Location-based services: architecture overview

Costas Pontikakos, Thomas Glezakos and Theodore Tsiligiridis

Informatics Laboratory
Agricultural University of Athens
75 Iera Odos street, Athens 11855, Greece

Abstract: Location-Based Services (LBSs) stands for the provision of information about the position of a device or a user, often offered as a service via various means of media. The position can be combined with spatial information so as to integrate an LBS system with Geographical Information Systems (GISs) or other location dependent information. The quality of the services provided by the LBSs depends on the utilized architecture that would support differentiated service levels, each of which guarantees a specific Quality of Service (QoS).
The current survey opens up by presenting a review on the various LBS systems and then focuses on their architectures and the different governing platforms and technologies on which they are based. The general concepts of these systems are discussed by presenting a first level of classification which depends on the positioning infrastructure namely, indoor, satellite or network-based configuration. Several specific LBS architectures are categorized by means of the various characteristics regarding the design and functionality of each one. The survey furthermore expands towards the integration of the LBS and the various GISs. In order to increase interoperability among the various systems and technologies, the necessity for standardization and homogenization is also taken under consideration.

Keywords: Location-Based Services (LBS), LBS architecture, Geo-lactation, Positioning systems, GIS, Internet GIS.

1. Introduction

Location information is important in many computing applications. The emerging convergence and integration of digital communication technology based on mobile networks, driven by the success of Internet technology, are now focused on offer services that are related by the location of individuals. Such services are generally referred to as Location Based Services (LBSs) and can be defined as services that integrate a mobile device's location or position with other information so as to provide added value to a user (Schiller and Voisard, 2004) They can be seen as the convergence of mobile services, location aware technologies (positioning) with the Internet and GIS (Figure 1). Thus, the various systems of LBSs must be able to integrate information related to geographic position and information (mapping), routing, searching, multimedia content and address location functionalities with user-specified profile and content.

LBSs are met in multiple fields and applications. They have been seen as a key for differentiating between the mobile and fixed Internet worlds since LBS capitalize on the nature of mobility by bringing together the user and his/her immediate environment.

According to Schiller and Voisard (2004), the most interesting approaches distinct LBS applications into *person/device oriented* and the *push/pull services*. The quality of the services provided depends on the utilized architecture that would support differentiated service levels, each of which guarantees a specific Quality of Service (QoS).

This paper aims to provide an overview of the different architectures in which the LBSs are based. The work is organized as follows. Section 2 describes the geo-location technologies, Section 3 presents the architecture, Section 4 deals with the integration of LBSs with GIS, Section 5 presents the LBSs platforms, and lastly, Section 6 some conclusions are drawn

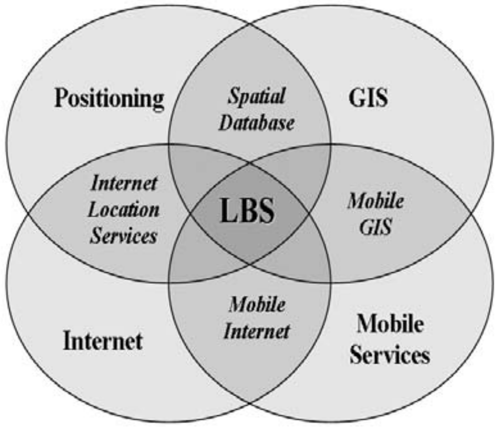

Figure 1: Convergence of technologies to create LBS

2. Geo-location Technologies

2.1. Location identification technologies

The design of a LBSs system focuses on the degree of accuracy in targeting a user's location. A number of geo-location technologies promise an accurate pinpointing of an object or person's position on earth (Rao and Minakakis, 2003). The following strategic considerations assume importance while choosing and deploying these technologies: the range of coverage and scalability of applications, the degree of service quality that can be established and maintained at a reasonable cost, and the careful alignment of the overall technology costs. Systems that determine the location of a mobile user can be tracking or positioning. In the case a sensor network determines the location the term that is used is tracking. Otherwise, if the mobile system determines the location itself, the term positioning is used. The types of location identification technologies are summarized and compared in Table 1.

2.2. Taxonomy of Positioning Systems

Positioning systems are divided into three classes: satellite positioning, indoor positioning, and network-based positioning systems.

- **Satellite positioning**

Using satellites for positioning has important advantages, such as the following:

  - Positioning can in principle be carried out everywhere on the earth.
  - Environmental conditions, such as the weather, have only minimal influence on the positioning process.
  - A high precision is obtained.

NAV-STAR GPS system is a most popular world-wide positioning system. There also exists the GLONASS system, and there is to come the GALILEO system. GPS has an accuracy ranging from 100m to few millimeters depending on equipment and procedure. GPS systems can operate effectively mostly in outdoor clear space environments. Indoor GPS technique is based on generating a GPS-like navigation signal from a number of local area pseudo-satellites to allow compatibility with GPS receivers with minimal adaptation to simulated signal (Salaur, 2005).

- **Indoor positioning**

Indoor positioning systems require cost-intensive installations and are restricted to buildings or even some rooms inside a building. Although the mechanisms of the satellite navigation systems are very similar, indoor positioning systems are very different concerning the basic mechanisms, precision, and costs. The indoor positioning systems are based on infrared, radio, ultrasound, and video.

Technology	Description
User Input	o User enters an address
Cell ID (Cell Identifier)	o The network knows which cell the handset is in. o Works well in cities where cells are small.
GPS (Global Positioning System)	o It based on 24-satellite network. o Outdoor precision within five-meter range. o User device must be in direct line of sight.
A–GPS (Assisted GPS)	o Like GPS. More accurate. o Enhancement over GPS. o No "cold starts". o Faster fix on location.
DGPS (Differential GPS)	o Similar to GPS. o More accurate relative to GPS. o A reference receiver computes corrections for each satellite signal received.
CoO (Cell-of-Origin)	o No modifications needed to networks or handsets. o Relatively low accuracy.
TdoA (Time Difference-of-Arrival.)	o The network uses its base stations to triangulate a fix on the handset, based the time of arrival of signals from the handset.
E–OTD (Enhanced-Offset Time Division)	o Use the triangulation technique to calculate the position. o Software modified handsets needed.
ToA (Time of Arrival)	o Uses existing CDMA network features.
AoA (Angle of Arrival)	o Complicated antennae required.
IN (Intelligent Network)	o Location Finding System independent.

Table 1. Location identification technologies

- **Network-based positioning**

Existing wireless networks can be used for positioning services. The network-based positioning may be subdivided by infrastructure into the following three subclasses:

a) Positioning in cellular networks

The GSM is a world popular standard for cellular phone service. Without any further installations, a simple positioning is possible within the GSM network, which knows exactly in which cell which mobile telephone is registered. Ericsson developed a system called the Mobile Positioning System (MPS) (Schiller and Voisard, 2004), which makes more exact positioning possible in large cells. Before such systems can be used for positioning, they may be needed to be trained.

b) Positioning in wireless LAN

Positioning is based on wireless LAN infrastructure and uses the measurements of signal strength of wireless LAN access points or bridges to compute physical location of the target device equipped with WLAN card – network adapter. It is mostly useful in indoor environments but, it may also work for outdoor environments. There has been proposed various WLAN positioning systems that use different algorithms, differ in performance and target environments.

c) Positioning in ad hoc sensor networks

Positioning is based on sensor networks and uses short distance signal propagations to determine mobile user's location with accuracy up to the coverage of short-range signal-emitters. The examples of this subclass of systems include Bluetooth, IrDA, Active Badge, Cricket, Dolphin, Active Bat, Cyberguide, and others. One of such systems uses Radio-

Frequency IDentification (RFID) Tags. Table 2 provides a comparison of the above and others positioning systems.

Name	Category	Tracking / Positioning	Mechanism	Medium	Precision
GPS	Satellite	Positioning	TOA	Radio	25m
DGPS	Satellite	Positioning	TOA	Radio	3m
A-GPS	Network/ Satellite	Positioning		Radio	
WAAS	Satellite	Positioning	TOA	Radio	3m
Active Badge	Indoor	Tracking	COO	Infrared	Cell
WIPS	Indoor	Positioning	COO	Infrared	Cell
SpotON	Indoor	Tracking	Signal Strength	Radio	3m
Active Bat	Indoor	Tracking	TOA	Ultrasound/Radio	0.1m
Cricket	Indoor	Positioning	TOA	Ultrasound/Radio	0.3m
RFID	Indoor	Tracking	COO	Radio	Cell
Visual Tags	Indoor	Both	Video	Optical	Depends on camera resolution
GSM	Network	Both	COO, AOA, TOA	Radio	Cell, distance in 555m steps
MPS	Network	Both	COO, AOA, TOA	Radio	150m
Nibble	Network	Positioning	Signal Strength	Radio	3m

Table 2. Comparison of positioning systems.

3. LBS Architecture

3.1. General concept

The LBS architecture basically comprises the following components:

- *Mobile positioning system*.
- *Wireless network*, which delivers the service to users. Their function is to connect positioning systems with the wireless network and the LBS application.
- *LBS application* itself. This consists of an application server and a spatial database.
- *LBS middleware,* which facilitates the development and deployment of LBS applications in heterogeneous network environments.
- *Aplication server*, which is the processing centre for a LBS platform that handles user interface functions and communicates with the spatial database.

3.2. Client / server architecture

Most of the LBS applications have client/server architecture and can be abstracted into three main parts: Client, Server, and Wireless Communication to connect Client and Server. Client is responsible for sending the user's request and the geographical location of the mobile device to Server, and Server is responsible for providing services based on the geographical location of the mobile device. Client can make contributions to information acquisition by collecting data in the field. Server will put the information collected from the field into the database and will then provide services for all clients based on the database. In fact, the role definitions of Server and Client are becoming more and more ambiguous. Server can analyze this critical information and put it into the database for service. Although it is a trend for LBS to collect information at the Client side, there are still some problems caused by wireless communication (Liu, 2002). The architecture of LBS is shown in Figure 2.

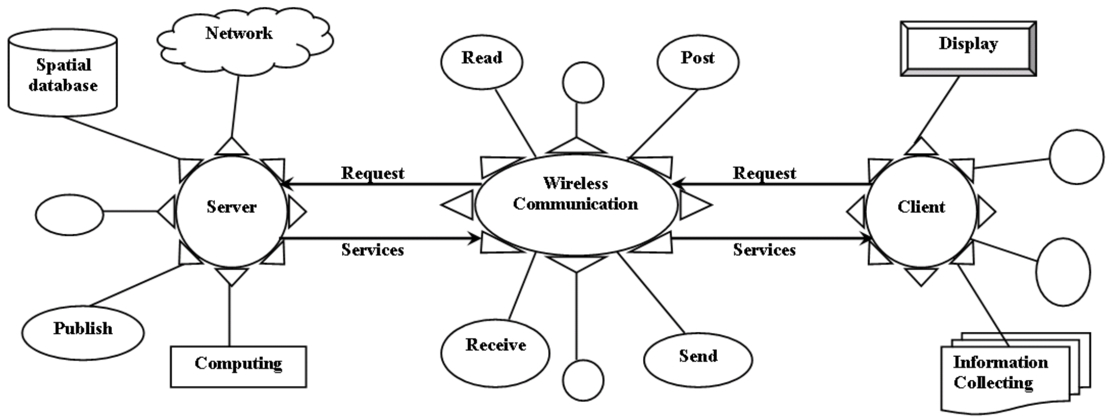

Figure 2. LBSs Architecture

Client, Server, and Wireless Communication of LBS can be further divided into an aggregation of functions, which for a certain application will fall into a subset of the following function pools.

- Client functions: *Display, Information Collecting, Peripheral Control, Computing, Wireless Connection, Save* and *Multimedia*.
- Server functions: *Network: Database, Computing, Multimedia, Business Logic,* and *Wireless Connection.*
- Wireless Communication functions: *Receive, Send, Real-time, Post , Read*, *Encryption,* and *Information Security*

The above classification is the first step for Client, Server, and Wireless Communication to pursue reusability. However, the methods and the procedures used to realize reusability for each of them are different in each case. At the Client side, hardware compatibility which is the core problem for application developers to realize reusability is now available. Considering power consumption, computation ability, size, hardware interface, and screen issues, there is not a universal solution to meet the requirements of all users. At the Server side, the crucial problem lies in network compatibility. The program running on the Server side should support multiple operating systems, web browsers, and protocols that are proliferating rapidly on the Internet and Intranet. The most common and dominant method of wireless communication available today is the commercial cellular telephone system. Compared to Server, the protocols for Wireless Communication are much less. Moreover, different types of wireless communication are highly complementary and easily merged (Liu, 2002).

3.3. Middleware perspective

LBS middleware has to bridge protocols and network technology with wireless and Internet technology. Standards that are emerging in this domain are the Wireless Access Protocol (WAP) and interoperability standards (OGC, 2005). LBS middleware is either deployed within the network operator’s network or hosted by an application service provider. The middleware integrates with the network infrastructure, including location servers, WAP gateways, subscriber portal services, customer care, customer activation services, billing systems, accounting systems, and operational systems. An end-to-end system architecture is presented in Figure 3.

LBS middleware differ in the kind of services offered to the subscriber, the network operator, and the application provider. Applications are layered on top of the middleware, without much concern for the lower-level services. There is not one standard architectural reference model that uniquely describes the components of LBS middleware available to date.

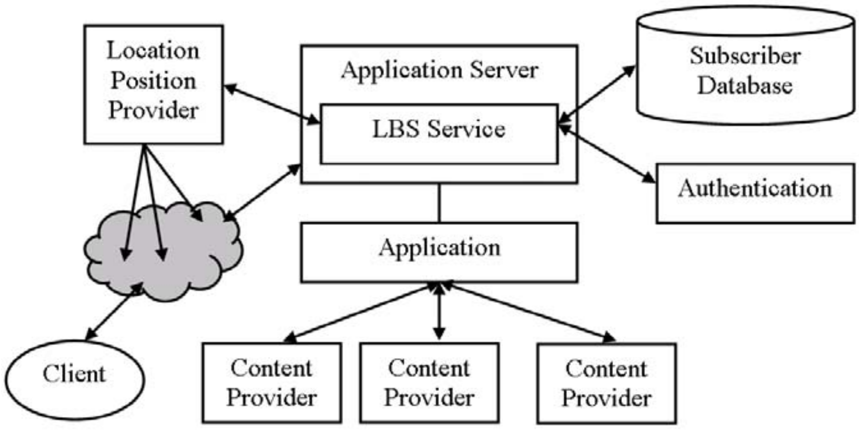

Figure 3. Middleware

3.4. Mobile Communication

The concept of LBS rests on the ability to communicate while being mobile. Different requirements lead to different architectures and LBS can be built on top of many of these different system architectures. Their common task is to provide communication among different entities, whether they are mobile or fixed, and LBS use this facility to communicate. But the differences in system architectures will affect the type of communication support LBS can expect.

The most common architectures of mobile communication systems that their functionality can offer to the realization of LBS are: Cellular-based Mobile Communication, Wireless LANs, Internet-based Mobile Communication and Ad-hoc Networking.

4. Integration with GISs

4.1. GIS and LBS

LBSs is an information system that processes geographic data. The presentation of maps in various forms is based on the development of cartographic knowledge on map design. Clarke (2001) and Casademont et al. (2004) have presented the technology currently available for use in wireless GIS systems and its capabilities by reviewing portable devices that can run mobile cartography and GIS applications. Spatial data usually consist of complex spatial objects (Shekhar *et al.*, 1999), while an LBS spatial index contains a large number of simple spatial objects (points) that are frequently updated. These "moving object databases" pose new challenges to spatial data management (Prasad Sistla et al., 1997; Wolfson et al., 1998; Pfoser and Jensen, 2001). There are several important aspects of a GIS, which have to be analyzed when trying to enhance an advanced LBS with GIS features, such as geographic data collection, conversion, management, analysis and presentation (Longley *et al.*, 2001). The power of LBSs lays in delivering GIS functionality and location-based information across fixed and mobile Internet-based networks, to be used by anyone, anywhere, at any time and on any device.

4.2. Mobile GIS architectures

Mobile GIS and LBS have special demands on the presentation of maps and on the interaction with spatial objects, which result from the varying position and orientation of the user and from the typical applications performed on mobile devices (Brinkhoff, 2005). The characteristics of a mobile GIS are mobility and interconnectivity through wide area wireless networks, while utilizing certain Spatial Information Servers (SIS). The analytic, data storage and retrieval and data collection technology are just background serving technologies as LBS

The main architectures of a Mobile GIS system are:

- *Stand-Alone Client architecture* (Figure 4): It is the simplest architecture where the application resides entirely on the mobile device which stores geo-data, out-of-the box mobile GIS software to interpret and display that data, and the application, which is built on top of the GIS software. The limitations inherent in the architecture lie within the restrictions posed by the hardware and the lack of communication between systems using the same application.

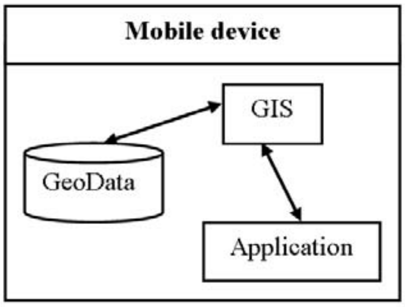

Figure 4. Stand-Alone Client architecture

Client-Server architecture (Figure 5): This model addresses limitations of the Stand-Alone Client architecture. The geo-data are moved to a separate computer and served to the client by a GIS server software. The advantages over the Stand-Alone Client architecture are that the hardware, being an enterprise server, has virtually limitless resources. Moreover, several applications can concurrently access the server. A disadvantage of this architecture arises when the connection with the server cannot be realized.

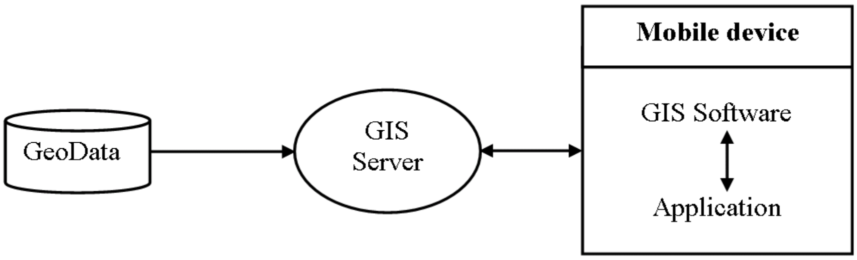

Figure 5. Client-Server architecture

- *Distributed Client-Server architecture* (Figure 6). To address the above connectivity problem, two key distributed system concepts must be employed: *Persistence* in connection tries and *resource management* in the form of locally cached data. This architecture will support most mobile GIS applications in a robust, reliable way, but it does not allow for extensibility on the back end.

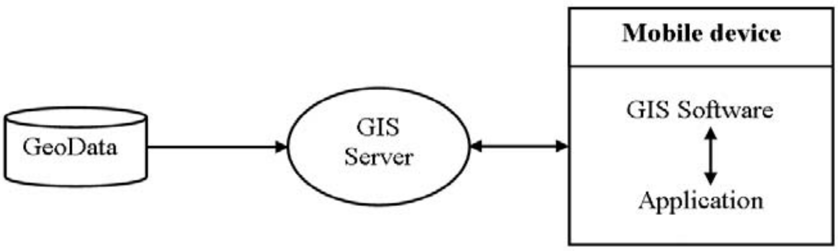

Figure 6. Distributed Client-Server architecture

- *Services architecture* (Figure 7). The GIS server is viewed as a web service and other web services are part of the application as well. As long as the same communications protocol is used, the mobile device(s) can communicate with them while the services can also communicate with each other. A natural fit for this common communications protocol is SOAP XML, the industry standard for passing messages between software components. This architecture is not suitable for collaboration in remote areas where connectivity to servers is unavailable.

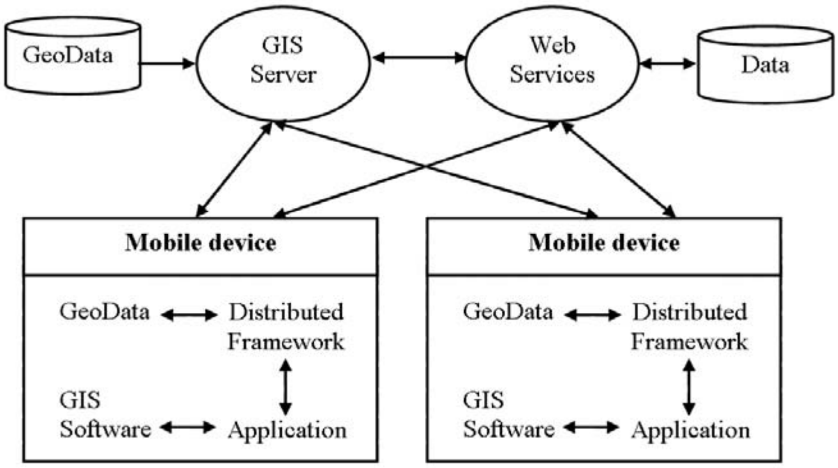

Figure 7. Services architecture

- *Peer-to-Peer architecture* (Figure 8). Each mobile device houses just a subset of the geodata making the use of a server needless, while still addressing the shortcomings of the Stand-Alone Client architecture.

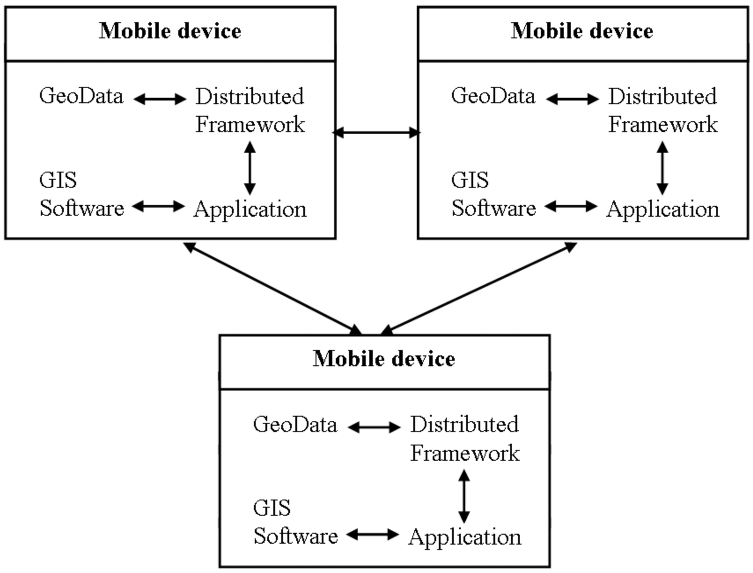

Figure 8. Peer-to-Peer architecture

4.3. Internet GIS and LBS

The various Internet information systems have evolved from static natured systems, which provided users with limited interactive view of information, into the contemporary 3-tier information systems (client, application and data server tiers), assembled of self-contained, self-describing modular applications (services) which can be published, located and invoked across the Web using computing devices. There are two basic approaches to development and deployment of GIS on the Internet: the server- and the client- side applications (Gifford, 1999).

a) In server-side Internet GIS, a Web browser is used to generate server requests and display the results. An Internet GIS server usually combines a standard Web (HTTP) server and a GIS application server, and the GIS databases and functionality reside completely on the server(s). The disadvantages encompass poor performance on one hand and limited user interface or interaction on the other.

b) In client-side Internet GIS, the client is enhanced to support GIS operations, while the middle tier, represented by the application server, is populated with application logic (Figure 9). In such systems either a substantial amount of GIS functionality is moved to the client, or only the user interface is enhanced slightly to enable specific user interaction. The advantages of this approach are the enhanced user interfaces, the improvement in performance and the implementation of advanced solutions using both raster and vector data. The main problems relate to distributing software and data. ISO TC 211 (ISO/TC 211, 2001) and OpenGIS (OCG, 2005) are working on open standards for interoperability within geo-information infrastructure, which have to be the foundation of contemporary Internet based GISs.

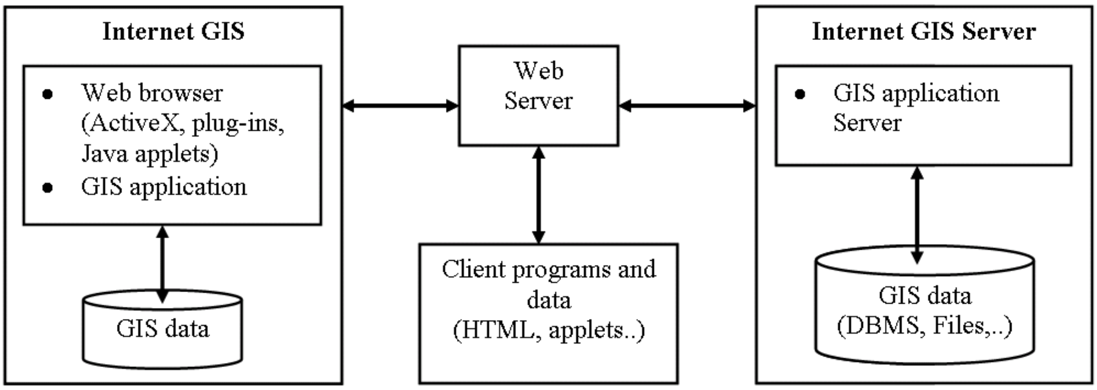

Figure 9. Client-side Internet GIS architecture (3-tiers)

The Internet GIS technology behind LBSs will empower an increasingly diverse range of applications, since they provide access to spatiotemporal information by utilizing various GIS components, this way enabling the dissemination of even more valuable information.

5. Platforms

LB solutions are of major interest in the wireless domain, invoking many corporate vendors to develop software tools and middleware platforms to handle their delivery. Table 4 enumerates the key characteristics of the most common location-based platforms available today, most of which are based on JAVA/J2EE technologies. Some of them are of general-purpose, while others are oriented to specific application domains.

6. Conclusions

Although considerable attention within LBS technology has been placed to its constituent technologies, like wireless Web, mobile Internet-enabled devices and mobile positioning, the heart of the whole system represents Internet-enabled GIS technology.

In the future, LBSs will benefit from real-time information acquisition at the Client side. Client will be equipped with sensors to collect information automatically and send it back to Server.

Location Platform (Source / Provided by)	Key characteristics
ALBS (Ibach *et al.* (2005))	o Utilize their ability of location-awareness to simplify user interactions and adapt to the specific context. o WSDL, GPS, WLAN, Bluetooth.
ArcLocation Solutions (ESRI)	o WAP/SMS/HTTP/GMLC connectivity.
AROUND (José *et al.* (2003))	o Enables the discovery of LBS over the Internet. o Distance-based and scope-based models. o GPS/GSM.
Autodesk Location Services (AutoDesk)	o Service deployment through java or web services APIs.
Cellocate (Cell-Loc Inc.)	o Proprietary positioning hardware for delivering LBS.
Celltick Platform (Celltick Technologies)	o GSM and GPRS networks using SMS or WAP connectivity.
Cloudberry (Air-Trak)	o GPS-enabled vehicle tracking system.
Dumb Pipe (Spinney (2003))	o Assumes all spatially enabled applications residing outside the network firewall in the IP domain exploit the wireless network as a resource from which to collect location information. o MPC/GMLC, LES, and GIS.
GeoMobility Server (OGC (2005))	o Open LBSs platform.
GiMoDig (GiModig, (2005))	o Develops test methods for delivering geospatial data to a mobile user.
LOC-AID.net (Datumcom Corporation)	o Location tracking for CDMA and GSM networks.
Location Engine (Kivera Inc.)	o No interface to positioning infrastructure.
LocationAgent (Mapflow)	o Service deployment over 2G/3G networks.
MapInfo MapXtreme Java Edition (MapInfo)	o Java middleware for LBS but without positioning interface.
Mobile Positioning System (Ericsson)	o LBS for 2G/3G networks.
PanGo Proximity Platform (PanGo Networks)	o Proximity services for WLAN environments.
PLM (Karimi and Liu (2003))	o Predicts locations in LBSs with road-level granularities. o Geometrical and topological techniques allowing users to receive services on time. o GPS positioning. o Client-Server architecture.
POLOS (Spanoudakis *et al.* (2003))	o Component-based. o Accommodate new transport protocols. o Open interface. o 2G/3G networks, WLAN, GPS, SOAP, SCL language.
SpatialFX (ObjectFX Corporation)	o Java enabled software for performing spatial queries.
The Cellpoint MLS/MLB architecture (cellpoint)	o 2G/3G Networks.
Webraska Products (Webraska Mobile Technologies)	o GMLC positioning interface, SOAP HTTP/XML APIs for service development.
Xypoint Location Platform (XLP) (TeleCommunic ation Systems)	o GSM, CDMA, TDMA and 3G support.

Table 4. LBS platforms

Reference:

Brinkhoff T., (2005). Towards a Declarative Portrayal and Interaction Model for GIS and LBS. In Proceedings 8th Conference on Geographic Information Science (AGILE 2005), Estoril, Portugal, 2005, pp. 449-458.

Casademont J., Lopez-Aguilera E., Paradells J., Rojas A., Calveras A., Barcelo Fr., Cotrina J., (2004). Wireless technology applied to GIS. Computers and Geosciences 30, 671-682.

Clarke K.C. (2001). Cartography in a mobile internet age. In Proceedings, The 20th International Cartographic Conference, ICC2001, Beijing, China, August 6-10th, 2001, vol. 3, pp. 1481-1488.

Gifford F., (1999). Internet GIS Architecture: Client v Server - which side is Right for You?, Mapping Awareness, Vol. 13, No. 7, August 1999, pp. 40-42.

GiModig, (2005). Geospatial info-mobility service by real-time data-integration and generalization. http://gimodig.fgi.fi/

Ibach P., Tamm G., Horbank M., (2005). Dynamic Value Webs in Mobile Environments Using Adaptive Location-Based Services. Proceedings of the 38th Hawaii International Conference on System Sciences.

ISO/TC 211, (2001).- Geographic Information / Geomatics, 19100 series of standards, http://www.statkart.no/isotc211

José R., Roreira A., Rodrigues H., (2003).The AROUND Architecture for Dynamic Location-Based Services. Mobile Networks and Applications 8, 377–387,

Karimi H. A. and Liu X., (2003). A Predictive Location Model for Location-Based Services. GIS'03, November 7-8, 2003, New Orleans, Louisiana, USA.

Liu Z., (2002). A Java-Based Wireless Framework for Location-Based Services Applications. Department of geomatics engineering, University of Calgary, Alberta.

Longley P.A., Goodchild M.F., Maguire D.J., Rhind D.W., (2001). Geographical Information Systems and Science, John Wiley & Sans, UK.

OGC, (2005). Open Geospatial Consortium, Inc., http://www.opengeospatial.org/

Pfoser D., Jensen C.S., (2001).. Querying the trajectories of on-line mobile objects. In Proceedings of the ACM International Workshop on Data Engineering for Wireless and Mobile Access, Santa Barbara, CA, May 2001.

Prasad Sistla A., Wolfson O., Chamberlain S., Dao S., (1997). Modeling and querying moving objects. In Proceedings of the IEEE International Conference on Data Engineering (ICDE), pages 422–432, Birmingham, UK, April 1997.

Rao B., Minakakis L., (2003). Evolution of Mobile Location-based Services, communications of the ACM December 2003/Vol. 46, No. 12, 61-65.

Salaur L., (2005). Building a Commodity Location-based Service at Botanic Garden of University of Freiburg. Master Thesis. Communication Systems Department University of Freiburg

Schiller J., Voisard A., (2004.). LBSs, Morgan Kaufmann, London, UK.

Shekhar S., Chawla S., Ravada S., Fetterer A., Liu X., Chang tien Lu., (1999). Spatial databases: Accomplishments and research needs. IEEE Transactions on Knowledge and Data Engineering, 11(1):45–55, January 1999.

Spanoudakis M., Batistakis A., Priggouris I., Ioannidis A., Hadjiefthymiades St., Merakos L., (2003). Extensible Platform for LBSs Provisioning. in proceedings of the 3rd International Workshop on Web and Wireless Geographical Information Systems (W2GIS 2003), Rome, Italy, December 2003.

Spinney J., (2003). Mobilizing Existing Users of Geographic Information— The Dumb Pipe Approach for LBS. http://www.directionsmag.com/article.php?article_id=411

Wolfson O., Bo Xu, Chamberlain S., and Liqin Jiang, (1998). Moving objects databases: Issues and solutions. In Proceedings of the International Conference on Statistical and Scientific Database Management (SSDBM), pages 111–122, Capri, Italy, July 1998.