

Location-Based Services: Technical and Business Issues

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Abstract

Geographical Information System (GIS) and Global Positioning System (GPS) technologies are expanding their traditional applications to embrace a stream of consumer-focused, location-based applications. Through an integration with handheld devices capable of wireless communication and mobile computing, a wide range of what might be generically referred to as "Location-Based Services" (LBS) may be offered to mobile users.

A location-based service is able to provide targeted spatial information to mobile workers and consumers. These include utility location information, personal or asset tracking, concierge and route-guidance information, to name just a few of the possible LBS. The technologies and applications of LBS will play an ever increasingly important role in the modern, mobile, always-connected society.

This paper endeavours to provide some background to the technology underlying location-based services and to discuss some issues related to developing and launching LBS. These include whether wireless mobile technologies are ready to support LBS, which mobile positioning technologies can be used and what are their shortcomings, and how GIS developers manipulate spatial information to generate appropriate map images on mobile devices (such as cell phones and PDAs). In addition the authors discuss such issues as interoperability, privacy protection and the market demand for LBS.

Introduction

Mobile location-based commerce ("mobile e-commerce" or simply "l-commerce") refers to the provision of location-based information on mobile devices as a result of a user request. In other words, it "aims to provide specific, targeted information to users based on each specific user's location at any time" (Benson, 2001). In the case of emergency calls, it is obvious that if the call responders have information concerning the location of the people making the call, then the response time can be reduced. Hence security and safety are important considerations for a "mobile society". The second type of application is where location-specific information on something *nearby* (to the mobile device, or user's location) is sought. These are so-called "concierge services". The requested information may be related to points-of-interest such as hospitals, restaurants, cinemas, car parks, ATMs, and so on. Such a service may provide information *about* the point-of-interest, or route-guidance to find it.

There are also many examples of applications in typical work practices which might not be viewed as a form of "l-commerce", but which nevertheless benefit from using procedures that have a "spatial component". For example, in the case of a gas pipeline breakdown emergency call, a worker has to go into the field and quickly find the location of the broken pipe, details of the owners of nearby properties, etc. A mobile device (with positioning capability) can be used to query a GIS database of valves that would permit the isolation of the gas supply at the appropriate location.

One of the main drivers for the development of *ubiquitous* positioning technology that can support a wide range of location-based services is the U.S. Federal Communications Commission (FCC) requirement for emergency service response to mobile E911 calls (AllNetDevices Staff, 2001a). The FCC's accuracy requirements are 100 m (67%) for network-based technologies and 50 m (67%) for handset-based technologies (FCC

2001). The deadline for the implementation of a nationwide E911 service (the "E" is for "enhanced") was October 2001. However this deadline was waived for one year because many telecommunication carriers did not have the necessary technology in place. As far as Europe is concerned, "Early in 2000, it seemed likely that the European Commission would follow America's lead in mandating mobile network operators to automatically locate subscribers via their wireless device" (Hoyde, 2001). In order to satisfy such requirements, telecommunication carriers have been forced to make large investments to incorporate location-determination capability within their networks (or at the very least ensure that the handset capability can be linked to their network).

Investors are now considering what business plans could support revenue-raising location-based services -- "It is a critical element for wireless operators as they search for ways to turn costly government-mandated enhanced 911 technology into profit-generating services" (Marek, 2001). Another driver for LBS development (as opposed to location determination capability to support the mandated E911 requirements) is that wireless network operators want to distinguish themselves from their competitors by offering special services. The most valuable (and profitable) service is therefore likely to be one that addresses a mobile user's request, via a small handheld device -- by providing pertinent information with minimum delay, *appropriate for their location*.

In essence, LBS can only be provided through the integration of wireless communications and computing technologies, with 'spatial elements' such as positioning technologies and spatial data sets. These components form a network using wireless communication standards to transfer service requests and information between a mobile user and a service (or server) facility. The location-based service facility is able to perform spatial functions based on the user's location, generally with the aid of a Geographical Information System.

Many mobile wireless product manufacturers (e.g. Compaq, Palm, Ericsson, Motorola, Nokia, etc.), and mobile computing and mapping software developers (e.g. Autodesk, Intergraph, MapInfo, Xmarc, Oracle, Webraska, AirFlash, Cell-loc, CellPoint, and others), are entering the competitive market of LBS. First generation location-based services have been deployed in Europe, on the American continent, in Japan, throughout Asia and in Australia. One of them is *Genie* (in Japan and Australia), provided by Intergraph and Xmarc. The *Genie* LBS can provide users with routing, proximity searching, geo-location and map rendering functionality (<http://www.xmarc.com>). IntelliWhere, a division of Intergraph, launched a new platform for location-based services in December 2000 called *IntelliWhere Genie*, also targeted for mobile workers (<http://www.intelliwhere.com>).

Another popular location-based service in Japan, called *J-Navi*, was jointly developed by Xmarc and J-Phone. *J-Navi* is a type of mobile 'yellow pages', and services up to a million transaction requests per day (<http://www.xmarc.com>). Webraska, a worldwide provider of wireless navigation, mapping and traffic information services and technologies for telecommunication carriers, has also launched a location-based service platform called *Webraska Personal Navigation Suite*. The Webraska-based LBS was introduced in Europe in 2000 (<http://www.webraska.com>). In Australia one of the first location-based services was the product of a cooperation between Ericsson and Tourism Victoria. The service provides traveller information such as accommodation and restaurant details, relevant to their current location (McLorinan et al, 2000). *L4 Mobile*,

a provider of location-based wireless applications and services for the mobile data market in Australia and New Zealand, also announced a commercial location-based services platform. "This will allow L4 Mobile to provide wireless operators with the opportunity to offer high value location-based services to business and consumer customers" (Simon, 2000). In addition, AutoDesk and MapInfo, two well known mapping/spatial software developers, have developed two location-based services, *AutoDesk OnSite* and *MapInHand* respectively, that can be accessed by mobile workers using PDAs.

The E911 Phase II completion due date was 1st October 2001, however this deadline has been extended. "RCN notes, yet current estimates indicate it may be years before Phase II is fully implemented.... With handset-based technologies, deployment could take up to four years from the proposal deadline" (Wrolstad, 2001a & b). "Sprint PCS and Verizon Wireless are seen as possibly meeting the Oct. 1 deadline" (Sutherland, 2001). Several carriers, in partnership with location technology developers, are currently conducting field trials with a view to meeting the FCC requirement.

Despite setbacks concerning the E911 rollout in the U.S., many telecommunications carriers see location-based services as being the new 'boom' that will drive developments in wireless communication technology as well as promising new sources of revenues. "Location information will become an integral part of the personalized mobile Internet applications and services" (Location Interoperability Forum, 2001). However, note the warning about 'overselling' LBS: "Mobile location Services are still a technology, not an industry" (ibid, 2001).

Mobile Wireless Communication Standards and LBS

Mobile Wireless System Components

In general, a wireless communication system consists of three main components: the Mobile Switching Centres (MSC) or central processing equipment, the base stations and the user handsets (e.g., Prasad 1998). The MSC is responsible for interacting with a large number of base stations, controlling call processing and billing. They make use of some very important databases, such as the home location register (HLR) and the visiting location register (VLR). The HLR contains subscriber registrations and service profile information. The VLR is used when a customer of a serving system area has 'roamed' into another area.

The base stations are the 'links' between the MSC and the handsets. A base station manages a cell within a wireless telephony network, containing many mobile handsets. The base station typically comprises a control unit, radio base station equipment and an antenna. The mobile handsets may be cell phones or small handheld computing devices known as Personal Digital Assistants (PDA). A mobile handset consists of a control/interface unit, a transceiver and an antenna system.

When a user (calling party) makes a call from his/her cell phone, the calling base station receives the call and transfers it to the calling MSC. The calling MSC processes the call, retrieves the caller profile from the database and makes the relevant information available to the MSC. The called party receives the call via a called base station. Communication between MSCs is performed via the fixed telephone system.

Mobile Communication Protocols

Wireless mobile communication protocols are complex and, unfortunately, not globally interoperable. The U.S. has developed their mobile network based on the IS-41 (Interim Standard 41) standard, while Europe uses the GSM (Global System for Mobility) standard. Nowadays, GSM networks seem to offer superior solutions for value-added services and hence are becoming increasingly popular in many parts of the world, including the U.S. GSM has also deployed two important standards for the development of LBS, the Short Message Service (SMS) and the General Packet Radio System (GPRS). GSM uses both Time Division Multiple Access (TDMA) and Frequency Division Multiple Access (FDMA) multiplexing techniques.

Advanced Mobile Phone Service (AMPS) was the first analog cellular system introduced in the U.S. AMPS employs the FDMA technique, and uses IS-41 for roaming management. Digital AMPS (D-AMPS) provides digital services. It uses TDMA, and the IS-41 standard for roaming management. Code Division Multiple Access (CDMA), or IS-95, is another standard that also uses IS-41 for mobility management. This is a comparatively new cellular phone standard. While GSM is used in Europe, DAMPS and CDMA are mostly used in the U.S. In Australia, the mobile networks are mostly GSM-based, although CDMA services have also been recently introduced. Current LBS applications are usually developed with either the CDMA (IS-95) or GSM mobile network standards in mind, as well as future Universal Mobile Telecommunications System (UMTS) standards.

Standards that support LBS

LBS span technologies from 2 generation (2G) wireless communication through the so-called 2.5 generation (2.5G), to the third generation (3G). 2.5G is an evolution from the 2G technology such as GSM, and currently includes SMS and GPRS. These are 'always connected' network standards. SMS is able to transfer text messages, that can be a combination of words and numbers. Each short message is up to 160 characters in length for Latin alphabets, and 70 characters for non-Latin alphabets like Chinese or Arabic. SMS is now one of the standards used for providing mobile mapping information, such as turn-by-turn directions, in text format. However, the SMS limitations (primarily the ability to send only 160 characters of text) can be overcome by using GPRS, and enhanced forms of SMS that it supports.

GPRS is a newly introduced standard in Europe and the U.S., and has been available in Australia since the end of 2001 (<http://www.telstra.com.au>). GPRS is supported by GSM and TDMA mobile networks. GPRS has some advantages in comparison to 2G data services on GSM network and SMS. First of all, GPRS is Internet-enabled. Secondly, GPRS theoretically offers higher data transfer speed. The highest speed that GPRS can reach is up to 171.2Kbps when all 8 timeslots are used. ('Time slot' is a unit of division of a frequency range in TDMA techniques.) This speed is three times faster than a fixed telecommunication network (56Kbps). In reality each user will normally be assigned about 3 timeslots and therefore the speed is much lower. The data transfer speed over the mobile network will therefore not be quicker than over the fixed network. Moreover, GPRS needs support from other technologies such as SMS for storing and forwarding messages, as well as 3G technologies such as EDGE and HSCSD (High Speed Circuit Switched Data) with higher capacity for data transfer. Hence some LBS applications may have to wait for several years to be supported by fully operational 2.5G or 3G mobile telephony networks.

The so-called 'Wireless Internet' or 'Mobile Internet' also permits telecommunication carriers to add more services, including location-based services, to existing wireless networks. The Mobile/Wireless Internet is being developed under some constraints. First of all the range of wireless communication systems is very diverse. The Mobile/Wireless Internet must be compatible with GSM, CDMA and AMPS. Secondly, the small size of mobile devices means a restricted user interface, less powerful CPU and comparatively low memory capacity. The wireless network, in comparison with the standard wireline network, "has limited bandwidth, longer latency and lower degree of reliability to deliver wireless data" (Lin & Chlamtac, 2001). Moreover, standard Internet content will not be interpreted correctly by the micro-browsers found in mobile devices. Therefore new mobile Internet standards are needed, such as the Wireless Application Protocol (WAP) and the Wireless Markup Language (WML).

WML is based on the eXtensible Markup Language (XML), which is a markup language developed for delivering database contents via the standard Internet. WML is therefore similar to HyperText Markup Language (HTML), but is designed for the efficient delivery of data across limited bandwidth mobile telephony networks. A WML page is called a 'deck', and in one WML page it is possible to have many sub-pages, referred to as 'cards'. Each WML card is identified by an Internet-standard Uniform Resource Locator (URL). Users navigate with the WML browser through the WML cards.

WAP is designed to operate over many wireless networks. It is a stack of protocols, which are similar to the standard Internet on PCs, as indicated in Figure 1. WAP gateways provide efficient wireless access to the Internet, as shown in Figure 2, and handle requests from WAP-enabled handsets, and pass requests to, and receive data from, a server (because handsets cannot communicate directly with the server). Moreover, the gateway translates WAP to the TCP/IP Internet protocol for application servers which do not support WAP.

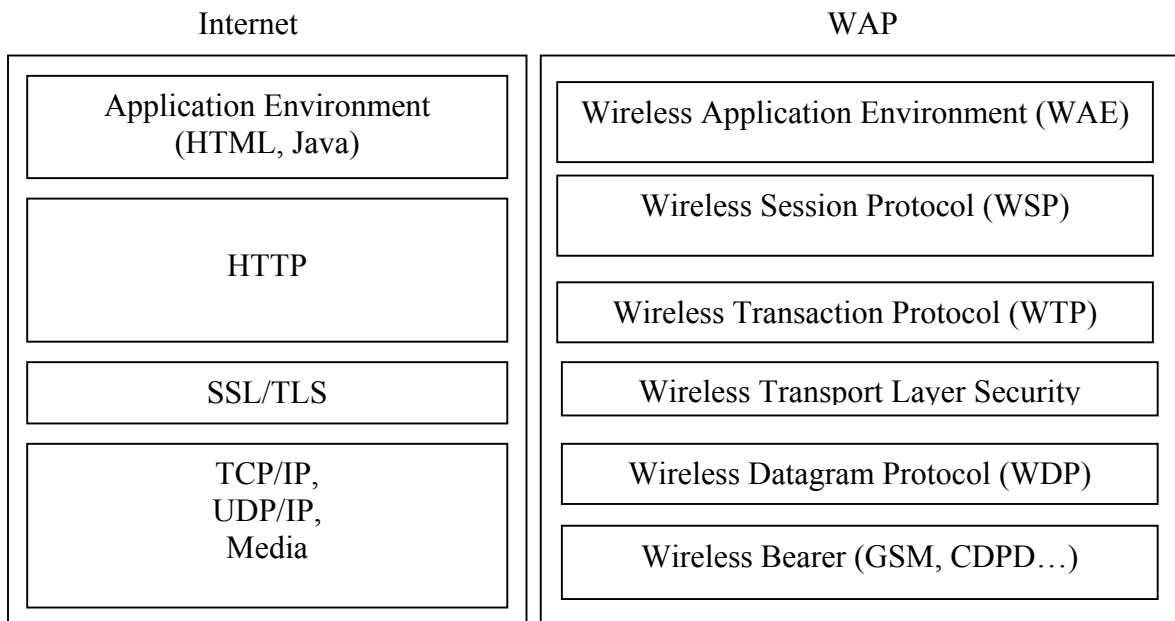


Figure 1: WAP Architecture (Lin & Chlamtac, 2001)

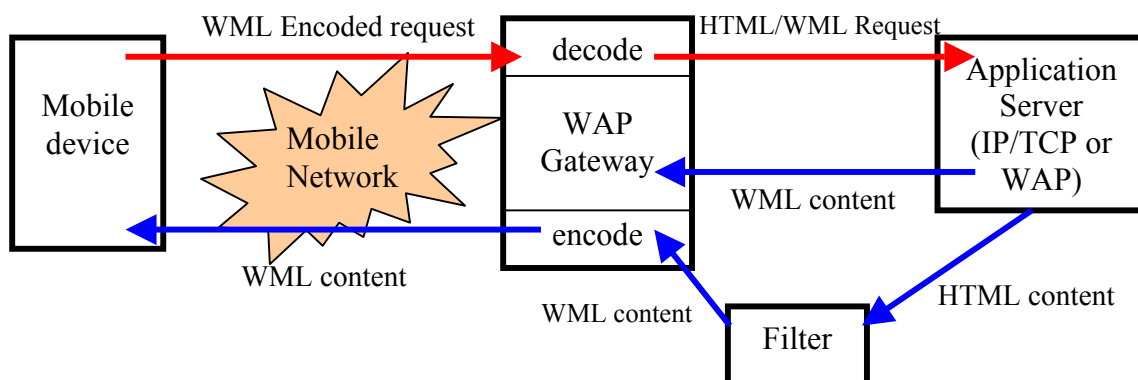


Figure 2: WAP Model (Lin & Chlamtac, 2001)

Positioning and LBS

Determining the location of mobile users is one of the most challenging tasks that must be undertaken in order to enable a location-based service. LBS providers currently use different methods to determine locations.

Non-GPS Positioning Techniques

The most common non-GPS solutions for mobile positioning are: Cell of Origin, Time of Arrival, Angle of Arrival and Enhanced Observed Time Difference. All make use of the wireless telecommunications system itself.

Cell of Origin (COO) is the most straightforward solution, and uses the cell identification information within the mobile telephony network to identify the approximate location of the caller. However, this technique is often not very useful because of the low positioning accuracy. Time of Arrival (TOA) is a commonly used network-based solution for determining the position of mobile callers. The differences in the time of arrival of the signal from a user's mobile device to at least three base stations are used to calculate the location of that device. The Angle of Arrival (AOA) technique seeks to determine the location of a mobile device based on the angle at which signals transmitted from the device arrive at the base station(s).

The Enhanced Observed Time Difference (E-OTD) technique determines the location of a mobile device by using location receivers which are geographically dispersed across a wide area. These so-called Location Measurement Units (LMU) each have an accurate timing source. When it is possible for E-OTD (software-enabled) mobile devices and the LMUs to receive signals from at least three base stations, the time difference of arrival of the signal from each base station at the handset and at the LMU are calculated. The estimated location of the handset is calculated, based on the combination of the differences in time, through a hyperbolic positioning technique. The E-OTD technique offers an accuracy level from 50 to 125m (Prasad, 2002).

Global Positioning System

The Global Positioning System (GPS) is a satellite-based navigation system developed and operated by the U.S. Department of Defense. GPS is a position, velocity and time

determination system that is truly global, is able to operate 24 hours a day under all weather conditions, and charges no user fees. GPS offers comparatively high accuracy, when operational conditions are favourable. In cases of outdoor positioning, when signals from the constellation of GPS satellites are not obstructed, sub-dekametre horizontal accuracy (<10m) is assured (Ludden, 2000). GPS is a relatively mature technology, and current receiver hardware is smaller, lighter, cheaper and uses less power than earlier generation equipment.

GPS does, however, have some serious limitations due to the strong attenuation of the satellite signals by buildings, foliage, etc. Therefore GPS does not operate well (or at all) in dense 'urban canyon' areas, or inside buildings. Yet these are often the very areas where demand for location-based services is the highest. Furthermore, in order to use GPS, the mobile handsets must be modified to integrate GPS receiver chips.

However, since GPS offers so many advantages it is considered a 'first choice' solution for many mobile positioning applications, even for the FCC's emergency service E911 requirements, and the LBS that can be supported by the location determination technology implemented for mobile telephony. Although modifying mobile handsets is required, this is not seen as a significant disadvantage as most handsets are replaced every 3 or 4 years. The cost of upgrading a handset to incorporate a GPS receiver is not very expensive. According to SnapTrack, a leading mobile handset-based GPS designer, "Those handset upgrades are estimated to cost an additional \$5 - \$10 per handset, but that likely will be reduced as handset makers step up mass volume production" (<http://www.snaptrack.com>). Moreover, handset-based positioning techniques offer users the ability to turn on, and turn off, the location-determination function when they want to, something which cannot be done in the case of network-based positioning techniques. In order to overcome the problem of positioning indoors and in urban areas, some GPS receivers have been developed that can operate in weak signal environments.

Assisted GPS

Assisted GPS (A-GPS) refers to the GPS positioning technique whereby there is assistance data provided from a special GPS server/base station by the mobile telephony network. A-GPS enables GPS positioning even in urban and indoor areas, where the signal is too weak to be acquired using standard signal tracking procedures within the receiver. For example, the approximate location information of the GPS-enabled handset (derived from the COO technique) can aid the tracking of the satellite signals, and the ephemeris data (transmitted to the mobile device from a GPS base station receiver) can permit fast position computation even in a so-called 'cold start'. Sometimes the actual measurement and position computation is done not in the handset, but at a location server integrated within the mobile telephony network.

SnapTrack deploys a location server connected to one or more stationary GPS base station receivers to implement the A-GPS technique. The process takes just a few seconds, whereas conventional GPS receivers can take many minutes (if at all). The SnapTrack mobile GPS can provide position accuracy from the sub-dekametre level (in ideal, outdoor conditions) to comparatively low accuracy of many tens of metres (indoors or where there are significant amounts of multipath) (<http://www.snaptrack.com>). Similar A-GPS implementations include those by Global Locate (<http://www.globallocate.com>), Parthus (<http://www.parthus.com>), Enuvis

(<http://www.enuvis.com>), and Sigtec (<http://www.signav.com.au>), though there are subtle differences in hardware, software and system architecture.

LBS Location Management Components – MPC and GMLC

The Gateway Mobile Location Centre (GMLC) and the Mobile Positioning Centre (MPC) are gateways to connect the positioning components of the GSM mobile telephony network and location-based service applications. One of their functions is to calculate the position of the mobile device (the technique used depends on the mobile positioning system used), and deliver this information to the application. To perform this task, it is necessary to have communication interfaces between the mobile telephony network and the LBS application. For the MPC the interface is the Mobile Positioning Protocol (MPP) (currently version 1.1). In the case of the GMLC, the interfaces are being developed and standardized by the Open Location Service initiative.

Ericsson's mobile positioning centre is an example of an operable facility. It delivers location estimates for mobile cell phones in a format that can be used by any Geographical Information System. "Ericsson's MPS is the only system available today that can position all mobile phones," and "The basic location method applies to GSM, TDMA and all other network technologies. Even more, it gives the end-user full control of when and by which service he wants to be positioned. That is a key to user comfort and commercial success" (Ericsson Mobile Positioning, <http://www.ericsson.com>).

Spatial Data and LBS

Apart from considerations of data transfer across wireless networks and mobile positioning, another essential component of the LBS architecture is storing and analysing spatial data. Geographical Information Systems are used to store, manage and analyse spatial data.

Geographical Information System

A Geographical Information System (GIS) refers to the computer-based capability to manipulate geographical data (i.e. all data that has a spatial attribute associated with it). A GIS includes functions to support the operations of acquisition, compilation, storage, update, management, retrieval, presentation and analysis of data. Spatial data in the form of maps or images can be stored in vector format or raster format. All GIS data are 'geo-referenced', so that all coordinate information is in a well-defined reference framework (or 'datum').

Data in GIS is of course *spatial*, and refers to a unique location on the earth's surface -- its geographical location with respect to a datum. A spatial object must have following four characteristics defined:

- Location: it exists at a known point on the earth's surface.
- Form: it has a geometric representation, with any geographical feature being represented by one of three basic geometric types: point, line and polygon.
- Attribute: properties that describe the nature of the object.
- Spatial relationship with other objects -- some basic relationships are boundary of an area, adjacent areas, distance between any two geometric objects, distance buffer of an object (consisting of all points within a given distance from that object), etc. (Syafi'i, 2000).

Database Management Systems for Spatial Data

Conventional Relational Database Management Systems (RDBMS) are generally used to store spatial data. However, a RDBMS is designed only for transactions involving comparatively simple data types such as characters and numeric data. Spatial data are usually complex objects that require more than one data structure to describe them, and their spatial relationships.

A new generation database management system, known as the Object Relational Database Management System (ORDBMS), has been developed. The ORDBMS merges the object-oriented management system that allows the storage of complex data as objects, and the relational database management system to offer the ability to manage the relationships between objects. A Structure Query Language (e.g. SQL2 or SQL3) can support all database management operations, as well as object-oriented data modelling (Syafi'i, 2000).

ORDBMS offers facilities such as user-defined data types (UDT) and user-defined functions (UDF). These enable users to store and manage complex spatial data, as an object, along with data from other sources such as CAD (Computer Aided Designs) and images in the same database. More importantly, ORDBMS allows spatial analysis to be performed in the database server using SQL commands instead of in the application. *Oracle8 Spatial Cartridge* is an example of a spatial database that stores geometric objects as Abstract Data Types (ADT), a user-defined data type, in feature-based tables, within the RDBMS. Most LBS developers, such as AirFlash, AutoDesk, CellPoint, GeoTouch, IntelliWhere, Webraska, Xmarc, currently use Oracle8 to store their spatial data.

From a GIS perspective, location-based services do not include many complex spatial analyses. However, it is the nature, completeness and accuracy of the database content that impacts on the quality of the subsequent LBS. For a certain service area, the database must include all the appropriate features such as roads and points of interest (hotels, parks, ATMs, restaurants, public traffic stations, tourist points, shops, etc.). In addition, digital 'maps' of the area are needed. These can be a portfolio of raster maps or images, a vector map that can be created 'on-the-fly' when requested, or archived aerial/satellite photographs or images. All roads and points of interest (and appropriate labels) must be shown, and be geo-referenced so that its location on the 'map' is correct.

The spatial data analysis functions used for location-based services are typically geometric functions involving the computation of distance, area, volume and directions. However, in a LBS a distance between two points may be expressed in travel time (for different means of transportation -- car, by foot, public transport, etc.), or in travel cost, rather than in metric units.

Among the location-based service concepts, the definitions of *geocoding* and *routing* must be clarified. *Geocoding* refers to processes of, for example, translating a real-world address such as a street number into a latitude/longitude coordinate value. There are also reverse-geocoding functions that convert a latitude/longitude coordinate into a street address. *Routing* functions are used to create a route, and display it on a map or image. The shortest route from point A to point B is also able to be calculated based on flow analysis of the appropriate geometric calculations. For example, there may be several possible routes to travel from point A to point B. The shortest route between these

points could be calculated based on a function of time, type of road and means of transport. For example, travel at 5am is generally quicker than at 8am, on the same road, with a car.

The Complete LBS System

The LBS architecture basically comprises the components shown in Figure 3. The first component is the mobile positioning system. This can be network-based (AOA, TOA, TDOA), or handset-based (E-OTD, GPS), or A-GPS. The second component is the mobile telephony network, which delivers the service to users. Service gateways in the mobile telephony network are essential. Their function is to connect positioning systems with the wireless network and the location-based service application. The third component is the location-based service application itself. This consists of an application server and a spatial database (or even a 'warehouse'). Components communicate with each other via application programming interfaces (APIs). These are designed to help wireless Internet developers integrate location-based services into mobile telephony networks. They also allow the application server to communicate with the spatial database and with the billing server. The processing centre for a location-based service platform is the application server that handles user interface functions and communicates with the spatial database or data warehouse.

LBS Issues

Diverse Mobile Mapping Standards

The issue of mobile mapping is important in the context of LBS as the ability to display mapping information on mobile devices such as cell phones and PDAs is limited. The spatial information may simply be text (street address of a point of interest, turn-by-turn directions, etc.), images (e.g. of current traffic conditions), map images (area of interest, shortest route from current location to a specific destination etc.), and so on. In general, attractive 'maps' are the best means of depicting spatial information, and are hence an essential element of LBS. Moreover, with the development of 3G telecommunications and the wireless Internet, users will be able to gain access to a wide variety of map information.

However, developing mapping applications for the mobile/wireless Internet is challenging, for several reasons. The major concern is the restricted display capability of mobile devices. Apart from the limited map features that can be displayed, the speed of data transmission to mobile devices is also slow in comparison to a wired network. Moreover, "Each device speaks a different wireless protocol and supports a variety of different Wireless Markup Languages (there are over 30 such languages) – these different standards preclude a web site developer from writing every application to individually support every single device available" (Oracle, 2000). For example, WAP-enabled cell phones support the WML. On the other hand, Palm Operating System devices support TTML (Tagged Text Markup Language), and voice-activated Internet applications support the VoiceXML and VoxML mark-up languages.

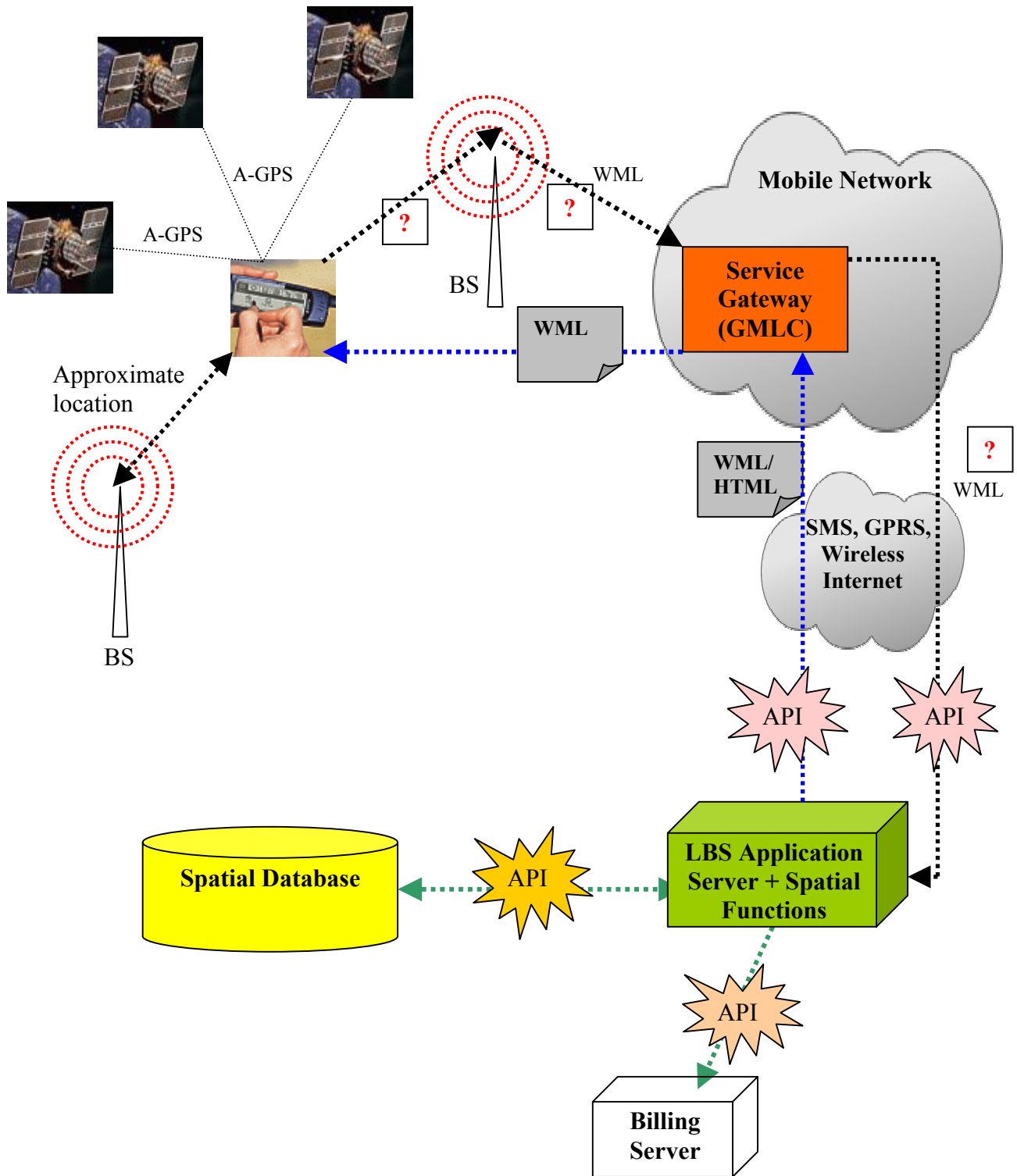


Figure 3: Location-Based Service Components (“?” is location information)

Mobile mapping requires standards that allow data content to be easily transferred and displayed across the wireless Internet to any one of a large variety of mobile devices. For displaying spatial data on the standard Internet, Scalable Vector Graphics (SVG) and Geography Markup Language (GML) are two important standards. The data in these formats are delivered across the Internet via XML. In the case of the mobile/wireless Internet, there should be conversion of standard Internet markup languages (XML and HTML) to languages that mobile devices can understand (e.g. WML, Handheld Device Markup Language - HDML, VoiceXML and SMS).

One leading mobile middleware product that enables these conversions is the *Oracle 9i Application Server Wireless Edition* (Oracle 9iAS Wireless). "It converts any Internet content to XML and transforms the XML to any markup language supported by any device (HTML, WML, HDML, VoiceXML, VoxML, SMS, etc.)". Therefore, "Oracle9iAS Wireless provides comprehensive support for the development of 'Location-based Services' (Oracle Technology Network, 2001). Oracle9iAS Wireless uses eLocation APIs, which are Java-based, to allow any Oracle9iAS Wireless application to interact with the spatial data management features in the spatial database.

Interoperability

Interoperability is a must for the widespread adoption of location-based services. "Achieving the full value for location services depends on consistent communication across different regions, technology platforms, networks, application domains, and classes of products" (Reichardt, 2001). Moreover, interoperability ensures network security and privacy. It also helps to facilitate billing and revenue sharing (Location Interoperability Forum, 2001). Therefore, "a truly interpretable Open Location Services Platform is essential for long-term success in this market" (Reichardt, 2001). The issue of interoperability needs to be addressed across:

- Wireless Systems/Networks (GSM, CDMA and TDMA).
- Positioning Technologies (COO, AOA, TDOA, E-OTD and A-GPS).
- Core Network (Multi-Vendor and Inter-Gateways).
- Applications:
 - Different network and contents interfaces (WAP, SMS and GPRS).
 - Different content formats (maps, routes and languages).

The Open GIS Consortium (OGC), which is the world's authoritative industrial organization for information processing matters related to spatial and location information, announced the Open Location Service (OpenLS) Initiative. The OpenLS Initiative focuses on developing interface standards "needed by industry to support implementation of the location services invoked by mobile or wireless Internet devices in end to end settings" (Hecht, 2000). "Similar to the way that HTTP protocols enabled the growth of activity in the World Wide Web, OpenLS standards, resulting from OGC's cooperative testbed process, have the potential to enable significant growth of Location Services markets in the Wireless Web" (Burnett, 2000). Figure 4 shows the components of a location-based service that the OpenLS focuses on.

The Location Interoperability Forum (LIF) is another organization dealing with specifications "pertaining to the query and response for the actual location or position of the mobile device" (Open Location Service, 2000). The following are the main objectives of the LIF:

- "Reduce/limit multiplicity of positioning technologies to be deployed.

- Promote common methods and interfaces for standards-based positioning technologies (Cell-ID, E-OTD, and A-GPS).
- Define common interfaces and methods between applications and the wireless networks irrespective of their underlying air interfaces and positioning technologies.
- Define/adopt common interfaces between applications and the different types of content engines and databases" (Location Interoperability Forum, 2001).

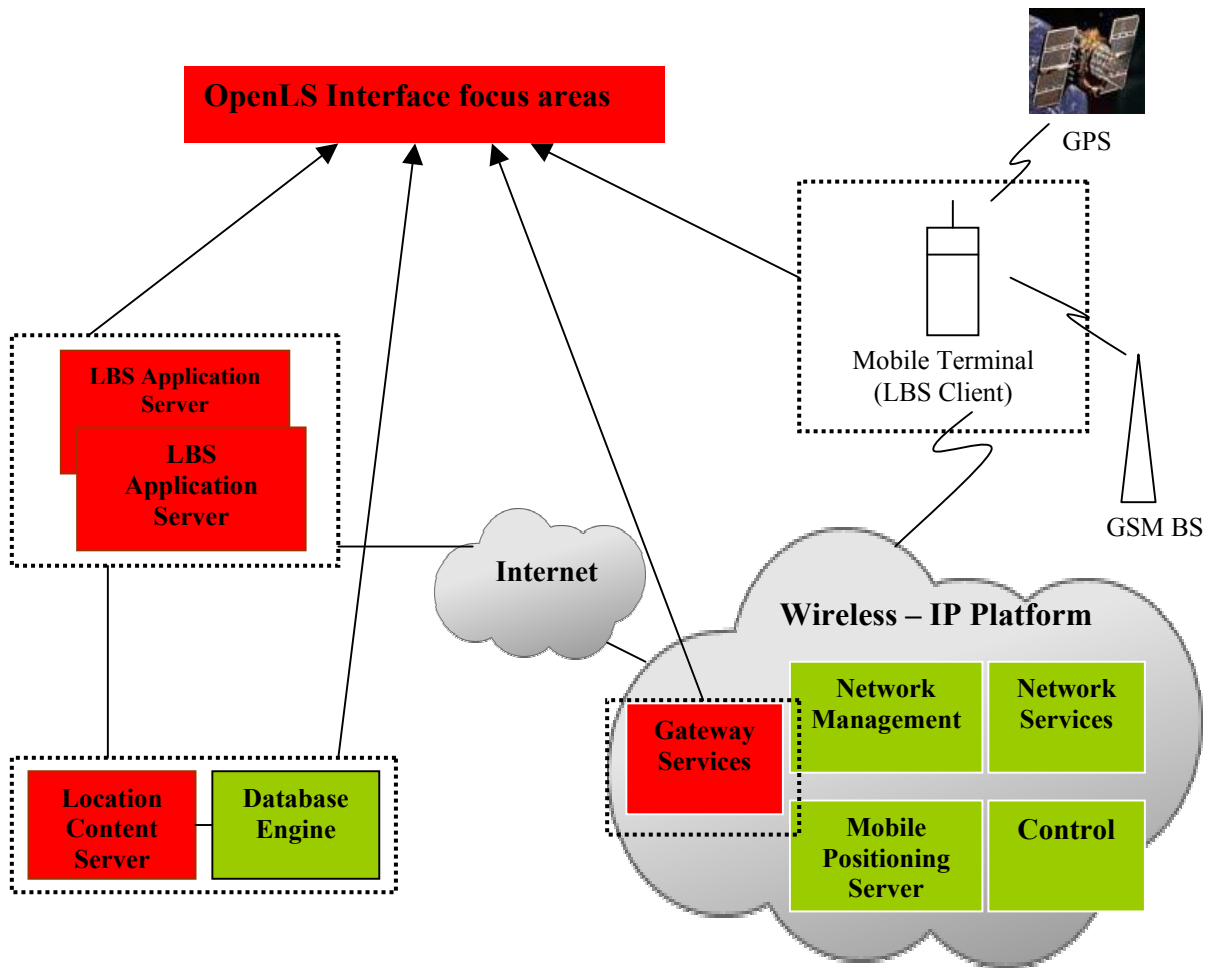


Figure 4: OpenLS interface Focus Areas (Hecht, 2000)

Market Capacity

Many computing and spatial information business analysts believe that LBS represent the ideal means by which spatial information can be provided to a wide range of public users. For mobile workers, all information needed to undertake the field work may be accessed from their mobile devices. For everyday activities LBS provide quick response to requests for location-related information. The capability of finding the nearest hotel or hospital location, and obtaining turn-by-turn directions to that destination, delivered via cell phones, is welcomed by everyone. Some even predict that LBS will, in the near future, be one of the most important sources of revenue for the wireless communications

industry. Reed (2001) states "telecommunication companies are making huge investments, and they know LBS technology is a key application from which they can generate revenue". VanderMeer (2001), Airbiquity Inc., a developer of wireless data communication solutions, "...predicts that by 2005 the location-based service (LBS) market will exceed \$11 billion in revenue...".

On the other hand, there are skeptical voices among analysts about the real attraction of location-based services. Reed (2001) states "...LBS technology faces limited bandwidth, hard-to-use interfaces, slow response, small screen size, high costs and limited applications as well as multiple, and often conflicting, standards". In addition, the LBS market seems to be speculative and "the real value and the future of mobile location-specific services lies in the developed relationships with customers and improved efficiencies of many business processes" (Sonnen, 2001). The most important concern is whether consumers are really interested in LBS, *and whether they are willing to pay for them.*

A study carried out by Driscoll-Wolfe Marketing & Research Consulting (summarized by Driscoll, 2001; and published by RCR Wireless News on 19/3/2001) tries to quantify customers' level of interest in, and willingness to pay for, LBS. From a survey of 20,000 households the study found that people would use routing assistance on average twice per month and look up a 'point-of-interest' less than twice per month. People who have Internet-capable PDAs or cell phones were found to be more likely to use LBS. "The research also indicates that more than 75% of respondents under age 45 would expect to use a routing assistance service at least once a month" (Driscoll, 2001). It also turns out that "16% of respondents who do not subscribe to cellular service expressed a strong level of interest in subscribing in order to obtain access to these services. An additional 15% expressed a slight interest in subscribing to cellular for location-related services. The majority (57%) of those who do not currently subscribe to cellular service would still have no interest in subscribing even if location-related services were offered at no additional cost" (ibid, 2001). It is clear that LBS developers need to "focus on killer applications", which are economically viable, "rather than frivolous services such as 'dial-your-daily-horoscope'" (Wee, 2001).

In summary, the market for LBS is currently very speculative. There are some serious concerns, such as whether consumers are prepared to pay for LBS and how much revenue can be generated by LBS. However, the potential for LBS cannot be easily rejected. Reed (2001) states "providers will quickly evolve their offerings, and the infrastructure will grow to meet the market requirements....I also believe the LBS industry has potential to completely reshape the geospatial industry". "Information about a potential customer's location can be particularly valuable" (Sonnen, 2001).

User Privacy

Another important issue for LBS is wireless location privacy protection. The locations of customers, whose mobile devices have position-determination capability, may be known to an accuracy better than 100m whenever they make a call. Hence their everyday 'tracks' can be recorded and analysed unless safeguards are introduced. Such customers are worried about the privacy of information about their locations. According to a study by Driscoll-Wolfe Marketing & Research Consulting (2001), there is concern about "potential threats to personal security and use of personal location records for

commercial purposes and legal actions." and therefore "Respondents emphasized the importance of being able to control who receives their location information."

It is necessary for telecommunications carriers to understand how important customers' location privacy is. Currently, "vendors and carriers are being naive [about wireless privacy concerns from consumers] and haven't done the proper market research to detect that concern" (Hamblen, 2001). The LBS vendors themselves have admitted that "privacy will be a concern" but "users must be assured that they have several ways to request receipt of location-based information (known as opt-in), as well as have opportunities to opt-out" (ibid, 2001). Carriers should be able to distinguish between those customers that want location-based services (or location-based advertising), and those who do not.

Furthermore, carriers should protect their location information by not forwarding it to advertisers or other service providers unless the users authorize them to do so. In the U.S., The Location Privacy Protection Act has been introduced into the Senate by Senator John Edwards. "The bill requires companies that provide wireless location-based services to notify users when they collect information about their location. The bill also prohibits the use or sale of the information without permission of the user" (AllNetDevices Staff, 2001b). "We need to get ahead of the curve on what will soon be a real problem" (ibid, 2001b).

Protection Groups of consumers seem to be very concerned about such issues. The Center for Democracy and Technology (CDT), in the U.S., is calling upon location-based service developers to pay particular attention to mobile customer location privacy. "CDT believes that a separate proceeding to craft strong, technology neutral privacy rules implementing the wireless location information provisions of section 222 of the Communications Act should commence immediately" (Dempsey & Mulligan, 2001). Section 222 requires "express prior authorization" before providing commercial access to user's location information. In Europe, the European Commission is also trying to address the location privacy issues by drafting a Europe-wide Data Privacy Act.

Concluding Remarks

The paper has discussed several aspects impacting on the implementation of location-based services. These include knowledge on the wireless network that is capable of supporting LBS, mobile positioning techniques, and issues concerning spatial databases. Additional issues such as interoperability, privacy and market capacity were also discussed. Despite current problems and drawbacks, location-based services represent a promising future class of spatially-enabled mobile applications.

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