Polaris Wireless

July 2009

POLARIS WIRELESS

LOCATION TECHNOLOGY OVERVIEW

Polaris Wireless Is An Industry Leader

Polaris Wireless has successfully developed and commercially deployed a proprietary, high performance wireless location technology that supports delivery of the full range of location-aware applications and services. Polaris was founded in 1999 with the sole purpose of developing industry-leading wireless location technologies; the company remains totally dedicated to that singular objective.

The company's products are currently deployed in over 20 wireless networks for demanding applications such as E911 emergency call and Lawful Interception systems. Customers include leading wireless service providers in the USA as well as government agencies in the Asia Pacific region.

Polaris currently has about 120 full- and part-time employees dedicated to research, development and deployment of its unique location system. The company is headquartered in Santa Clara, California, with additional offices in Seattle, Washington, Santiago, Chile, Bangalore, India and Tokyo, Japan.

Polaris's Wireless Location Signatures (WLS) technology delivers the best performance in challenging urban and indoor settings where A-GPS does not work well. WLS is a future proof solution with a robust roadmap of performance improvements, incorporating measurements from 2G, 3G and 4G air interfaces, as well as evolving handset technologies, such as A-GPS, WiFi, Bluetooth and UWB. WLS is a platform for enabling high quality location capabilities in today's and tomorrow's networks. It provides significantly better performance than alternatives, such as Cell-ID, Cell-ID/timing, ECID and O-TDOA. WLS can be used as a standalone system or in hybrid combination with A-GPS for both Control Plane and User Plane (SUPL) location implementations. WLS enables the full range of applications and services (e.g. E911, LI, LBS) in a scalable and economical platform.

Polaris's high performance, software based technology and algorithms are backed by more than 45 patents that have been awarded or are pending. Much of this intellectual property base is fundamental to achieving high accuracy and fast time to fix in a scalable software location platform.

The company also drives technology innovation through leadership in the creation and evolution of location standards. For many years, Polaris has participated in location committees and other groups within the 3GPP and OMA standards setting bodies. This includes significant contributions to location capabilities in 2G GSM, 3G UMTS and emerging 4G LTE. For LTE, Polaris has taken an active leadership role as the rapporteur for the control plane architecture and interfaces definition in 3GPP. In addition, the company actively participates in regulatory and industry bodies related to E911, Lawful Interception and location-based services.

Polaris Wireless Location Signatures (WLS) Technology

The Polaris Wireless Location Signatures (WLS) technology is an extremely cost-effective software based solution to the high-accuracy location determination problem, because no changes in the wireless device or in the wireless service provider's base stations are required.

All digital wireless networks have measurements, such as signal strength or signal-to-interference ratio, built into reporting protocols in the air interface standards in the form of call processing messages used to make handover decisions. WLS uses a pattern matching approach to capitalize on this reporting structure that is inherent in all wireless air interfaces. As a phone measures signal strengths and time delays from nearby cells, it compiles a list of these measurements and reports them back to the serving base station, with the reporting procedure varying from protocol to protocol. These measurements can be correlated against a database of radio environment maps, where the best match indicates the most likely position of the handset.

WLS has some significant advantages over other position location technologies including the following:

1) **High Accuracy** – The proven Polaris WLS technology yields accuracy results that meet the FCC's E911 Phase II mandate and commercial LBS requirements. WLS performs well in challenging environments, such as urban and indoor, where GPS does not perform well.

2) **Short Time to Fix** – The Polaris WLS system has very low time latency in calculating handset position. In fact, it can determine location using the first measurement report provided by the handset. Field trial and commercial deployment results show that the steady state accuracy of the Polaris WLS technology is achieved within about 5 seconds in urban environments.

3) **Low Cost** – Because the Polaris WLS technology requires only software on a location center connected to the network through standard interfaces, the cost of this system is an order-of-magnitude less than virtually every other high-accuracy location technology, such as TDOA, AOA and O-TDOA.

4) **Rapid Deployment** – The Polaris WLS technology requires no additional hardware to be installed within the network or the user handsets. Its relative simplicity enables rapid deployment throughout a wireless network.

5) **Hybrid Implementation** – The highly robust and independent Polaris WLS technology may be used as a standalone solution or in hybrid combination with A-GPS. Hybrid systems off the advantage of consistent location performance for both accuracy and time to fix across the range of environments, including urban, suburban, rural, outdoor and indoor.

Polaris WLS Performance

Polaris WLS is a high performance location platform that uses powerful pattern matching technology to provide location across the range of air interfaces and handset technologies. As Figure 1 illustrates, WLS currently performs in 2G, 3G and mixed 2G/3G network scenarios, with or without A-GPS capabilities in the handsets. This is the foundation for Polaris's 5-50h series Hybrid solution, which delivers 5 second time-to-fix with 50 meter accuracy at 67th percentile across the range of environments --- urban, suburban, rural, outdoor and indoor. As air interfaces evolve and handset technologies increase, Polaris's is creating more advanced solutions, such as the 4-40h series Hybrid designed to achieve 4 second time-to-fix with 40 meter accuracy. These advanced solutions take advantage of measurement information from multiple air interfaces (2G, 3G, 4G) and handset technologies (A-GPS, WiFi, Bluetooth, etc.).

As Figure 1 shows, Polaris's ultimate vision is to build the 1-10h series Hybrid solution, delivering 1 second time-to-fix with 10 meter accuracy. While such a solution does not exist today, the underlying pattern matching technology in WLS combined with the growing numbers of air interfaces and handset technologies provide a rich road map of future improvements to drive location performance to new levels.

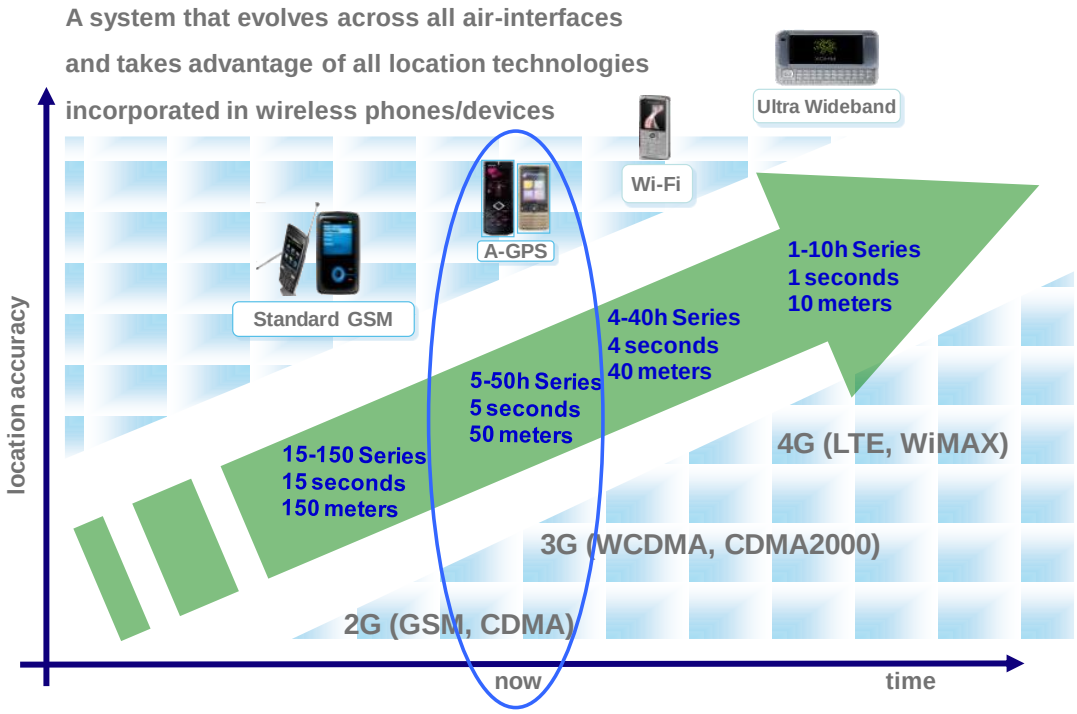


Figure 1. Polaris WLS performance evolution across air interfaces and technologies.

Polaris WLS consistently delivers high accuracy and rapid time to fix. Performance in urban areas is typically better than 50 meters for 67% of fixes and 150 meters for 95% of fixes, as shown in Figure 2. In suburban settings, WLS delivers 100 meters for 67% and 300 meters for 95% of fixes.

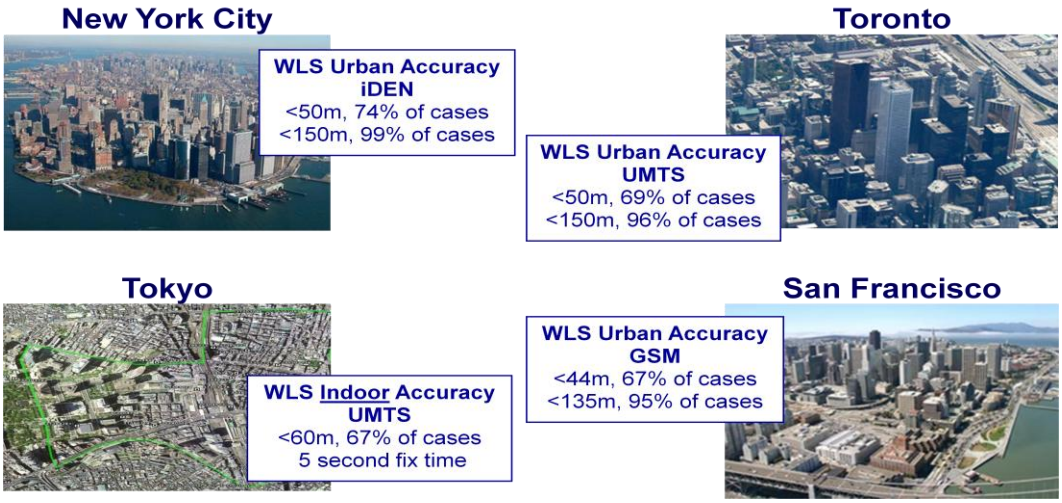


Figure 2. Polaris WLS accuracy for different cities on iDEN, GSM and UMTS for outdoor and indoor use cases.

In challenging indoor environments, accuracy is typically 60 to 70 meters for 67% of fixes, as is demonstrated in Figure 3 with results from indoor testing in Tokyo. The figure also shows that time to fix for WLS can be tailored to the application, with fix times of a few seconds possible. Optimal accuracy is achieved within 5 to 10 seconds in urban environments.

This WLS performance underpins Polaris's Hybrid solution, which combines WLS with A-GPS, to drive system performance into urban canyon and indoor areas where GPS signals are obstructed.

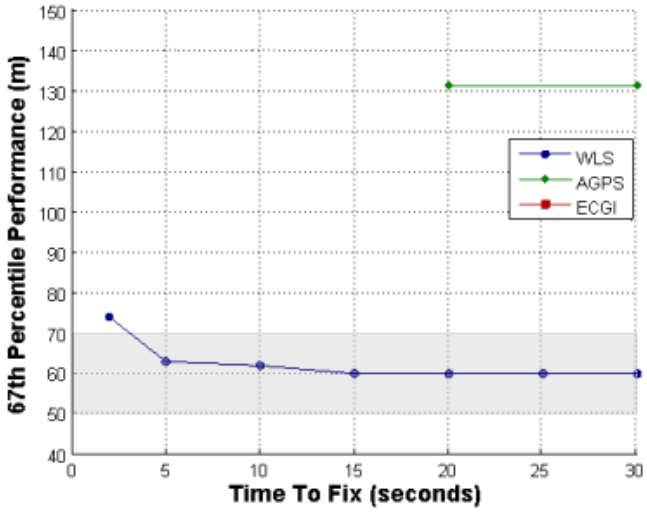
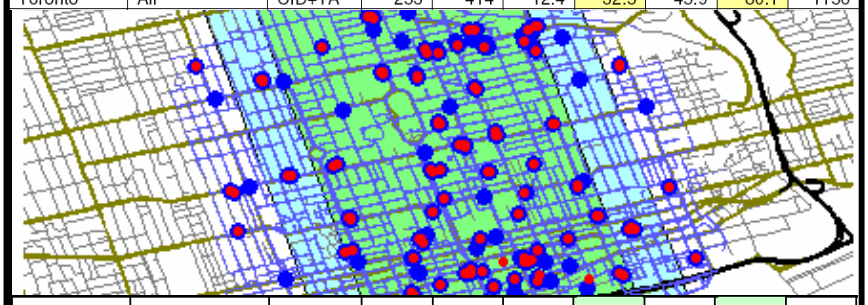


Figure 3. Polaris WLS accuracy and time to fix compared against A-GPS for all indoor fixes.

Accuracy of WLS is usually five to 10 times better than Cell-ID/timing methods, as can be seen from Figure 4 with results from Toronto. The figure also illustrates the consistency of WLS performance for different usage scenarios, such as stationary, pedestrian and vehicular mobile.

GSM Area	Test Type	System	67% Error (m)	95% Error (m)	CEP 50m (%)	CEP 100m (%)	CEP 150m (%)	CEP 300m (%)	No. Calls Total
Toronto	Stationary	WLS	56	170	63.5	84.6	93.6	98.7	531
Toronto	Walking	WLS	44	221	70.1	88.5	92.0	100.0	87
Toronto	Vehicle	WLS	57	158	59.1	87.6	92.4	99.1	105
Toronto	All	CID+TA	253	414	12.4	32.5	45.9	80.1	1156



UMTS Area	Test Type	System	67% Error (m)	95% Error (m)	CEP 50m (%)	CEP 100m (%)	CEP 150m (%)	CEP 300m (%)	No. Calls Total
Toronto	Stationary	WLS	48	139	68.7	90.2	96.3	99.8	591
Toronto	Walking	WLS	49	101	69.2	92.6	98.9	100.0	94
Toronto	Vehicle	WLS	57	147	63.9	85.3	95.1	100.0	122
Toronto	All	CID+RTT	230	454	13.5	32.9	46.4	80.1	1287

Figure 4. Polaris WLS accuracy versus Cell-ID/timing (Cell-ID/TA in GSM, Cell-ID/RTT in UMTS) for GSM and UMTS in different usage cases.

Polaris WLS is a future proof technology with a roadmap of improvements into the future. For example, WLS can take advantage of many different measurements (e.g. 2G, 3G, 4G, WiFi) to increase accuracy. In addition, WLS can capitalize on measurements available for other standard technologies, such as ECID, AFLT or O-TDOA; WLS incorporates these measurements using pattern matching techniques to achieve higher accuracies.

WLS Technology Overview

The Polaris Wireless Location Signatures (WLS) technology is based on the observation that the radio environment varies from location to location, and if enough elements of the RF environment can be measured with sufficient accuracy, each set of measured values will provide an RF signature that uniquely identifies a particular location. Because the control or overhead channels of a wireless network are broadcast at constant power, they provide a signature that is predictable and repeatable.

The basic elements of the Polaris WLS system for GSM, as shown in Figure 5, are the SMLC (Serving Mobile Location Center) and the PSD (Predicted Signature Database) Toolkit. The Location Applications element in this figure could represent multiple commercial LBS applications or E911 emergency services. The system architecture for WCDMA / UMTS will be very similar.

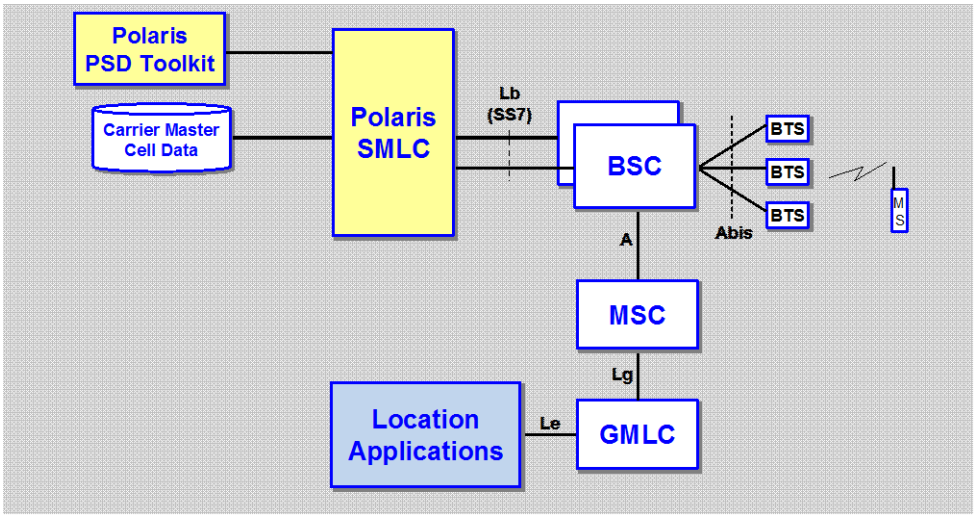


Figure 5. Reference Polaris WLS System Architecture for GSM

The GMLC (Gateway Mobile Location Center) receives the location requests and forwards that information to the SMLC. The GMLC subsequently provides the resulting

location estimate(s) that are calculated by the SMLC to the Location Applications element. The location requests can be initiated by the handset user or a specific location application. This interface also extracts the required information from the network messages and transforms them into the format needed by the SMLC. The SMLC consists of the Polaris Location Engine, the Predicted Signature Database (PSD), and the Polaris PSD Manager.

The Location Engine is comprised of proprietary algorithms that estimate the location of the handset by comparing the time series of reported signal strength measurements to the values stored in the PSD. These algorithms employ a very complex set of statistical pattern matching techniques. The Location Engine can provide a single time-tagged location estimate to the Location Applications element after a fixed time interval or it can provide a continuous stream of time-tagged handset location estimates if such information were required for tracking purposes. It is a straightforward process to configure the Location Engine to support a broad range of location reporting requirements.

The PSD Manager software automatically maintains the PSD. When network changes, such as frequency plan alterations, are made, the software automatically corrects the PSD for the change. These database updates are made automatically, without operator intervention, based on change information within the service provider's network configuration database.

The PSD contains predicted signal strength values for all of the control channels that might be reported by a handset at each point in the carrier's service area. Figure 2 illustrates a portion of the PSD, where the horizontal dimensions of the array represent a uniform grid of points, covering the service area and the vertical dimension has one entry for each reportable channel. Thus, a single column of the array contains the predicted signal strength value for each channel at that grid location. These predicted values are generated off-line through appropriate combinations of RF propagation models and field calibration measurements. Polaris has developed proprietary techniques for optimally combining this information to provide a highly accurate PSD. The predictions incorporate power and antenna characteristics of the base stations and absorption, reflection, and diffraction by the terrain, buildings, and other structures between the base stations and grid points of the PSD. The PSD for an entire nationwide wireless network could be large, but in practice, to estimate the location of a particular handset, it is only necessary to load the portion of the PSD corresponding to the reported serving cell and its neighbor cells.

Polaris Wireless in Standards

Polaris WLS is currently supported in 2G GSM and 3G UMTS air interfaces for control plane and user plane (SUPL) implementations. For 4G LTE, WLS is supported in 3GPP Release 8 for user plane and in Release 9 for control plane. Polaris's LTE product

roadmap includes Release 8 (with pre-Release 9 control plane features), Release 9 with control plane, and Release 10 as advanced features are defined in 3GPP.

WLS can take advantage of measurements available for other technologies, such as ECID, AFLT or O-TDOA; WLS incorporates these time delay and other measurements using pattern matching algorithms to achieve higher performance than is possible with these other methods. This approach provides great flexibility for WLS to incorporate measurements from different air interfaces (2G, 3G, 4G, WiFi) and location technologies (ECID, AFLT, O-TDOA) to improve performance.

The company actively participates in 3GPP and OMA standards setting bodies to ensure optimum location technology performance. Polaris's objectives in the standards development processes include the following:

- Advance the capability of pattern matching technologies through the accessibility of appropriate network measurements
- Support other initiatives within the standards organizations that best promote
    - better mobile and system performance
    - improved location technologies
    - improved network efficiency

Some of Polaris's current standards initiatives in 3GPP and OMA include the following:

- Development of control plane location solutions for LTE. Polaris is rapporteur for the architecture and interface definitions in 3GPP.
- Incorporation of Round Trip Time (RTT) mechanisms in LTE to better improve performance, particularly for asynchronous networks.
- Definition of pattern matching in UTRAN to allow improved control of messaging and measurements.
- Achieving optimal hybrid support by removing restrictions on simultaneous location sessions in control plane.
- Adding measurements, such as RTT, in user plane to improve performance and provide consistency between control and user planes.

Conclusions

As a company, Polaris Wireless is dedicated to creating industry-leading location technologies. The company has developed and demonstrated that the WLS technology is a high-performance and cost-effective solution for LBS, E911, LI and other applications.

The WLS technology has been extensively evaluated in commercial networks using TDMA/IS-136, GSM, CDMA2000, UMTS and future LTE air interfaces. The WLS system can be deployed as a standalone, complementary, or hybrid implementation.

Most importantly, WLS′s pattern matching approach addresses location in 2G, 3G and emerging 4G air interfaces, across the range of handset technologies, such as A-GPS, WiFi, Bluetooth and UWB. In other words, WLS is a universal wireless location solution forming the foundation for current and future networks. Numerous field trials and commercial deployments over the past four years have established that the Polaris WLS technology is robust, scalable, highly reliable, and provides excellent accuracy.

In addition, Polaris is an industry leader in location standards development, particularly for LTE, at 3GPP and OMA. The company′s software product roadmap includes all the standardized location technologies (Cell-ID, Cell-ID/timing, ECID, A-GPS) in addition to Polaris′s WLS pattern matching technology. This makes Polaris Wireless an excellent partner for leading-edge solutions for wireless location.

