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SPOT GNSS in Emergency and Location Based Services

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Abstract

Location Based Systems (LBS) market has emerged exponentially since early 2000 in the wake of growing need for Emergency Relief Applications. The argument of course outstanding is which device outperforms all other in diverse scenarios without failure. While many purpose built LBS are in use, SPOT satellite messenger gained attention for its reliability. This paper summates the system architecture and experimental tests results with those of competing Assisted and Global Navigation Satellite Systems (A/GNSS). Our test bed comprised of 26 test points with pre-established database of GNSS difficulty levels in diverse environments in UNSW. Parameters of interest are availability, accuracy and Time to First Fix (TTFF). Relative benchmarking proves SPOT's higher TTFF and higher failure rate in general. While High Sensitivity GNSS and Assisted GNSS (MS-Based and MS-Assisted) had higher availability, higher accuracy and lower TTFF. Altogether fewer failure scenarios, trustworthy coverage with cost effectiveness were observed for MS-Based AGNSS which is vital for LBS applications. However reliance on wired or wireless IP network potentially limits the performance in non-existent underlying infrastructure in remote applications. SPOT demonstrated higher TTFF and failure rates in test scenario. On the contrary Assisted GNSS (MS-Based or MS-Assisted) can provide a reliable, cost effective and open source alternative to SPOT satellite messenger with better TTFF, availability and accuracy for consumer and research applications.

Keywords: SPOT, AGNSS, LBS, Performance (Availability, Accuracy, TTFF)

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1. Introduction

GNSS has long been deployed for navigation and positioning since the early 1960s; however the universal performance and applicability has been questionable. Parameters like accuracy and availability can degrade substantially, in urban canyons, indoor or unclearly visible sky environments result in problems like signal blockage, attenuation, multipath and signal interference. (Brown and Olson, 2006). This is especially unacceptable in location determination for emergency services e.g. fire fighting, search & rescue and life saving (SoL) operations. Assisted GNSS (AGNSS) positioning systems may provide alternatives (LaMance et al. 2002; Bryant 2005) since conventional GNSS chipsets take around a minute to compute the first position fix (Diggelen, 2009). Several government mandates such as the US E911 (FCC, 2009), dictate time and response critical Location Based Services (LBS) systems to provide a fix more than 95% of the time within the first few seconds.

1.1 Generic LBS

Figure 1 demonstrates the conceptual building blocks of a generic Location Based System.

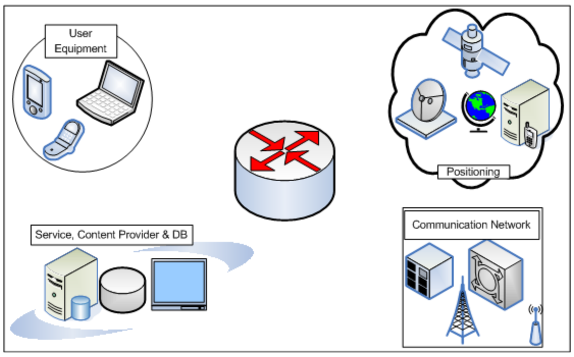

Figure 1: Building Blocks of Generic LBS

Generic LBS would consist of user equipment with embedded GNSS chipset which acquires a position fix from satellites. The user equipment is then remotely connected to first hop routing point to report the local parameters and system health. This routing point can be a base station (cellular or Wi-Fi) that serves the requests and interfaces with the outside world like internet and emergency service providers from where appropriate response is arranged.

1.2 Conventional LBS variants

A variety of LBS variants are available for the purpose. Conventional systems include Emergency Position

Indicating Radio Beacons (EPIRB), Emergency Locator Transmitters (ELT) or Personal Locator Beacons (PLB). EPIRBs transmit location and tracking beacons at specified intervals of time. They can be used for tracking, sending distress signals in close proximity and location detection. There are various generations of EPIRBs in the range of 121.5-406 MHz. Some of these frequencies have been phased out.

ELTs are primarily used for military applications where PLBs are used to indicate personal distress in maritime applications. All of these devices use Cospas-Sarsat system (incorporated 1979) predominantly used for military applications by Canada, France, US and Russia. The system consists of satellite and ground terminals responding immediately to beacons originating from EPIRBs, PLBs and ELTs. These three systems are somewhat similar to SPOT despite being old-fashioned. The network is operated by National Environmental Satellite, Data and Information Service (NESDIS), which is a division of National Oceanic and Atmospheric Administration (NOAA).

It operates the Search and Rescue Satellite Aided Tracking (SARSAT) System to locate mariners, aviators, and recreational enthusiasts in distress globally. The SARSAT system is based on NOAA satellites in low-earth (LEO) and geostationary orbits (GEO). The satellites relay distress signals retrieved from emergency beacons to terrestrial stations and ultimately to the U.S. Mission Control Center (USMCC) in Suitland, Maryland. The USMCC alerts the appropriate search and rescue authorities about the users and their location. The operation is graphically shown in Figure 2, (NOAA public domain, 2007).

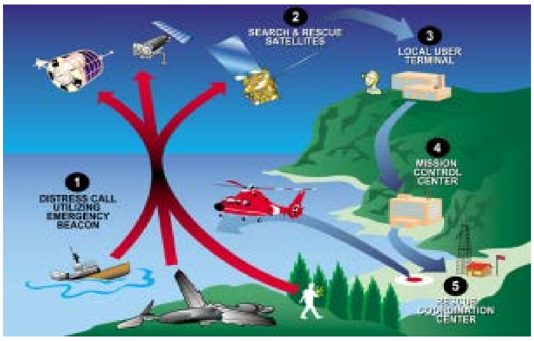

Figure 2: COSPAS-SARSAT Global Operation (NOAA, 2007)

On the other hand, SPOT is a modernized satellite messenger system marketed for location based services; the details of this system are introduced in the following section. SPOT claims to be ideal boasting an availability greater than 96-99% of the time within 1200secs (FindMeSpot, 2009) and the system to function with 98% accuracy in several positioning scenarios with clear sky view.

2. SPOT Satellite Messenger

SPOT Satellite Messenger uses the GNSS satellite network to acquire its coordinates, which up-link the information to the Global Star commercial satellite constellation. The Global Star network transmits this information to their earth stations. The information is broadcast to subscribed Cellular Operator which sends an SMS notification. Remote user coordinates are plotted on Google Maps and uploaded to the personalized web account.

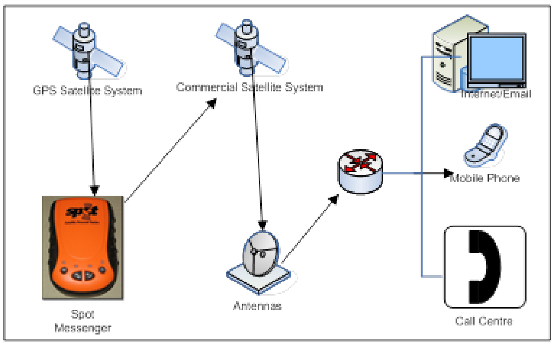

Figure 3: SPOT Satellite Messenger System

Figure 3 elaborates the simplex transmission flow where there is no feedback mechanism for the remote user. If sufficient GNSS and commercial satellites are available and communication is successful, the user is capable of conveying four message functions. Check-in (ON/OFF), Safety Notification (OK), Assistance Required (HELP) and Distress Signal (911). Four LED(s) show the device status and messaging status. The buttons can be re-configured for different responses. As a button is pressed the SPOT system operation starts with acquiring the initial position fix using GNSS. This is then forwarded with the location details to Global Star's commercial 48-56 satellite constellation. These satellites in turn relay this location to the terrestrial augmentation stations. The subsequent response is received on email, cell phone (SMS), the Emergency Response Centre with finally updating the SPOT user profile. The SMS received on mobile phones as shown in Figure(s) 4a and 4b.

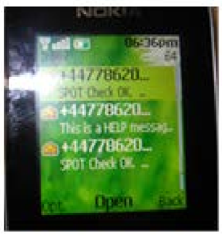

Figure 4a: Message updates on mobile phone

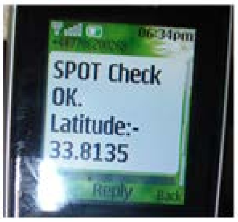

Figure 4b: Exact location received via SMS

Figure 5a shows the periodic updates on web-based user-profile. The Latitude/Longitude information plots, periodic updates on SPOT's user profile identifying the location, time and other details of remote person can be seen.

The location details received from the SPOT ground based network which in turn are conveyed via cellular network carrier.

GPX CSV KML

Select	Time (Australia/Melbourne)	Name	Message Type	Latitude	Longitude	Nearest Location
☑	10/31/2008 06:01:48 PM	sarwara	OK	-33.8135	151.1878	
☑	10/27/2008 08:36:32 PM	sarwara	OK	-33.919	151.2273	
☑	10/27/2008 08:32:03 PM	sarwara	OK	-33.9178	151.2257	
☑	10/27/2008 08:18:19 PM	sarwara	OK	-33.916	151.2266	
☑	10/27/2008 07:53:27 PM	sarwara	Help	-33.9183	151.2342	
☑	10/27/2008 07:51:40 PM	sarwara	OK	-33.9181	151.2341	

Figure 5a: Entry updates in user-profile

The updates on Google Maps which are plotted (Figure 5b) and uploaded in the user at ground station's internet server. User can configure three viewing modes i.e. the map, satellite and hybrid.

Figure 5b: Plots of tracking/logging updates

Figure 6 shows the tracking and logging updates in online user profile. The current location, tracking information, user profile, lat/long and time stamps can also be seen. Subsequent user foot prints can be plotted via the tracking function preconfigured for SPOT devices in the user profile.

The satellite mode is different from the map mode in that it provides a much granular area snapshot. Such view supports timestamps, location tracking and user profile information. Hybrid mode is recommended which gives detailed street, locality, maps, user profile, lat/long and date/time stamps.

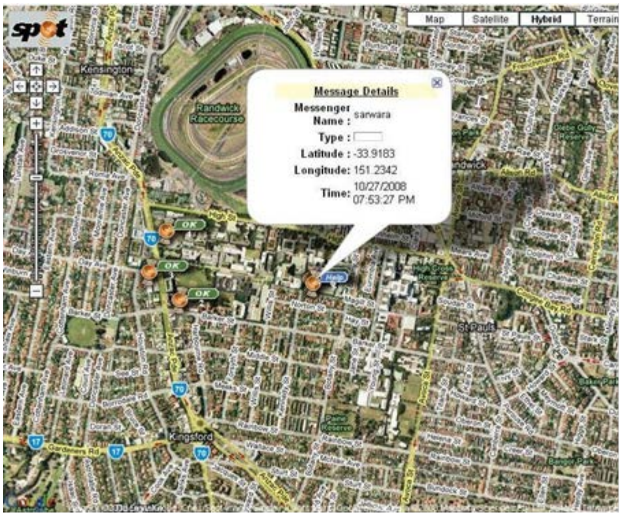

Figure 6: Lat/Long Plots on Google Maps (Hybrid Mode)

2.1 Hardware overview

The SPOT user handset is manufactured by AXONN LLC and marketed by SPOT Inc. The chipset used is Nemerix Nx2, (Nemerix, 2007) base band processor which is claimed to be ultra-low power, high performance, stand-alone and hosted AGNSS L1 C/A code capable. It uses the Low Earth Orbit; LEO satellite constellation of Global Star, which is claimed to be one of the leading communication satellite link providers. The SPOT uses the AXTracker STX2 technology, a small satellite transmitter, to determine a customer's location.

2.2 Coverage footprint

The SPOT network transmits that information to friends, family or an emergency service center, (FindMeSpot, 2009; Axonn, 2009). SPOT boasts a reliability of 96-99% or more in most places around the globe. It uses GNSS to determine a user's location and the SPOT satellite network to transmit that location and the user's status. The SPOT satellite network is a commercial satellite network with a claimed 99.4% reliability rate while processing over 6 million messages a month - the equivalent of 2.3 messages per second (FindMeSpot, 2009). A global footprint of more than 90-95% is posted on company website. This phenomenon is tested here in a mixed scenario environment against the following benchmarking equipment, to test the reliability of SPOT as an LBS solution.

3. Experimentation

3.1 Benchmarking equipment

The performance of SPOT is compared with normal GNSS, high-sensitivity GNSS and AGNSS. The test results are reported and then a modified system design to remediate problems found in competitor devices is proposed. The new system can eliminate the problems of one-way communication, incorporates a user health monitoring system, emergency support feedback mechanism and hybrid network support for seamless connectivity.

For benchmarking a Secure User Plane Location (SUPL) enabled AGNSS/GNSS device, Mio pocket PC phone, capable of providing a position fix in different modes has been used. SUPL is an emerging standard produced by the Open Mobile Alliance (OMA) (Open Mobile Alliance, 2007). The SUPL standard allows Mio's client to connect to Andrew Corporation's AGNSS location server using the TCP/IP protocol (Figure 7), and request its location. SPOT's performance has been compared with the results presented in SUPL performance and analysis.

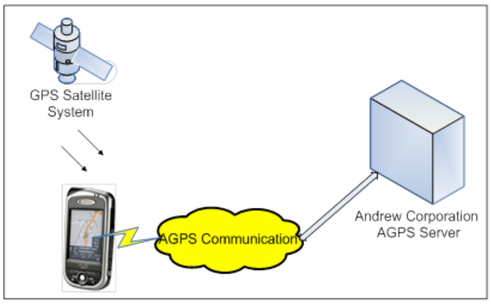

Figure 7: General A-GNSS Technique

Mio A701 can run in both MS-based and MS-Assisted AGNSS modes through Andrew Corporation's Server (CommScope, 2009). It also works as a High Sensitivity Stand-Alone GNSS receiver. Once a TCP/IP connection is established, the SUPL Enabled Terminal (SET) can determine its location using Assisted GNSS (Broadcom, 2007). Mio can also provide a position fix in Stand-Alone mode, incorporating a HS SirfStar-III GNSS chipset (-160dbm) (SiRF, 2009). Figure 7 shows the operation of Mio AGNSS system. Garmin eTrex (Garmin, 2005) was used as a normal GNSS (-120dBm) to analyse the relative performance of SPOT's Nemerix NX2/NJ1030, claimed to be Low RF noise, Ultra low power, L1 C/A code, with similar sensitivity.

3.2 Test bed

A test bed comprising a total of 26 positions was selected around the University of New South Wales, UNSW campus. These positions represent a diverse range of environments including open sky view, different levels of tree cover, adjacent to large buildings, under cover and indoors. Difficulty levels ranging from 1-10 are established depending on fraction of open sky visibility and potential of error factors like multipath. It is important to understand these difficulty levels on the basis category characterization.

Figure 8: Test Bed in UNSW vicinity

3.3 Material attenuation

For example indoors, L1 = 1500 MHz signals would experience different levels of attenuation (dB) when subject to different materials. A drywall, glass or plywood can cause much lower attenuation e.g. 1-3dB. On the other hand bricks and concrete can cause attenuations levels ranging between 5-33dB (Stone, 1997). Similarly the attenuation in buildings is 5-15dB for residential houses, 20-30dB for office buildings >30dB for underground car parks and tunnels as given in Table-2 (Mautz, 2009).

3.4 Test point classification

There are five categorical classifications of scenarios i.e. Urban, Suburban, Rural, Indoor and Open sky. Figure 8 shows the UNSW map marked with 22 outdoor TPs in the UNSW vicinity. The remaining 4 haven't been marked as they are indoors. These were first defined in (Li et al., 2009) as test points for AGNSS. Here we test SPOT in the same locations to see how it would perform in difficult terrain. SPOT was tested in these locations on the basis of difficulty levels to truly test its potential and verify the claims boasted by the company and its credibility as a reliable LBS solution.

4. Experimentation and Analysis

The performance was compared to Hi-Sensitivity GNSS, Assisted GNSS and Low-Sensitivity GNSS. Difficulty level, DL = GNSS difficulty levels are estimated at a particular site ranging between 0 (least) to 10 (most difficult). This is estimated based primarily on how much open sky is visible; e.g. 0 means open sky (more than 90% sky), 10 means indoor (less than 10% sky). A few TPs were not able to be revisited because of construction work. A total of 68 attempts to position using SPOT were made at 26 test points to verify the availability and TTFF claims.

All 26 test points are shown with the map references, difficulty levels and type of terrains. The results were segregated in Pass/Fail depending upon the successful communication, message delivery and online user profile update. Where the SPOT successfully delivered a message and/or updated the user profile a Pass was reported and a total of two attempts were made in each of those locations. Otherwise, a Fail was reported and a total of three attempts were made to verify if any other factors of physical diversity affected performance. Where multiple results are seen comprising both Pass/Fail, a total of three attempts was made comprising 1 Pass and 2 fails. The SPOT passed when eTrex tracked 6 or more satellites. Assumption was established that the relative sensitivity of eTrex~SPOT, hence subsequent parameters can also be related and substituted.

The further columns specify the Min/Max number of satellites seen by SET-Assisted and SET-Based AGNSS and Stand-Alone GNSS (high sensitivity) for comparison. The final column demonstrates the different SPOT TTFF in each scenario. It can be clearly seen that SPOT has the highest TTFF and lowest number of satellites visible as compared to AGNSS and HS-GNSS, in each scenario.

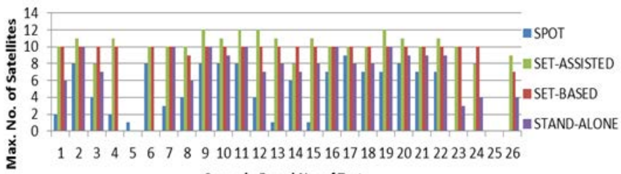

Figure 9a: Satellite availability with difficulty levels

Figure 9a plots the detailed test results of compared devices in diverse scenarios. SPOT and eTrex track the same number of satellites as of similar sensitivity levels=-120dBm, Min and Max (number of satellites) column about SPOT in the graphs. Since SPOT tracks the least number of satellites, obviously the main reason for failure appears to be the GPS chipset. The x-axis shows the test point and y-axis shows the maximum number of satellites visible for each test. Figure 9a shows the deterioration in performance in terms of satellite visibility for eTrex and SPOT with an increase in difficulty level. SET-Assisted AGNSS however consistently tracked more satellites in all scenarios. Here, Standard Deviation (SD) has been calculated using (RMS) by eq.(1) and (2):

$$\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - \bar{x})^2} \qquad (1)$$

Where   is the series of variable distribution in STD σ:

$$\bar{x} = \frac{x_1 + x_2 + \cdots + x_N}{N} = \frac{1}{N}\sum_{i=1}^{N} x_i \qquad (2)$$

Performance parameters of all devices in urban scenario are considered for empirical analysis. These figures provide the full-scope error value results of SPOT accuracy. The highest level of mean vertical errors in an urban scenario for SPOT was observed to be 155.8 with corresponding STD to be 49.7. Similarly, the highest level of mean horizontal error in urban environment was 167.5 with corresponding STD value to be 78.3 – with 4.5 visible satellites on average and TTFF of 680secs.

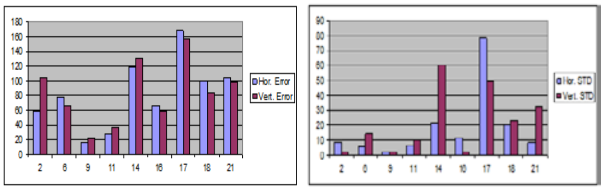

Figure 9b (i): Mean Horizontal vs. Vertical Errors (left)
Figure 9b(ii): Standard Deviation (right)

Here, Dilution of Position (DOP) – quality of satellite constellation geometry is an important factor to be considered in positioning accuracy. Satellite geometries can increase or decrease error values where DOP values are inversely proportional horizontal (HDOP) and vertical (VDOP) error values. Such error values are significantly impacted by the increase in difficulty levels. For comparison and ease of understanding, multiple identical values have been grouped together for all four devices under benchmark. The disparity between the HDOP and VDOP values is larger with drop in the numbers of visible satellites. Eventually the situation can further be implicated due to poor sky visibility or multipath errors.

For each of the comparable test point of the subject devices, the horizontal and vertical error values (m) are positively proportional to the corresponding difficulty levels. Figure(s) 9b, c, d and e demonstrate high horizontal and vertical errors with standard deviation.

It is obvious from the following plots Figure(s) 9 (c, d, e and f) that vertical error values are higher than the horizontal error values assuming zero clock errors. On the contrary, in some test points horizontal values have shown higher levels of error and standard deviation – such variation cannot always practically be eliminated, hence considered usual.

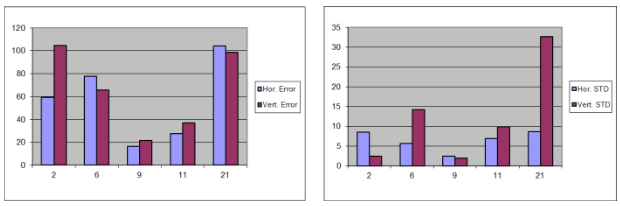

Figure 9c (i, ii) SPOT Messenger Mean Horizontal vs. Vertical Errors (left) and Standard Deviation (right)

The DOP values between 1-2 are considered ‘Excellent’ whereby the values between 2-5 are considered ‘Good’. The values between 5-10 are ‘Moderate’, 10-20 are considered ‘Fair’ where values higher than 20 are considered ‘Poor’. The mean horizontal error for SET-Assisted was 21.5 with STD of 32.5 in urban environment. In the same test point, the mean vertical error was 29 with corresponding STD to be 42.9 (Figure 9d). 11.2 secs TTFF was recorded with 6.4 visible satellites on average.

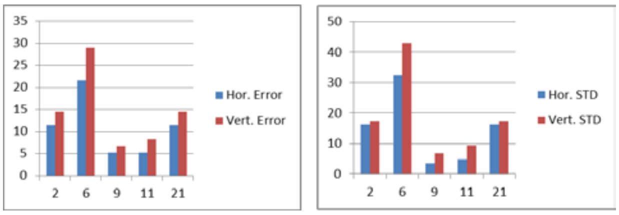

Figure 9d (i, ii) SET-Assisted AGNSS Mean Horizontal vs. Vertical Errors (left) and Standard Deviation (right)

The mean horizontal error for SET-Based was 23.3 with STD of 28 in urban environment. In the same test point, the mean vertical error came to be 32.2 with corresponding STD to be 42.8 (Figure 9e). 10.4 secs TTFF was possible with 6.9 satellites on visible on average.

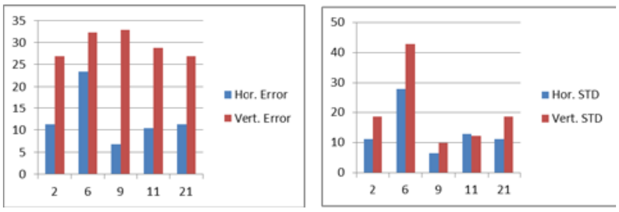

Figure 9e (i, ii) SET-Based AGNSS Mean Horizontal vs. Vertical Errors (left) and Standard Deviation (right)

The mean horizontal error for Stand-Alone system was 18.9 with STD of 28.3 in urban environment. In the same test point, the mean vertical error came to be 33.2 with corresponding STD to be 36.9 (Figure 9f). 42.1 secs TTFF was recorded with 5.3 visible satellites on average.

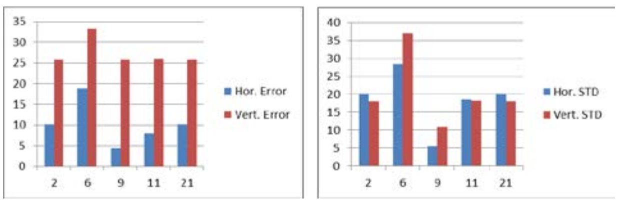

Figure 9f (i, ii) Stand-Alone GNSS Mean Horizontal vs. Vertical Errors (left) and Standard Deviation (right)

Figure 10 (a, b, c & d) show the individual device performance plots with Min, Max, and Mean of no. of visible satellites and TTFF. SPOT passed in Test Points where it tracked 6 or more satellites. Lowest numbers of tracked satellites, higher TTFFs and lower overall availability rates are obvious.

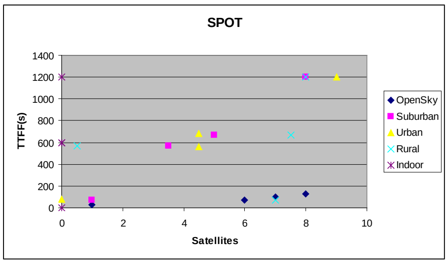

Figure 10a: SPOT Performance

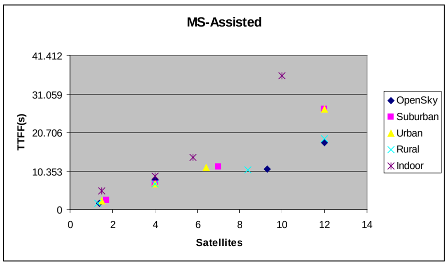

Figure 10b: MS-Assisted AGNSS Performance

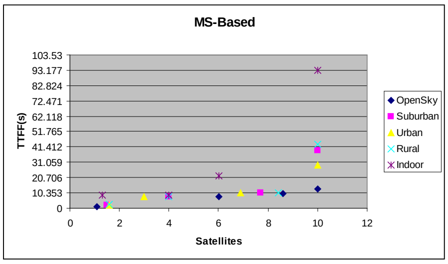

Figure 10c: MS-Based AGNSS Performance

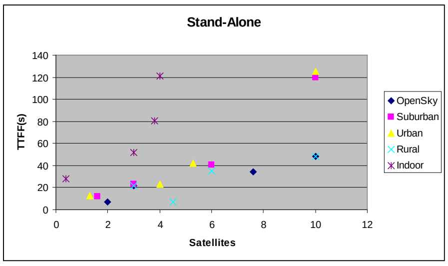

Figure 10d: Stand-Alone HS GNSS Performance

Figure 11(a, b) shows comparative overall performance; SPOT with lowest availability rate ~ 40%. Average numbers of satellites tracked by SPOT is 4.8 where Set-Assisted and Set-Based tracked 6.8 and 7.3 respectively. Stand-Alone system tracked 5.8 satellites which superior to SPOT. Mean TTFF=544s is the highest, where average of visible satellites is lowest and failure rate about 60% (Figure 10). SET-Based AGNSS outperformed the rest with lowest TTFF, highest mean satellites and lowest failure rate.

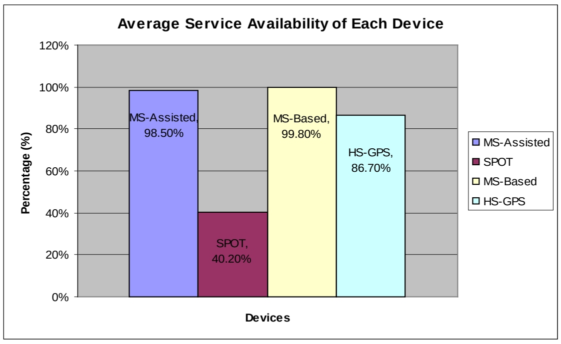

Figure 11a: Service Availability

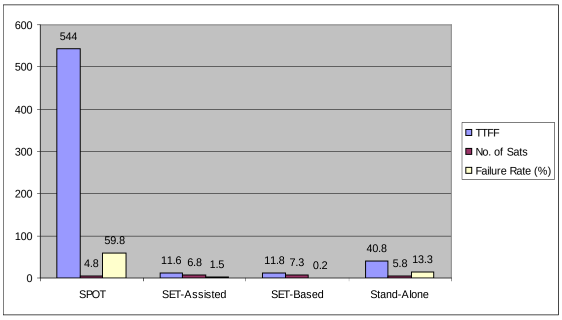

Figure 11b: Performance Parameters

5. Conclusions

SPOT claims a global footprint of 96% coverage with open or partial open sky availability. However the experiments revealed the average reliability and availability not exceeding 40% in test areas. This is evident from lack of communication throughout subject to ~ 6 satellites. AGNSS demonstrates an average reliability in the ranges of 98 and 99% by tracking more satellites. Stand-Alone HS GPS, which has a relatively lower availability rate than AGNSS stands at 86%, much higher than SPOT. Conclusively all three benchmarking devices conform to much higher availability percentages than SPOT satellite messenger.

SET-Based performed the best with lowest TTFF, highest mean number of satellites and lowest failure rate. Excluding the indoor scenario from test results provides a performance correction of ~ 4% to SPOT. This declares the device a questionable option for high demanding; time critical Location Based and Emergency Services.

6. Discussion

Through the years, LBS has remained an unexplored field due to which economic and human losses have been encountered. Most recently companies have realized the potential growth in the field but a lot has to be done. Its importance can further be understood by the fact that LBS market was 0.5B in 2003 and exceeded 28B by the end of 2008. However the R&D efforts have sped up with yet fewer had been promising.

More than GNSS or LBS, modern systems should serve beyond E911 e.g. asset tracking, community services, vehicular navigation, aircraft aiding devices, weather forecasting, intelligent transportation systems, environmental applications, telematics and kinematics. Specific applications might include security and intelligence operations, notification systems for emergency responders, public notification systems, people and asset monitoring, automatic emergency call down systems, raise preparedness in disaster situations and more. More research is needed into present devices to improve performance to required levels.

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Biography

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