# A Survey on LBS: System Architecture, Trends and Broad Research Areas

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**Abstract.** The Location Based Services (LBS) seem to be the next revolution on small computing handheld devices in terms of location aware advertising, security alerts, news updates, disaster management, geo-fencing, buddy-findings, gaming, criminal investigations, turn-by-turn navigation and so on. In today's scenario there is an explosion of technologies to communicate with mobile, connected devices and sensors. In this paper we are presenting a literature survey of LBS that includes the architecture of the LBS ecosystem, the key market players, and the latest trends in LBS development. Finally, the broad research areas such as location determination techniques, geo-sensor networks, and location based natural queries, location privacy and authorization, geo-social networks, LBS QoS, and Location Based Recommender Systems (LBRS) have been studied and presented briefly.

**Keywords:** Location Based Services (LBS), Location Determination, Location Based Service Providers (LSP), Location Determination Technology (LDT), Location Privacy, LBS Research Challenges.

## 1 Introduction

The Location Based Services (LBS) are information, alerts and entertainment services, accessible with the computers and mobile devices through Over the Air (OTA) network. It facilitates to make use of the geographical position of the mobile device for various services. The LBS refers to the services in which the user location information is used in order to add value to the service as a whole. Terminals can be fixed or mobile; both receive and transmit data. They include wireless phones, laptops, portable navigation devices, and embedded systems. The user location information consists of X-Y coordinates generated by any given Location Determination Technology (LDT), such as Cell-ID, A-GPS, and EOTD etc. These technologies usually require modifications in either the networks or the mobile phones, and in some cases in both. Main service categories for LBS include Emergency and Safety, Communities and Entertainment, Information and Navigation, Tracking and Monitoring, and M-Commerce. LBS have generated a lot of interest in recent years, as a new source for mobile operators to enhance their service offering.

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Predictions of LBS usage have generated a lot of interest and attracted many new players developing and offering numerous applications and services. Operators see it as an integral and inevitable part of their service offering, allowing them to better utilize some of their existing assets in order to be more competitive [6].

The LBS services can be divided into various major categories such as Pull vs Push services; Person vs Device oriented services, and Active vs Passive services. The Push Services keep track of current location of user for services such as security alerts, news updates etc. Such services require real-time location update to the location server. However, the Pull Services are based on demand by the user and thus do not require the continuous update of the user location. The examples of such services are point of interest (POI) Searches, Geocoding, Reverse Geocoding and so on. Person-oriented Services comprise all of those applications where a service is user-based. Thus, the focus of application is to position a person or to use the position to enhance a service. Device-oriented Services are external to the user, where instead of focusing a person's demand, an object (e.g., a car, a bus) or a group of people (e.g., a fleet) could be located. In device-oriented applications, the person or object located is usually not controlling the service e.g., car tracking for theft recovery. In Active Services, the user initiates the service request, whereas in the Passive Services a third party locates one user (locatee) at the request of another user (the locator). Typical Passive location services are friend finder services, location-based gaming, or fleet management [21].

Wireless Networking (WiFi), cellular telephone (GSM), Packet Radio, Radio Frequency Identifiers (RFID), Smart Personal Object Technology (SPOT), global positioning systems (GPS), and sensor networks are various technologies available to communicate with mobile, connected devices and sensors. The navigation systems and LBS informative applications have been useful on Turn-by-Turn navigation, POI Search, location search, Map Display etc. Currently there are several digital data provider companies (i.e. NavTeq, TeleAtlas, KIWI, Map My India) which provide the digitized geographical data. The route calculation between the source and the destination addresses, and proximity searches are some of the applications of the digitized data.

Apart from the brief introduction of LBS in this section, the architecture of an LBS ecosystem is discussed in section-2. The recent trends in LBS and the key players in LBS market are explained in section-3 and 4 respectively. Finally, section-5 talks about the broad research areas in LBS domain and the section-6 concludes the survey.

## 2 Architecture of an LBS Ecosystem

Due to the variety of positioning technologies, the model shall be independent of the location determination implementation. Also it should be able to work when the user switches from one positioning technology to another [5]. Fig.1 shows a generic architecture of the LBS ecosystem [22]. The components include Positioning, Communication Network, and the Content Providers as the basic infrastructure requirements. The Positioning can be done either by the client device using satellite based GPS (Global Positioning System) or a network positioning service. Afterwards the mobile client sends the service request, which contains the service goals and the position via the communication network. The content/data provider is the actual location engine that provides various LBS services.

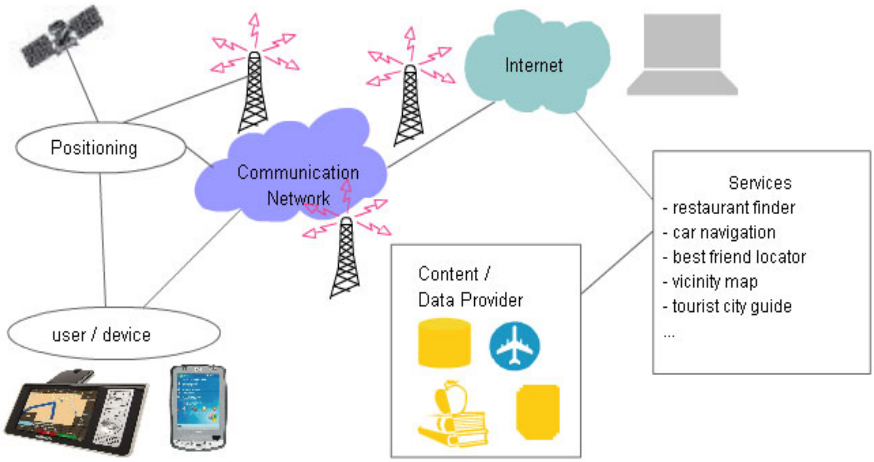


**Fig. 1.** Location Based System Architecture

Furthermore, the Middleware can be added into the generic architecture to ensure location privacy, subscription management, and transaction accountability. The Middleware based architecture and a popular LBS platform named Kivera Location Platform is discussed in the subsections below.

## 2.1 Middleware Based Architecture

A Middleware is a set of services that facilitate the development and deployment of distributed applications in heterogeneous environments. Middleware consists of a set of services exposing interfaces, a programming model, and an interaction model to the application developer. For the context of LBS, this refers to the services, abstractions, and models that implement mobile user coordination, information correlation, and information dissemination. A major component of LBS is the integration of location or position information. Various application categories have fundamentally different characteristics and impose a wide spectrum of requirements on the underlying middleware platform. The responsibilities of the middleware systems include managing subscriptions, user profile management, managing a potentially very large number of information providers and so forth. The LBS system needs to support high availability despite node failures. Fig. 2 shows a middleware based architecture where all the location service requests from the clients route through the middleware. Since the middleware has to manage all the subscriptions and work as an application router as well it becomes bottleneck [6]. A Flexible middleware based architecture has been proposed by S. Kaushik et al in 2011 where the middleware works as a certifying authority; however the clients can directly communicate to the actual location based service providers(LSP) [21].

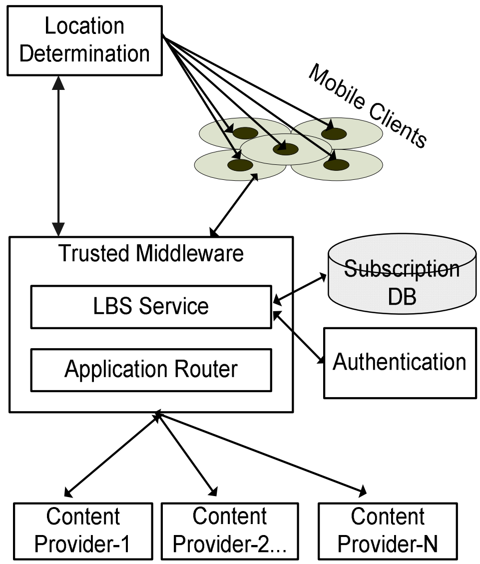


**Fig. 2.** Middleware Based Architecture of LBS Systems

### 2.2 Kivera Location Platform

In 2001, Kivera Inc came up with an LBS platform offering different services that was also used by AT&T Wireless for the E-911 services shown in Fig. 3 [6]. The platform exposes a set of services that uses static digitized geographical data along with the dynamic data for traffic flows, and traffic incidents.

**LBS Content.** The location engine uses both dynamic and static data. The dynamic data includes Live Traffic Flow and Traffic Incidents which get populated by various content providers (i.e. www.inrix.com). The static geospatial data includes the roads, parks, rivers, buildings, and railroads in the digital format. The POI data is a rich database about the user's day-to-day places. The Location Engine uses LBS content to serve the service requests.

**Location Engine.** The heart of any LBS system is the Location Engine, which contains the software components that add intelligence to digital map data. Though each component is responsible for a separate independent feature; however they might use each other in order to perform their functionalities. For example, the geocoding might be used by routing module as goecoding is necessary to generate a route. The fundamental features of the location engine are geocoding, reverse-geocoding, routing, and map rendering. Geocoding converts a street address to a latitude/ longitude (x, y pair of coordinates) position so it can be accurately placed on a map. The Reverse Geocoding is the process of deriving the location name of the nearest road segment from a given longitude/latitude. Routing is the technique of calculating the optimal path between an origin and destination based on specific criteria. A routing engine evaluates the numerous ways a driver might travel over the streets, while accounting for various attributes of the street networks. Starting at the route origin, the software uses the A* (A-star) algorithm to calculate the optimal route. POI Search, Vector Data generation and Map Rendering are other sub-modules of a Location Engine.

**Traffic Server.** The traffic server gets the dynamic data from various traffic data vendors and provides the traffic data to Location Engine in compatible format. The traffic server is responsible of parsing the vendor provided traffic information, storing the data in a common format and finally serving to the location engine, and to the other traffic applications. The traffic history is also maintained in the traffic server that can be used for the future predictions and city transport planning. The traffic flows are used by the location engine to render the traffic density on the map and while calculating the routes between two addresses; the routes with the heavy traffic are avoided.

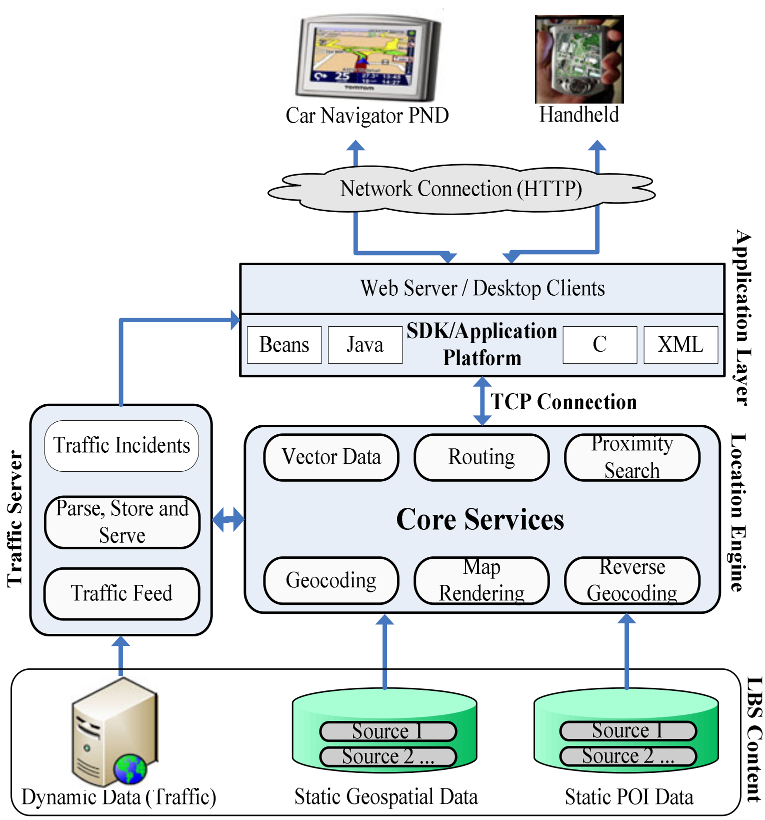


**Fig. 3.** Architecture of Kivera Location Platform

**SDK/Application Platform.** The features offered by the location engine can not be directly accessed by the end clients as the location engine is not deployed as a web server. It needs a scalable LBS SDK platform with a set of core services for building applications. The SDK is a set of C, Java, and XML APIs which help application developers to build custom LBS applications, Desktop applications, and Web Services. The APIs communicate to the location engine via TCP socket connection after the successful key verification and handshake procedure. The SDK platform allows the application developers to use the location engine features in their custom applications for different platforms.

## 3 Recent Trends in LBS

The average consumer now has many choices of navigation and GPS-enabled tools. There are onboard navigation systems for the vehicles and navigation applications available on cell phones or smart phones. The vehicle tracking, fleet management, geo-fencing, location based advertising, and security systems are some of the latest location based applications [23]. Some of the location based applications that are popular these days are discussed below.

### 3.1 Location Based Tour Guide and Navigation Systems

Location based tour guide is an intelligent system that proactively guides the user on the basis of its location, interest, environment, and context. The tour guide systems are able to handle the tourist's different queries, i.e. "I have 3 hours of time, what can I do?". The tour guide uses the personal interests of the tourists like history, nature and it offers a well computed tours. The services of a tour guide system include tour planning, route finding and navigational assistance, route and plans evaluations, location based site commentary, peer tourist information sharing, adaptive and personalized maps. The tour guides also predict the tourist requirement and it poses the information, probably the user will be asking about. J. Lee et al proposed a tour planning system for the telematics users considering the route planning as a TSP problem as the tour starts and ends from/to the hotel visiting all the interesting tourist POIs. The tourist POI feature vectors and the user profile attribute vectors are used to calculate the similarity and interest based POI filtering [28]. The current digital guidance systems can be classified as follows:

**Static Content on Device.** Systems that store the audio-video data in the guidance media. Visitors are expected to use these systems by themselves. These systems are limited to some particular aspect of the guidance. Due to the size limitation of the device, only the limited amount of data can be stored.

**Static Content on Server.** The content is stored in the server. The user can download the multimedia files as per the interest and use them for the desired destination. Examples of such systems are: the Personal Digital Museum Assistant in Japan, the

Wireless Museum PDA Tour Guide System in the Tate Modern Art Gallery in London and the National Palace Museum Tour Guide System in Taipei.

**Dynamic Content Based Tour Guide.** The client has processing capability and it can compute the location of the user at run time. In such systems most of the data is located at the server. The clients request the computed tours to the server at the runtime along with the current location and get the well computed tours as per the user interest.

### 3.2 Location Aware Browsing

Location aware browsing is possible through the IP/Network based location determination. IP based location determination is the act of using measurements taken from the access network to calculate or compute the physical location of a device. There are different techniques on network based positing given in [24]. Using the network positioning the web browsers can tell the websites about the user’s location. The websites can be more intelligent and hence can find information that is more relevant and more useful. Let us say you are looking for a pizza restaurant in your area. A website will be able to access your location so that simply searching for “pizza” will bring you the answers you need in the appropriate proximity [8]. The web-browsers gathers information about nearby wireless access points and your computer’s IP address. Then web-browser sends this information to the default geo-location service provider to get the location in terms of latitudes and longitudes. Accuracy is greatly dependent on the service provider’s database accuracy. The location based social networking websites use the network based location determination to locate the users approximately.

### 3.3 Landmark Based Navigation

The Google Maps directions have been using some new phrases such as "Take the 2nd right" rather than just "Turn right". This is based on natural concepts that relate to the way we think about navigation in real life. Without road names, it's difficult to produce a set of directions that makes sense. The countries like India, the street signs or names tend to be less important than landmarks such as civic buildings and gas stations [9]. The suitable landmarks are selected based on visibility, importance, and closeness to the turns that the user is making. The landmarks are used in two ways: to identify where users need to turn, and to provide confirmation that they are on the right track. Using landmarks in directions helps for two simple reasons: they are easier to see than street signs and they are easier to remember than street names. For example, spotting a pink building on a corner or remembering to turn after a gas station is much easier than trying to recall an unfamiliar street name. Following are the situations in which people resort to landmarks [4].

**Assurance to the Location.** The landmarks are used when people need to orient themselves, for instance, they just exited a subway station and are not sure which way to go. The older navigation systems would generally say "Head southeast for 0.2 miles". The landmark based navigation system would say "Start walking away from the McDonald's for 02 miles".

**Turn Description.** This is a situation when people use a landmark to describe a turn. For example, "Turn right after the Starbucks."

**Confirmation of the Track.** This is the most interesting scenario where the landmarks are used just to confirm that the user is going on the correct path. People simply want to confirm that they are still on the right track and haven't missed their turn.

## 4 Key Players in LBS Market

The launch of the LBS is driven by both regulation and competition [17]. Other than the mobile operators there are other players like Location Based Service Provider (LSP), Client Application Developers, Trusted Middleware and LBS Regulatory Authorities as explained below:

**Network Operators.** The network operators play an important role on helping the device determining its location quickly using AGPS method. The operators also help getting the location on the non-GPS mobiles using the cell based location determination techniques. The operators can control the accuracy and the quality of the location services running on the client devices. Sometimes the network operators also play a middleware role for the managing users profile, transaction accounting and the location security.

**Location Based Service Providers (LSP).** The actual location based service providing entity that take the location as an input and offer the services to the end users. Sometimes the LSPs are integrated with the network operators and the network operators host the location servers.

**Client Application Developers, and End Users.** The role of application developers include a combination of one time set-up fees, revenue sharing and monthly payments for additional services such as technical support upgrades and customer care. The client applications are developed using various platforms i.e. J2ME, Symbian C++, Android, and iPhone OS. The end users are one of the most important parts of the LBS market. It is important to consider whether subscribers will be willing to pay additional fees to use the offered services. General usage figures based on past experience with other services show that the answer lies in the usability and value services bring to users. The services should be tailored and offered to specific user segments, maximizing their value from such services. Operators are in a key position to define and package such services, and tailor them to the needs of their different subscriber segments [17].

**Trusted Middleware Parties and Secure Gateways.** The middleware is a trusted party that does authentication, and application request routing. Sometimes the network operators deploy and operate LBS within their own network, leaving less room for others players such as application service providers due to the information sensitivity. In many cases though, operators still lack the expertise and are willing to accept outsourced solutions, using various means to hide the actual user information from the third party. The middleware plays an intermediate role between the users and the actual service providers.

**LBS Regulatory Authorities, Standards.** The regulatory authorities play an important role on regulating the location sharing agreements, location storage, location privacy laws and service provisions. The regulations help shaping and success path creation for the LBS products. Regulation is likely to have an impact on the accuracy operators will provide, as well as on the use and handling of user information. This will affect both the technology choice and the availability and usability of user location information for the different players. There are separate regulatory bodies for different countries. For example, ETSI for Europe, ANSI T1 for the USA, ARIB and TTC for Japan, TTA for Korea, and CWTS for China [10]. The Open Geospatial Consortium (OGC), an international voluntary consensus standards organization that collaborate in a consensus process encouraging development and implementation of open standards for geospatial content and services, GIS data processing and data sharing [16]. A lot of effort is put in standardizing LBS, both on the network and application side. Main forces are the 3G Partnership Program (3GPP), defining mainly the addition of LBS capabilities to future releases of 3G networks, and Location Interoperability Forum (LIF), formed by vendors and interested parties to develop and promote common and ubiquitous solutions for LBS which are network and LDT (Location Determination Technology) independent [17].

## 5 Broad Research Areas in LBS Domain

The LBS is not only limited to applications that push promotional offers or other content to cellular subscribers as they move into a particular geographical area. But there is a whole lot more to LBS. The LBS also can be used to help cellular service providers with network management, policy enforcement and billing, and to enable new, productivity-enhancing capabilities within the enterprise. It is a huge domain containing several research areas shown in Fig. 4. Some of the research areas are discussed as below:

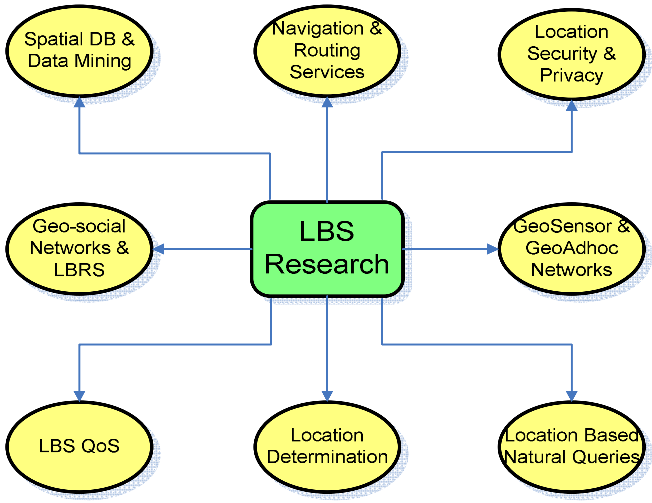


**Fig. 4.** Broad Research Areas in LBS

### 5.1 Location Determination Techniques

Mobile positioning has become a popular technology for more than half a decade now. There are various means for doing mobile positioning, but they can generally be divided into four categories i.e. Radiolocation Techniques, Satellite-Based Techniques, Techniques used in Proximity Systems and Dead Reckoning Techniques. Each of these methods has their advantages and disadvantages in their possible application of providing location services in cellular and PCS (Personal Communications Service) networks [12]. Some of the examples of the location determination techniques are – GPS, AGPS, Cell-ID based, and WiFi. A comparison of the various positioning methods is given in Table-1 [13]. Some of challenges in LDT are discussed below [25]:

**Accuracy and Precision.** The accuracy is a measurement of how close the location has been estimated with respect to the real geographic location. The ability of network-based LDT technologies to achieve desired accuracy levels is a challenge in rural areas, due to the limitations in tower placement and the resulting limits on triangulation capabilities. The satellite based GPS has been able to provide 5 to 20 meters of accuracy in the clear sky. The precision deals with the closeness of a number of position fixes to their mean value.

**Yield and Consistency.** Yield is the ability to get position fixes in all environments. Consistency is the stability of the accuracy in different environments. Consistency of location data has been an issue across LDT technologies and carrier procedures due the lack of standards early on, and the proliferation of different technologies. It is important for careers and positing entities to test the compliance with the standards and present the location information in the well defined formats.

**Overhead.** Computational overhead is concerned with the power required for processing the databases and the network while signal overhead occurs in the air and relates to the number of messages that need to be sent. Overhead needs to be taken into account when considering accuracy and precision.

**Power Consumption.** This is a factor at the terminal device where battery life needs to be taken into account. Usually high overhead leads to high power consumption.

**Latency.** This is the time delay between each position fix. Time to First Fix (TTFF) depends on the type of system used. A high TTFF is often a factor in the popularity of positioning systems with everyday users.

**Roll-out and Operating Costs.** Roll-out costs are the costs involved with setting up the infrastructure. Operating costs depend on the complexity of the infrastructure.

**Table 1.** Comparison of the Positioning Techniques

| LDT | Location Accuracy | Time to Fix | Remarks |
|---|---|---|---|
| GPS | - High Precision<br>- Sky Line of Sight<br>- 5 to 20 meters | - 10 to15 mins start time<br>- 1 to 2 second updates | - Device support only (HW)<br>- This is useful for the car navigation, vehicle tracking.<br>- It does not require network operator support. |
| A-GPS | - Very High<br>- Sky Line of Sight<br>-5 to 50 meters | - 10 to 40 second start time<br>- 5 to10 seconds updates | - Requires GPS hardware.<br>- Needs network operator support for the location determination.<br>- Useful for the mobile devices. |
| WCDMA/<br>GSM/<br>CDMA | - Medium Strength<br>- Depends on cell density 40 to 400 meters | - 6 to10 seconds start and update time. | - Requires Base Station Support (BSS), Mobile Switch Center (MSC) and HLR support and usually always requires<br>- Network operator involvement |
| Cell-ID | - Quite Weak<br>- Dependent on cell density<br>- 100 to 5500 meters | - 4 to 8 seconds start and update time. | - Needs Mobile Switch Center (MSC) and Home Location Register (HLR) support, or requires device and Cell-ID database. |
| WiFi | - Quite Strong<br>- Dependent on WiFi AP density<br>< 50 to 250 meters | - 4 to 8 seconds start and update time. | - Device and network support.<br>- Requires WiFi DB. |

While GPS has solved most of the outdoor real time positioning problems, it fails to repeat this success indoors. A number of technologies have been used to address the indoor tracking problem and indeed for movement within university campuses. The ability to track the location of people indoors accurately has many applications including medical, military, logistical and social. However, current systems cannot provide continuous real time tracking of a moving target or else they lose capability when coverage is poor. Some of the popular indoor positioning methods are Wi-Fi Positioning, Cellular Positioning, RFID, Infra-RED (IR), and Bluetooth based positioning.

### 5.2 Spatial Databases and GeoData Mining

Spatial database is optimized to store and query data related to objects in space, including points, lines and polygons i.e. Census Data, terabytes of data satellites imagery, weather and climate data, rivers, farms, ecological impact and medical imaging. It addresses the growing data management and analysis needs of spatial applications such as geographic information systems. It has been an active area of research for couple of decades. Many research problems exist at the logical level of query processing, including query-cost modeling and strategies for nearest neighbor, bulk loading as well as queries related to fields and networks. Query processing in spatial databases containing obstacles, indexing fuzzy data types are some open problems. However, very little work has been done on file clustering and on indices for network spaces such as road maps, telephone networks. Approaches for concurrency-control techniques are needed for spatial indices. The spatial temporal databases are another recent research trend in this area. There a need to apply spatial data management accomplishments to newer applications, such as data warehouses and multimedia information systems. The techniques developed for spatial data management have been driven by the specific applications hence they are mostly not generalized [31].

### 5.3 LBS QoS (Quality of Services)

With increasing attractiveness of location-based services (LBS), the need for consistent establishment and deployment of the LBS Quality of Service (QoS) hierarchy is strongly demanded [20]. LBS QoS is primarily concerned with position estimation performance, including position estimation errors and response time, achieved by either single position sensor, or a combination of several position estimation sensors and methods. Common LBS QoS establishment approach consists of either “as-is” (i. e. no-guarantee) or “best-effort” (no-guarantee, but with some concern) approach. The LBS QoS has following key points that should be considered:

**LBS Quality Assessment.** The speed, memory, processing, power consumption, response time, errors on the location estimation and services are some of the LBS quality parameters.

**QoS Aware LBS System Modeling.** No-Guarantee model, AS-IS model, Best Effort model, guaranteed models are some of the models that are considered depending on the service requirements.

**QoS Friendly Navigation Systems.** Quality aware location determination, seamless zooming and panning of the maps. The navigation systems are real time applications and need real time system response. For example, there is no use of the instruction “take a right turn” after crossing the intended crossing. It should prompt the turn instruction in well advance so that the user can be prepared. Taking a quick turn in a moving car at high speed could be life critical.

**Privacy and Safety Systems.** Quality aware privacy protection services, QoS aware traffic safety solutions, for example, predicting if the car coming towards you is in unusual state. The location based incident history data mining can be used to warn the tourists for the dangerous and accident sensitive tourist spots.

## 5.4 Location Privacy and Authorization

An advertisement where a shopper received a coupon for 10% discount on this mobile device while walking by that coffee shop indicates that the shopper is being tracked in some ways. This is important to share the user’s location in order to get the services; however it is also important considering the location privacy and user security. There are various techniques to hide the user’s location; however it is still a topic of research for the researchers [14]:

**Authorization and Access Control.** There are issues to answer the questions: “who and when is allowed to access my location?”; “who is allowed to access what service?”.

**Location Privacy.** The privacy solutions with personalized privacy policies versus performance tradeoffs are on the horizon of LBS research. Location obfuscation techniques, location blurring techniques, and privacy protection strategies (dynamic/static data based) are the key privacy methods.

**Identity Privacy.** Ubiquitous anonymity within the user device and k-anonymity are the ways to hide the user’s identity while revealing the location to the service providers. The anonymity can be achieved by using a trusted middleware or by using pseudonym while communicating to the location based service providers (LSP). The pseudonym generation at the client device and communicating directly with the LSP is still a challenge as hiding the real identity creates issues of authentication and transaction accountability.

## 5.5 GeoSocial Networks

Many a times, it is important to know the person’s physical location to know what their background or interests are. For example, a network of business partners based in

California might be interested in meeting one another face-to-face, or one of the customers in Chicago might like to find a local developer who can meet with them in their offices. The members connected in such community may search, browse, and connect with one another based on their location as well as their expertise. The Fig. 5 shows a screen of GeoSocial network developed by a company known as Leverage Software using Google Maps APIs that allows the member search around a region [30].

Geosocial Networking is a social networking in which geographic services and capabilities such as geocoding and geotagging are used to enable additional social dynamics. User-submitted location data or geolocation techniques can allow social networks to connect and coordinate users with local people or events that match their interests. Geolocation on web-based social network services can be IP-based or use hotspot trilateration positioning. For mobile social networks, mobile phone tracking can enable location-based services to enrich social networking [29]. The Friend Finder application, Ad-hoc networking, food sourcing, location-planning, mood-sourcing, paperless ticketing, location based gaming are some of the key examples of the geo-social networks. The users using mobile based GeoSocial network applications can get an alert – "Your School Friends are in the Same Food Court". Such systems can automatically geocode the address given by the user or it can use the relevant LDT for the mobiles. The location aware browing can be used for the web based applications to get the actual latitudes and longitude coordinates [8, 24]. The research challenges include geo-relation mining, system and framework designing, geo-clusters, co-occurrence analysis, information retrieval and storage techniques, information processing, and performance analysis.

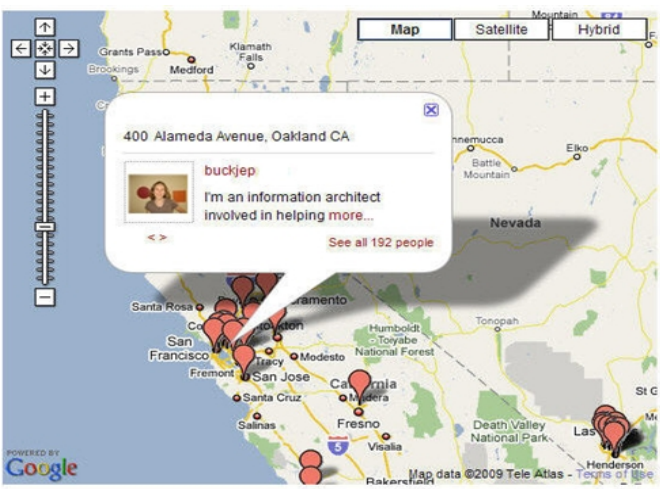


**Fig. 5.** GeoSocial Network Web Application (Leverage Software Inc)

### 5.6 GeoSensor and GeoAdhoc Networks

Increasing decentralization is a widespread feature of information system architectures, made possible by the advances in computer networks over the past two decades. Decentralized information systems are acknowledged as offering several advantages over centralized architectures, including improved reliability, scalability, and performance. In a conventional location-based service, each mobile user accesses information services from remote service providers, which perform the task of capturing, managing, and updating any information relevant to their application domain. The centralized remote service provider can act as a weak point in the system. The bottleneck of a single access point decreases system reliability and performance. Advances in sensor technology and the development of inexpensive small-form, general-purpose computing platforms have lead to the study of sensor networks. Sensor networks comprise multiple miniature ”PCs”, each of which contains a CPU, volatile and stable memory, short-range wireless communication, battery power, and attached sensors. The on-board sensors are used to collect information about the physical world, like temperature, humidity, or the current location of objects. Sensor nodes can be deployed in high density within the physical world and enable the continuous measurement of phenomena in unprecedented detail. A geo-sensor network is defined as a sensor network that monitors phenomena in geographic space [18]. The advent of nanotechnology makes it feasible to deploy low cost, low power devices with on-board sensing and wireless communications capabilities. As a result the fields of GIS and remote sensing face multiple research challenges related to real-time geosensor data collection, data analysis, information management and delivery. Some common geo-sensor applications are: traffic sensors and transportation modeling, ecology observation systems – i.e. assess plant health and growth circumstances, observe and measure geophysical processes and real-time event detection – i.e. volcano sensor network. The geo-sensor networks can be used for various purposes:

**Emergency Services.** Sensing with active landmarks, low-end devices communicating with GPS enabled devices, resource sharing in the rural and remote areas.

**Data Acquisition and Processing.** Data selection and queries to geo-sensors, data storage and access model and optimizations, load management and high availability.

**Data Analysis and Integration.** Visual geo-sensors for 3D sensing, mining geo-sensor data and event predictions, and using geo-sensor data into a variety of applications.

### 5.7 Location Based Recommender Systems (LBRS)

Web based recommender systems are quite common and are in general using traditional content based, collaborative or hybrid techniques for delivering personalized contents. Since location based systems typically involves “physical entities” (i.e. a shopping center) therefore we cannot directly apply existing web recommendation techniques to

LBRS. The current generation of location-based recommendation does not provide users with personalized recommendations, but mostly suggests nearby POIs based on their distance from the user current location. The new generation of Recommendation Systems (RS) needs to identify user preferences, information needs and aspect related to the context of use, thus suggesting personalized recommendations related to possible POIs in the surroundings. Therefore the location based recommendation techniques should be able to integrate location information, customer needs, and vendor offerings for the success of businesses. Following are some of the challenges for the success of LBRS:

**Scalability, Convenience and Latency.** High scalability, user convenience, and low latency must be the key requirement while making recommendations in LBRS. These systems have to be scalable to handle to support a rapidly expanding population of mobile users and information. Such RS indicate a very high potential of a users to follow-up on the recommendation – thus, a mobile user requesting a recommendation typically wants to know not about the best match, but rather about the best match that also happens to be conveniently-situated given his current location. Location based recommender system need to provide more appropriate information as the user is not willing to spend much of the time in selecting the information from a small screen device and entering a large amount of inputs through slow input interfaces. Since user carries a more resource-limited device, therefore more specific information should be provided [26].

**Dynamic Environment Adaption.** LBS pay more emphasis on the dynamics and diversity of the information provided to the user. From the perspective of a mobile user, the environment is ever-changing as user moves from one location to another. Therefore adaptability to the changing environment plays an important role in LBRS.

**P2P Architecture.** Most of the current recommender systems are based on centralized architecture and the techniques used in such recommender systems are not suitable for P2P environment. P2P architecture is attractive as centralized architecture suffers from shortage in scalability [27]. Even though there has been much work done in the industry and academia on RS research, issues such as sparsity, scalability, cold start problem and accuracy still remain a challenge in LBRS. Therefore P2P architecture can be used as an alternative solution to overcome the problems of traditional recommender systems. People with similar interest are now a day's connected with social networks. The idea of social network can be exploited to provide efficient recommendation in P2P environment.

### 5.8 Location Based Natural Queries

Another enhancement that may be crucial to the business success of the LBS systems is the use of natural language. Multilingual capabilities in LBS systems will play a major role for tourism industry, location based learning, and navigation systems for the physically challenged people. The interactive LBS queries can be taken in natural languages that will make the system more interactive and user friendly. Most of the current LBS systems take the input through the form based user interface. The free form natural language input in the form of text or speech would be very useful for the technology fledgling users. The natural language queries like – "create me a route from A to B via C"; "where is the nearest ATM?"; "where is my kid this time?" would increase the usability of the system. The phonetic location searches (accent aware location searches), and natural language analysis for geo-spatial relations are some of the research challenges in this area.

## 6 Conclusion

We have briefly reviewed some of the important technologies, market players, and the research issues in LBS. We discussed the emerging telecommunication platforms and positioning systems along with issues related to contemporary mobile computing. The LBS is surely an area of modern mobile services where considerable growth is observed. The developments in the internet domain, wireless/mobile networking as well as the proliferation of positioning technologies expedited such evolution. The impact on nomadic users is tremendous. The technologies and issues involved in LBS deployment and provision cover a very wide spectrum including operating system capabilities, user interface design, positioning techniques, terminal technologies, and network capabilities. We have also investigated the latest LBS trends and development in this survey. The broad research areas like location determination techniques, geo-sensor and geo-adhoc networks, location based natural queries, location privacy and authorization, geo-social networks, location based recommendation systems (LBRS) and LBS QoS have been studied and presented briefly.

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