reliability and continuity. Signal masking, signal attenuation, low number of observation redundancy, measurement corruptions due to high noise and multipath and measurement quality inconsistence are very popular problems. The second generation of GNSS is thus urged to be developed in order to provide emerging location-based services market, which has enormous potential for growth and impact, more accurate, reliable, available and continuous positioning solutions.

In order to fulfill the above demand, GPS is being modernized to provide more civilian signals with the use of a third civil frequency L5 (1176.45 MHz) and put C/A code on L2. As a result, the GPS SPS solution accuracy will be improved to 8.5 m RMS using dual frequency code measurements [9]. Beside, GLONASS system is also planed for modernization. By 2010, the Galileo system is expected to be completed. Civilian users are impatiently waiting for benefits it brings along. Galileo stand-alone promises to provide 15 m solution accuracy horizontally for OS using single frequency and 4 m solution accuracy using dual frequency [7]. GPS, GLONASS and Galileo all in combination will no doubt offer the benefit of excellent signal coverage and enhanced GNSS positioning and navigation solutions. The wish to have indoor positioning solutions of "10 m in 10 s anywhere at any time" [4] might possibly become true in the future.

6. Conclusions

The paper endeavored to delivery a brief overview of GNSS system. It is unquestionable that GNSS is state-of-art technology achieved an evolution in human capability to position and navigate on Earth and contributed in many different professional fields with the success of GPS especially. Standing in front of a huge demand to improve performance for civilian applications driven by many profit-generating and/or safety-of-life services, the GNSS second generation has started with the plan to modernize GPS, GLONASS and to develop Galileo. As a result of GPS, GLONASS and Galileo combination, many predict important improvements in positioning accuracy and reliability for both outdoors and indoors, while some others show uncertainties in system interoperability and the ability to satisfy all GNSS users. A clear picture of what can be achieved with GNSS and at which cost is important.

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