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# The Future of GIS: Real-time, Mission Critical, Location Services

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**Paper 8.1**

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## Abstract

Geographic information technologies are rapidly transitioning from desktop solutions to Web and wireless services. New safety and security requirements now demand that spatial applications be highly scalable, reliable and secure as organizations deliver content services to hundreds, and thousands of users. The next generation of GIS will be realized as the use of spatially-enabled data and services become embedded into an organization's mainstream computing architecture. This paper highlights the emerging the software architecture necessary for deploying this new class of real-time location services.

## Introduction

Interest in spatial information is on the rise. This interest is both stimulated and realized by the increasing use of geographic information systems, online mapping systems and other geographically referenced information on the Internet, the Global Positioning System, location based services, and navigation systems. The increasing complexity and diversity of georeferenced data, combined with continued progress in information technology, generally make geospatial data an important information source for many commercial, scientific and public sector decision making activities. Increased commercial opportunities for using geospatial information, an increased rate of technological advances, a reduction in costs, and an expanding demand for novel applications are all on the horizon. National mapping agencies play a critical role in these advances by providing much of the core spatial datasets essential for these emerging applications. As the missions and products of NMAs change from analog to digital, it is important that NMAs understand their new customers, partners, and uses of their digital data products. This paper examines one important application area – location aware computing or commonly referred to as location based services (LBSs).

Location-Based Services (LBSs) consist of a broad range of services that incorporate location information with contextual data to provide a value-added experience to users on the Web or wireless devices. In contrast to the passive fixed Internet, users in the mobile environment are demanding personalized, localized, and timely access to content and real-time services. Targeted data, combined with location determination technology, is essential to create personalized value to an end-user's mobile experience. This allows wireless carriers and portals to significantly increase the value of services to subscribers while opening up new revenue opportunities.

Through new applications, mobile offerings can be personalized to a user's lifestyle, tastes and preferences and can be immediately synchronized with other portable devices. The variety and breadth of applications and services is large, from pure content and advertising, to emergency 911, navigational services, fleet and asset management, logistics, and location-sensitive billing. The high level of interest in these services coupled with corresponding technology developments have spurred the emergence of the LBS industry and created a multifaceted assortment of players, service concepts, and business models. This chapter is designed to introduce the major concepts in this rapidly evolving technology and services market.

## Types of Location-Based Services

The separation of services from the telecommunications networks will lead to the establishment of an open, Internet Protocol (IP) based service environment. In the initial phase it will primarily be digital content services that are implemented in this IP environment. However, it will not be long before technologies such as voice over IP will enable multimedia messaging services and real-time call control services to be implemented in an open, IP-based service environment. The first generation location-based services (LBSs) can roughly be divided into six categories:

- **Safety Services**: End-user assistance services, such as Enhanced 911 (E-911), are low usage services designed to provide the end-user assistance in the case of an emergency. These type of services can expect to gain a high market acceptance due to the general concern of the public for the personal security. With a push from the United States Federal Communications Commission (FCC) E-911 mandate and new location solutions, wireless carriers will be able to route an emergency call based on the caller's location and the Public Safety Answering Point (PSAP) jurisdictional boundary, determining the nearest emergency center and drastically reduce response time (FCC, 1996).
- **Information Services**: These services comprise a vast area of applications. Some of these include traffic information, navigation assistance, yellow pages, travel/tourism services, etc. Users will come to expect voice-enabled driving directions and walking directions, as well as information services, whereby requested information is delivered in various ways, such as Wireless Application Protocol (WAP), by a Short Message Service (SMS) message, by Interactive Voice Response (IVR), Multimedia Mark-up Language (MML), or by a call center operator.
- **Enterprise Services**: These services include vehicle tracking, logistic systems, fleet management, and workforce management, and "people finding". Today, many of these services are offered by legacy, mobile data systems. However, with the growing availability of broadband wireless capability, it is likely that many of these services will be merged into the digital wireless networks. It is the enterprise applications where the deployment of mobile LBSs is taking hold first.
- **Consumer Portal Services**: As consumer technology platforms and wireless carrier infrastructures are upgraded to support ubiquitous, accurate location information, consumers will begin to access navigational services, such as driving directions. Location-aware services will enable the delivery of "local" news, weather, and traffic information determined by location of devices – all provided through an icon-based user interface.
- **Telematics Services**: Telematics is most often used to describe vehicle navigation systems, such as OnStar, where drivers and passengers employ Global Positioning System (GPS) technology to obtain directions, track their location, and obtain assistance when a vehicle is involved in an accident. In-car systems, however, are car or machine centric as opposed to hand-held mobile devices, which are user centric by nature. Unlike static CD-ROM-based in-car navigation systems, online mobile systems provide accessibility to up-to-date, time sensitive information and databases.
- **Triggered Location Services**: As carriers form partnerships with location-based application providers and develop direct content relationships with businesses, they will be able to trigger services as consumers or corporate clients enter predetermined areas. Example triggered services include: location-sensitive advertising, location-sensitive billing, and location-sensitive logistics.

## What is unique about Location-Based Services?

There are important similarities and differences between LBS technology and geographic information systems (GISs). For beginners, much of the underlying mapping, spatial indexing, spatial operators, geocoding and routing technology that is used to deliver LBSs originate from the GIS industry. However, what makes LBS technology different is that it is a service deployed on a foundation of IT and wireless technology. The value chain of a GIS is generally limited to the providers of a desktop or client-server solution, whereas the value chain of LBSs includes many players ranging from hardware and software vendors, content and online service providers, wireless network and infrastructure providers, wireless handset vendors, and branded portal sites. Another major difference is that LBSs impose significant technology and service capabilities that exceed the general requirements of static GIS uses, namely:

- **High Performance**: Deliver sub-second queries required for Internet and wireless
- **Scalable**: Supports thousands of concurrent users and terabytes of data
- **Reliable**: Capable of delivering up to 99.9999 up-time
- **Current**: Supports the delivery of real-time, dynamic information
- **Mobile**: Available from any device (wireless and wired) and from any location
- **Open**: Supports common standards and protocols, HTTP, WAP, Wireless Markup Language (WML), Extensible Markup Language (XML) and Multimedia Markup Language (MML)
- **Secure**: Leverages the underlying database locking and security services
- **Interoperable**: Integrated with e-Business applications (Customer Relationship Management, Billing, Personalization) and wireless positioning gateways

There are also significant performance and scalability requirements that further differentiate GIS solutions and LBS solutions. One might consider the delivery of wireless LBSs as service infrastructure – unlike the delivery of other utilities services. Online content services generally require large data servers, large enterprise hardware offerings, significant mid-tier cached application servers that allow the service to scale and perform. LBSs routinely publish personalized content to tens of thousands of users on an hourly and daily basis. Contrast this with GISs, where a handful of users perform relatively complex spatial queries on desktop of client-server systems. Another difference is that LBS developers increasingly rely on subscriptions to off-the-shelf data products that are accurate, precise, and updated. This has great implications to traditional data producers like national mapping agencies, while also creating opportunities for value-added resellers.

Interoperability is a fundamental requirement of any LBS. Unlike GISs that manage all vector and attribute data locally using proprietary data structures and data models, LBSs rely on Standard Query Language (SQL) to access locally hosted content, and XML and Simple Object Access Protocol (SOAP) interfaces to incorporate syndicated online content. Building upon standard query languages, interfaces, encodings, and protocols, it becomes possible to chain basic LBS functions (e.g, geocoding, mapping, routing, real-time traffic) for the creation and delivery of a complex end-user service. Take for example the delivery of a wireless location-enhanced dining service. A wireless restaurant finding service requires a provider to fuse handset position acquisition services with a yellow page proximity search. These inputs can also be referenced with a personalized profile of dining preferences. This example can be further enhanced with syndicated access to an online restaurant menu and reservation service which simplifies the decision making process for the hungry diner. While this example of a “location-enhanced” dining guide is consumer oriented, one can envision other types of business-to-business applications in domains like logistics, customer care, field sales, real estate and marketing, and electronic marketplaces.

Customers also want the provision of LBSs to be automatic – they want carriers and wireless portals to take care of integrating a variety of Internet and enterprise information services with a customer's preferences, enabling a user to focus on informed decision making. For example, a real-time telematics service may access multiple syndicated data services (traffic, business directories, driving directions) from multiple sources – and integrate the information in a meaningful manner for the customer. A customer checking on the availability of a hotel in a given city might access geocoding services that identify his/her location and the nearest hotels, and would cull data from real-time travel services to check availability and book a room, and from a driving directions service to route him/her to the hotel.

## Integration with e-Business Solutions

A unique capability of LBSs is the ease to which they can be integrated with or incorporated into corporate e-Business applications like Customer Relationship Management (CRM), Enterprise Resource Planning (ERP), and Business Intelligence (BI). Organizations have demonstrated that effectively managing location can provide strategic differentiation when managing customer information and efficiently managing corporate assets, both critically important in business. LBSs make use of spatial information and the functions that operate on this information, thus enabling the incorporation of "location awareness" and "location sensitivity" into an organization's e-Business applications, field operations, Web offerings and more. Wireless carriers for example, now recognize that they will compete on the basis of how effectively they can integrate their CRM and field service operations with those of customers and suppliers to create a positive business experience.

By integrating enterprise information with location-enhanced customer information, carriers obtain comprehensive business intelligence, and value builds exponentially. Mobile operators become better positioned to use real customer information to determine wireless service expansion, improve service delivery, and determine load demands. On the customer end, by automating information integration and interpretation, the customer is able to deal with a much richer set of location-enhanced information for better decision-making (Figure 1). With the introduction of event-driven e-Business, wireless carriers and portals can send fresh information as it becomes available or as users roam into a new location, rather than waiting for customers to check in with the service. Customers, mobile operators, and partners can react immediately to the changed location of a handset user by delivering personalized services for his/her new roaming region.

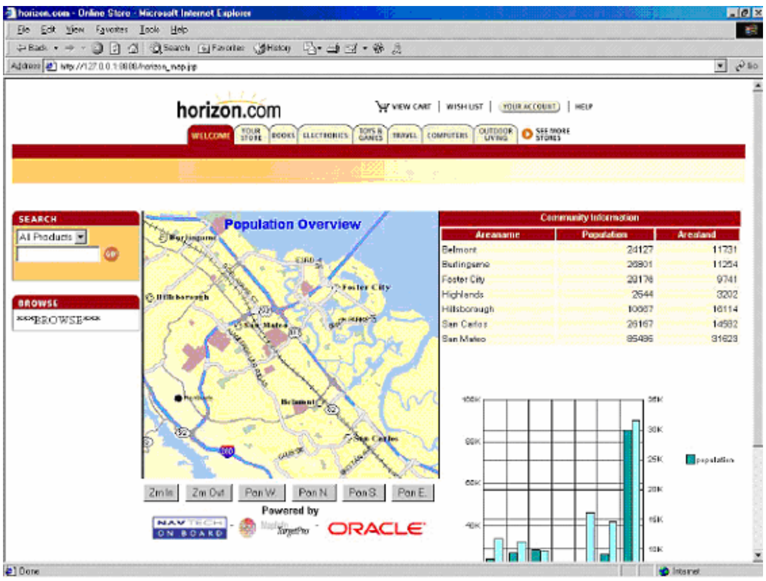


Figure 1 CRM Application incorporating location information

## Enabling technologies

The performance and capability requirements expected for wireless LBSs can easily approach that of a top Internet portal – millions of queries on a daily basis, hundreds of concurrent transactions, and millisecond query response times. Thus, a typical LBS must support all the unique CPU-intensive location queries, and provide scalability, storage, and interoperability.

### Spatial Data Management

A robust LBS platform should be carefully designed to meet the unique performance, scalability, and flexibility requirements of wireless and Internet portals. For example, an LBS service is generally built around a robust database and middleware technology stack that supports multiple internally and externally hosted applications (Figure 2). This Internet platform must also interoperate with the wireless network and with a variety of client devices. A spatially-enabled database serves as a foundation for deploying Internet and wireless LBS. It provides data management for location information such as road networks, wireless service boundaries, and geocoded customer addresses. With the object-relational model it is possible for GIS applications to manipulate data – query, update, and add new information – independent of the database implementation. This abstraction of the database to a conceptual model is the hallmark of database technologies, and spatial databases in particular. By separating the application logic from the database implementation, the model makes it possible to accommodate changes – for example, in the physical organization of the data –without disturbing the application software or the users' logical view of the data. This separation also means that efforts made to optimize performance or ensure robust recovery will immediately benefit all applications that can make use of the spatial data.

Spatial database technology enhances the development and deployment of LBS applications by allowing users to easily incorporate location information directly in their applications and services. Spatial databases by vendors such as Oracle provide spatial object type storage, SQL access, spatial operations, fast R-tree indexing, and projection and coordinate transformation support. These databases can also perform location queries on geocoded yellow page databases, find the nearest hotels, restaurants, and gas stations. Spatial databases, in combination with specialized geocoding, routing, and mapping tools enable wireless carriers, portals and e-Business applications with the capability to incorporate location into their services.

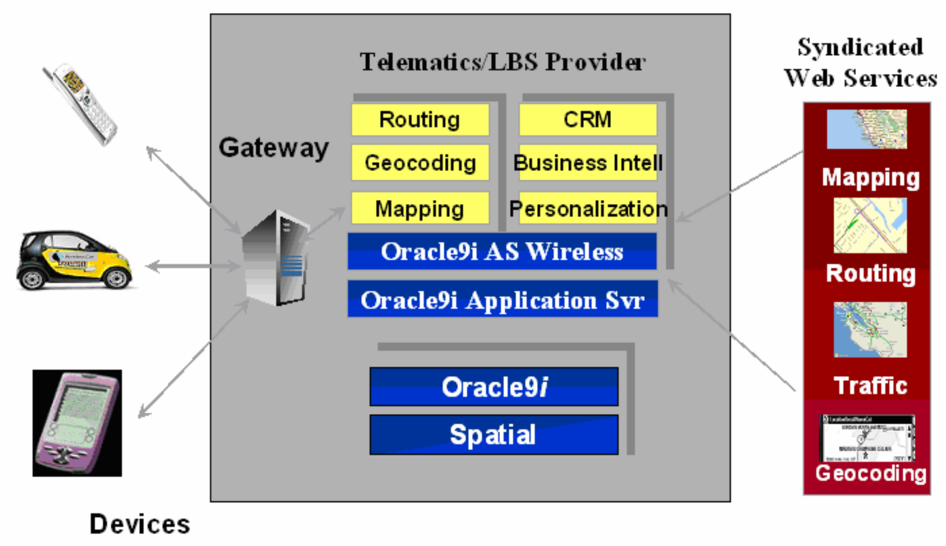


Figure 2 A LBS Architecture Platform

Platforms for LBSs are designed to meet the unique performance and scalability requirements of wireless and Internet portals. In Figure 2 above, business and location content is stored in local database and spatial database servers. The middle-tier applications server delivers critical load balancing, caching, and messaging, and security (see details below). In addition, specialized LBS tools like routing, geocoding, and map rendering can run inside the application server's Java 2 Platform, Enterprise Edition (J2EE) container for fast performance. The wireless extension to the application server handles content transformation (using XML) to various wireless devices, while also incorporates the syndication of LBS Web Services that may be hosted externally. The middle-tier server must also support the various positioning gateways from vendors like Ericsson, Nokia, and Qualcomm, preferably via the Location Interoperability Forum's (LIF) XML positioning interfaces.

Routing engines, mapping, and geocoding can be run in the middle tier or the database. Results of LBS queries could be delivered to mobile devices in the form of raster, vector, text, or text to voice objects. Locally hosted business directory and customer information page can be managed in a local database which allows the results of powerful server side location queries (e.g., within distance, nearest neighbor, route buffering) to be fused with other types of map content or externally syndicated web services. By intelligently leveraging database and mid-tier processes, developers can increase performance, optimize processing, and minimize the amount of data transmitted between the server and application tier. On the client side, web browsers, Personal Digital Assistants (PDA), and wireless handsets can now readily handle the new types of LBS content, such as raster, vector, Scalar Vector Graphics (SVG), Geographic Markup Language (GML), and Macromedia Flash, which also provide enhanced graphic interface, query and analysis capabilities.

## Mobile Middleware

The core technology for Internet and mobile solutions is an application server. Application servers provide built-in features like portal software, wireless and voice, Web page caching, powerful business intelligence features, complete integration, and more, pre-integrated in a single product. For example, the Oracle9i Application Server (9iAS) supports all major J2EE, Web services and XML industry standards, and its open and integration-ready architecture ensures that Web applications can integrate with standard IT environments (Figure 3). Application servers provide the critical scalability, reliability and security necessary to keep critical LBS applications up and running (Lopez, 2000).

Wireless application servers also allow end-users of the portal to customize and tailor their wireless browsing experience to their personal requirements. In addition to sophisticated, personalized content transformation, mobile middleware should also provide a portal interface for the user. An important feature of mobile middleware is personalization, which allows users to define, organize and personalize the services that they want to access from the mobile device. This personalization capability should enable users to easily define the class of LBSs requested and how to trigger them (query, event driven). Other key features of mobile middleware include:

- Separates application logic from service access by always calling Java or XML interfaces;
- Supports well-defined XML interfaces for transfer of yellow pages, geocoding, mapping, driving; directions, and real-time traffic information; with ability to define XML services;
- Repurposes available online services in a variety of wireless and e-Business applications;
- Makes development of value-added applications easier and faster by brokering services from variety of online and wireless service providers; and
- Enables robust and dynamic improvement of services without affecting existing applications.

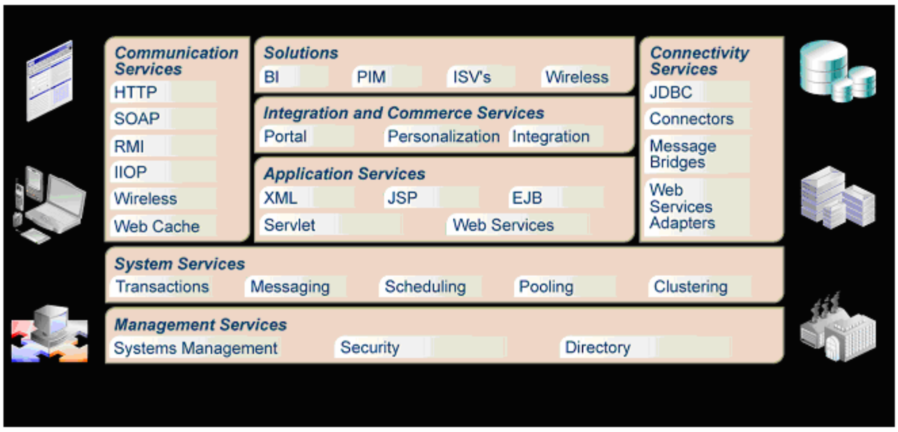


Figure 3 Core Application Server Capabilities

Mobile operators, content providers, or wireless Internet Service Providers (ISPs) create custom portal sites that utilize all kinds of content, from existing web pages to custom Java applications to all new XML-based applications. Wireless-enabled application servers from vendors like BEA Systems, IBM and Oracle are capable of dynamically transforming existing database and Internet content to a generic XML format, and then generating any device specific output desired. Applications can use any content available on the Web, in the database, or a file system. In the case of Oracle9iAS Wireless, the wireless application server can either accept data in MobileXML (Oracle's device-independent XML) or use one of its many adapters to convert content into MobileXML (Figure 4).

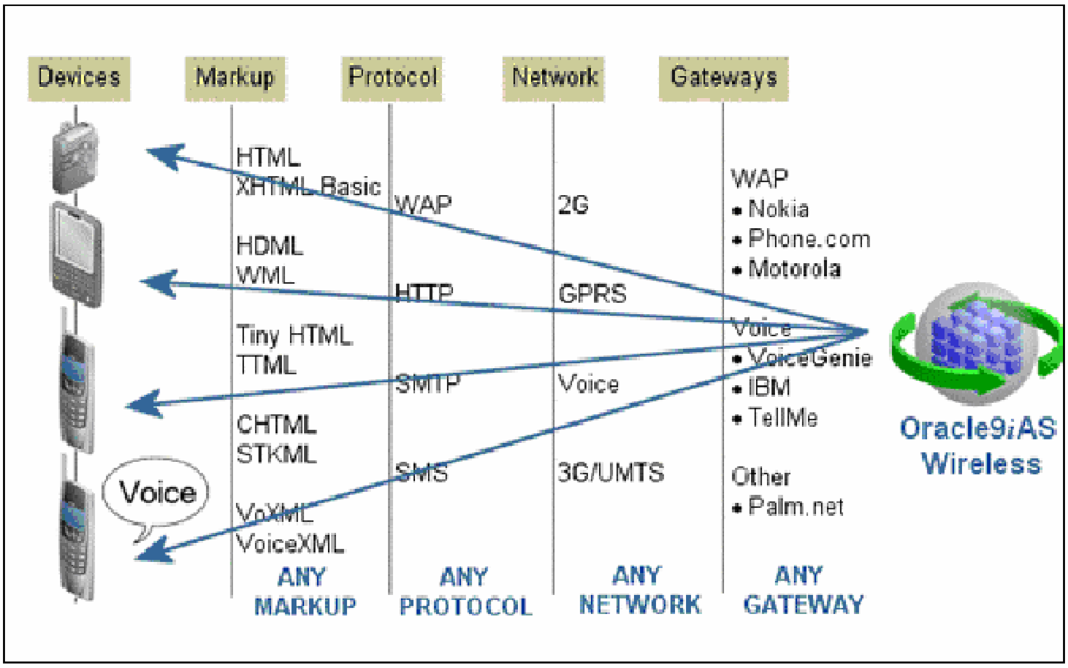


Figure 4 Wireless Application Server Capabilities

Opportunities for reusing code and content are considerable, and the advantages for development time and cost are apparent. Oracle9iAS Wireless Transformers then convert the MobileXML into the markup language required by each mobile device (WML, TinyHTML, c-HTML, VoiceXML etc). Obviously, devices vary in their ability to display certain content in a reasonable manner, or even to store it in memory. However, MobileXML is flexible enough to enable different input and output options depending on a specific device's capability. The application server exploits the maximum hardware capability of the device to present information. Most importantly, applications that work on today's devices will continue to work without limitation with tomorrow's more advanced devices and markup languages. This approach makes the creation of services very simple. Once a web service is created, it is immediately available on all mobile devices.

In short, the application server tier provides a simple yet flexible framework that enables wireless and Internet services to build value-added services. This platform enables rapid deployment of new services and ultimately increasing the quality and reducing the development cycle of Internet applications.

Real-time, transaction-based LBSs have specific feature and performance requirements listed in Table 1.

Table 1 Feature and Performance Requirements for LBSs

| Feature Requirements | Performance Requirements |
|---|---|
| Address verification and matching | Scalable architecture |
| Map rendering | Gigabytes to terabytes of data |
| Yellow page directory query | Multiple CPU processing |
| Driving directions | DBMS table partitioning |
| Personalization by location | Distributed computing |
| Proximity analysis | Native spatial data management |
| Standardized location interfaces | Online services interoperability |
| Personal/in-car navigation | Millisecond location query |
| Voice (VoXML) capability | Million + daily queries |
| XML integration | 25,000+ user sessions per hour |
| Web Services Directories | Portal caching |
| Multi-lingual | |
| Lightweight Directory Access Protocol (LDAP) support | |

### Open Interface Specifications

Location-awareness for mobile applications is incomplete without specialized services, such as geocoding, reverse geocoding, driving directions (routing), yellow pages, white pages, maps, weather forecasts, traffic reports, and demographic information. The OpenGIS Consortium (OGC) has defined a suite of Open Location Services (OpenLS) interface specifications that enables developers to incorporate remotely hosted/syndicated LBSs using HTTP protocols (OpenGIS, 2002; Bishr, 2002). This enables developers of LBSs to easily ingest different sources of location services providers worldwide using a single, consistent XML or SOAP interface. For companies that do not have the resources or data to locally host their LBSs, OpenLS interfaces enable them to syndicate LBS data streams from third-party providers. This gives the developer the choice of selecting those services to be hosted locally and those that are accessed remotely. It also allows them to register redundant services in case one fails.

Underlying services supported through these interfaces include:

- **Geocoding**: Geocoding determines the longitude and latitude coordinates of an address and is the most fundamental service, because it is used directly or indirectly by the other LBSs.
- **Reverse Geocoding**: This feature returns address information associated with a given Longitude/Latitude. This information could include postal code, city, and street intersections.
- **Routing**: Commonly known as driving directions, provides turn-by-turn driving instructions based on an address of origin and destination. Routing engines might also provide maps of each turn and of the complete route or provide a solution to more complex problems such as “traveling salesman”.
- **Mapping**: Mapping enables users with capable devices to visualize rendered map data that is generated from locally hosted map server or an externally syndicated data.
- **Find Nearest**: Given an address or location, this service is able to return nearby geographic features, such as restaurants, health centers, or gas stations, ranked by distance.
- **Real-time Traffic**: Provides traffic reports from Traffic Data Sources. LBS developers can incorporate this traffic on real-time basis or cache it in their server for integration with routing instructions.
- **Directory Services**: A directory service helps identify one of more businesses falling within a given geographical region and consisting of a business name or a category. Directory services are generally hosted locally and use spatial database technology to perform large numbers of spatial queries (e.g., find nearest, within distance).

This list of LBS interfaces is by no means comprehensive. These core interfaces do, however, serve as building blocks for the delivery of more complex services that fuse location with other types of static and real-time content. However, one thing they all have in common is the need for various types of digital map products, namely road network datasets, geocoded business listings, administrative boundaries, and topographic features.

## Market for Location-Based Services

The LBS market is developing and being defined and fielded under trying economic conditions. The market is also directly dependant on a wireless industry that is suffering under the burden of 3G spectrum acquisition costs. Because of this, initial predictions for market growth and schedules for LBSs rollout and corresponding market penetration have not been consistent with initial forecasts. In fact, analysts’ estimates today are much more conservative than they were in mid 2000, both in terms of the rate of growth and in terms of the services that will be available (BWCS, 2002). Today’s estimates are far more pragmatic reflecting the realism that comes from a reduced capital base. Moreover, the years 2000-2002 witnessed the consolidation of many players in the LBS industry. The burst of the "Dot-Com" bubble eliminated many of the smaller, non-viable technology players and resulted in mergers and acquisitions of many others. Acquisitions of MapQuest by AOL, SnapTrack by Qualcomm, and Signalsoft by OpenWave, are examples of the industry restructuring currently underway.

According to the Strategis Group (2001), a leading telecommunications research firm, the market for wireless LBSs is expected to generate $4 billion a year in annual service revenue for carriers. Many vendors (Nokia, Ericsson, and Motorola) are already in the process of developing such services for carriers like Verizon, Vodaphone, Sprint, and AT&T. Despite the slowdown in the wireless industry, analysts are still predicting rapid take-up of this technology by 2005 and will remain strong through 2010. This industry can expect a major boost in the near future as service providers undertake significant expenditures for hardware, software, content, and location servers and enhanced networks. Soon, the number of web-enabled mobile handsets will surpass the number of desktops. To consumers, this will bring widespread availability of powerful location and mapping capability into the hands of every user with a Web browser or web-enabled wireless handset.

How did the LBSs market emerge? Surprisingly, the United States Federal Government regulation has been an important factor in the early development of LBSs. The FCC introduced regulations requiring mobile service operators to provide comprehensive location information for E- 911 situations. By October 2001, wireless service providers in the United States were required to provide the location of mobile handset users within approximately 125 meters, for 67 percent of the time. However, most carriers requested waivers and extensions of time. Nevertheless, some progress has been made, and the business opportunities for LBSs are still there, even if they have been postponed.

In September 2001, Sprint PCS became the first carrier to sell a GPS-enabled mobile phone, known as the SPH-N300; Samsung developed the phone and Qualcomm developed the GPS chip set. Since then, Samsung has begun producing similar phones for Verizon. Both Sprint and Verizon are in the process of equipping their nation-wide networks to support this new positioning capability.

Much of the same infrastructure needed to support mandated E-911 services can also be used for chargeable LBSs like car navigation, traffic information, travel information, and yellow page directory access. Moreover, as wireless and wired Internet infrastructures converge, service providers will make LBSs a mainstay of their offerings.

## Location-Based Service Market Players

The LBS marketplace is both complex and still evolving. There are a variety of players vying for market leadership in various parts of the LBS value chain. For simplicity, the following categorizations of key LBS players are used:

- **Infrastructure Software Providers**: BEA, IBM, Lucent, Microsoft, Motorola, Nokia, Oracle and Sun provide much of the core software infrastructure (e.g., databases, application servers, enterprise applications, and positioning servers) necessary for wireless and Web service delivery.
- **Network and Handset Positioning Vendors**: Alcatel, Cambridge Positioning Systems, Ericsson, Lucent, Motorola, Nokia, Qualcomm, Siemens provide positioning technology as part of the network infrastructure. In addition, handset providers are beginning to embed A-GPS positioning technology into a new generation of handsets.
- **Specialty Tools and GIS/LBS Platform Vendors**: Autodesk, Environmental Systems Research Institute (ESRI), Ionic, Intelliwhere, MapInfo, Telcontar, and others, provide specialized mapping, geocoding, and routing technologies for LBS deployments.
- **LBS Services**: These specialized LBS providers offer re-branded services like real-time traffic (SmartTraveler, TrafficMaster), mapping, driving directions and yellow pages (MapQuest, Vicinity, Webraska, Yahoo), geocoding and gazetteers (Whereonearth), and satellite imagery services (GlobeXplorer).

- **Content Providers**: National mapping agencies, and companies like Navigation Technologies, and Tele Atlas are important providers of road network datasets, administrative boundaries, address points, and topographic features. Meanwhile, major business listing providers are important sources of geocoded demographic and business directories. Finally, local, state and federal government agencies are an important source of both raw and value-added content mapping and directories information.
- **Wireless and Web Portals**: Portals come in various flavors: (1) Wireless carriers such as British Telecom, Vodaphone, Verizon, AT&T, France Telecom, Telefonica, and Deutsche Telekom; (2) Branded Internet portals like AOL and Yahoo; (3) Wireless Application Service Providers (ASPs), like InfoSpace; and (4) Telematics portals, like the General Motor's OnStar service.

As the LBS market achieves its potential over the next five years, we can expect market consolidation and the emergence of clear market leaders in each of these domains.

## Importance of Architecture and Standards

To fully realize the benefits of LBSs, the design of system architecture becomes paramount. As with the deployment of mission critical data warehouses, CRM, and e-commerce solutions, wireless LBSs require a solid architecture that is extensible, secure and standards-based. This generally means a consolidation of database, application servers, and tools for reasons of performance, scalability, and cost effectiveness. LBS will also take advantage of performance-enhancing IT features like caching, parallelism, partitioning, and high availability, all of which are delivered by leading database and application vendors. For flexibility and robustness, these systems are now leveraging the power and flexibility of Java across all tiers of solutions architecture (Lopez, 2001).

The delivery of location applications introduces challenging technical issues as the system architecture (client, middleware, data server) grows in complexity and as the number of system dependencies increases. Dependencies exist between software and operating system compatibility, system and network interoperability, and network capability. As LBSs incorporate locally-hosted and externally syndicated content services, dependencies spill into the inter-organizational realm. These system dependencies can make or break a system. And although they cannot be completely avoided, if these dependencies are not managed carefully, they can decrease reliability and performance, as well as increase the lifetime cost of a system.

An important way to minimize the problem of co-dependencies across technology layers and systems is to use standards-based technology. Open standards permit interoperability and minimize system degradation caused by versioning conflicts. Standards also minimize vendor lock-in dependencies by moving away from proprietary technology, application programming interfaces (APIs), and unique data formats. Industry consortia and standards bodies like the World Wide Web Consortium (W3C), International Organization for Standardization (ISO), Open Mobile Alliance (OMA), and OpenGIS are playing a significant role in addressing LBS interoperability. The extraordinary success of the Web is, after all, a direct result of the rapid adoption of W3C protocols (HTTP) and markup languages (HTML, XML). The richness of available content and services provide an opportunity to link proximity searches to a whole new category of services. This is why open-standards-based technology and adherence to standards is critical – it enables wireless and Internet portals to quickly extend their services and to interoperate with other systems and on-line services.

A number of standards efforts are currently underway that will steer the evolution of LBSs. These include the OpenGIS Consortium, the OMA, the Internet Engineering Task Force (IETF), and the WAP forum, among others. Of particular note is the OpenGIS, which recently launched an industry-led interoperability program for LBSs. The OpenGIS is working with the OMA, IETF and WAP forum to demonstrate the delivery of end-to-end LBSs – from handset, through the wireless carrier infrastructure, hosted LBS applications, links with Internet content providers, and back to the handset. While the LIF and IETF are focusing their interoperability work on positioning, the OpenGIS is advancing standards for key LBS interfaces like geocoding, web mapping, driving directions, yellow page search, and real-time traffic acquisition.

GML is a related XML encoding specification that is likely to impact the evolution of LBSs and GISs in the coming years. The significant trend here is a move away from proprietary GIS and mapping formats and APIs that have prevented the diffusion of spatial technology in the past.

### Java and Spatial Technologies

Recently, there has been an unprecedented level of acceptance of Java as an emerging standard for the deployment of LBSs (Niedzwiadek, 2002). Developers and end users alike recognize the simplicity and power of Java applets, servlets, and beans for the delivery of LBSs. Java for spatial and location applications, or Java location services as it is now being referred to, delivers some unique capabilities such as:

- **Power**: Java is a modern, object-oriented language complete with single-state inheritance and multiple interfaces. This combination has been found to be both powerful and efficient, and is a good complement to standard programming models.
- **Simplicity**: Java retains most of the power of C++, but with far less complexity. It is designed for automatic storage management, which is an enormous simplification since the programmer no longer needs to deal with pointer arithmetic. Java is essentially C++ done right.
- **Familiarity**: Java borrows heavily from the syntax and semantics of the ubiquitous C language. While a relatively new language, Java is familiar to a large and rapidly expanding population of developers because of its widespread acceptance and its derivation from C.
- **Efficiency**: Java's design enables highly efficient interpretation and compilation. Its virtual machine-based organization defines a highly compact set of byte codes that can be efficiently transported in the Internet/Intranet environment.
- **Portability**: To maximize its intrinsic portability, Java has been carefully specified with a standard, platform-neutral format at both the source and binary levels. Furthermore, Java defines both a language and a set of standard class libraries (packages) to ensure that real-world applications may be easily constructed to run on any Java virtual machine in any environment.
- **Safety**: While powerful, Java is fundamentally safer than low-level languages such as C or C++. Because Java has uniform reference semantics and automatic storage management, it completely avoids various storage management and pointer errors. All Java operations are type-safe, and the language provides a sophisticated lexical exception mechanism by which developers can produce robust code.

## Example Location-Based Services

### J-Phone J-Navi (Japan)

In May 2000, J-Phone, Japan's second largest wireless telecom, launched their J-Navi service. J-Navi delivers all the standard types of LBS that one expects from a wireless carrier (geocoding, driving directions, yellow page information). In addition, J-Navi rich graphic handsets are also capable of displaying the results of location queries using color maps resulting in the world's first operational graphical map delivery to mobile phones.

J-Phone is Japans #3 wireless service provider. The J-Phone J-Navi location applications were written in Java and run on a spatial database. Java Server scripts running in the database and the mid-tier provides lightweight and scalable geocoding, map rendering, and location capability (Figure 5). This particular deployment runs nearly all of its LBS functions directly from a spatial database and is able to achieve scalability requirements of 30,000 user sessions per hour. The results is the ability to deliver over 1 million color vector and raster maps per day to a new class of General Packet Radio Service (GPRS) and Universal Mobile Telecommunications System (UMTS) enabled multimedia handsets. The average query processing is less than 200ms and average download time is two seconds.

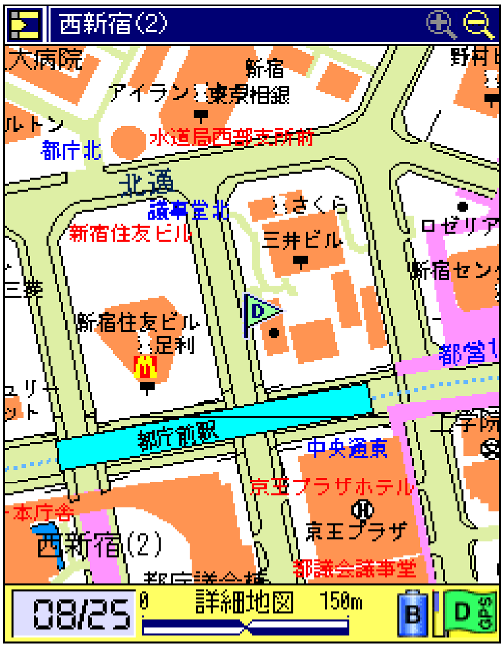


Figure 5 J-Phone handset and J-Navi Map Images Courtesy of J-Phone

The J-Phone deployment, in combination with partner technologies and services leveraged performance-enhancing features like caching, parallelism, partitioning, and high availability. This is particularly relevant to wireless location-based applications where new application components may need to be created and enhanced regularly to differentiate service offerings. The two other leading Japanese carriers NTT DoCoMo (#1) and KDDI (#2) also use Oracle database technology and application server infrastructure for the deployment of their advanced LBS content services.

## Conclusion

The recent convergence of network computing and wireless telecommunications with spatial technologies is giving rise to a new class of location-based applications and services. Internet and wireless service providers are beginning to deliver web mapping, street routing, and electronic mobile yellow services to both web and wireless handsets. The broader Internet and wireless industry has now realized the importance of incorporating location information into existing software solutions. LBSs provide a means to deploy horizontal services that can easily be embedded in existing tools and applications or as a stand-along point-based solution. In delivering LBSs, IT vendors are developing germane software and hardware products that enable the delivery of location-based voice and data services to wireless network operators. These services unlock the central element of mobile telephone networks, the location of their users. The location of the wireless user is central to the delivery of a whole new class of services by wireless operators. In short, LBSs will become a key enabler of mobile commerce, which is the extension of Internet-based electronic commerce, to mobile phones.

LBSs imply a broad range of concepts, technologies and potential applications and services. In fact, the LBS value chain includes the development and delivery of wireless handsets, wireless network positioning infrastructure, positioning servers, application servers, database technology, LBS specific tools (e.g., mapping, routing, and geocoding engines). LBSs also include content and mechanisms to aggregate and publish that content in the form of personalized information services to users. These mission-critical LBSs all require a solid architecture that is extensible, secure and standards-based. This has led to the centralization of services for reasons of performance, scalability, and cost effectiveness. The successful adoption of LBSs will rely on flexible and secure approaches that can be readily scaled-up without being locked into a particular vendor's solution. The technology infrastructure now exists for application developers to build a "best of class" technology platform that is open, scalable, secure, manageable, and standards-based.

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