Location-Based Services

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INTRODUCTION

The past decade has seen advances in wireless network technologies and an explosive growth in the diversity of portable computing devices such as laptop computers, handheld personal computers, personal digital assistants (PDAs), and smart phones with Internet access. Wireless networking technologies and portable devices enable users to access information in an "anytime, anywhere" fashion. For example, a mobile user (MU) on the highway may query local weather, traffic information, nearby gas stations, next rest areas, or restaurants within 10 miles. Such new demands introduce a new type of services, ***location-based services*** (LBS), where certain location constraints (e.g., the user's current location) are used in the service provision.

The idea of queries with location constraints is originally introduced by Imielinski and Badrinath (1992), in which mobile users are likely to query information relating to their current positions, leading to the need for LBS. Such services are also termed as location dependent information services (LDIS) in Lee, Lee, Xu, and Zheng (2002). LBS system is the context sensitive systems in a mobile computing environment that consider the user's location as a significant and dynamic factor affecting the information and services delivered to the users. The major LBS applications include:

- Destination guides with maps, driving directions, and real time prompt
- Location-based traffic and weather alerts
- Wireless advertising and electronic coupons to nearby mobile devices
- Movie, theatre and restaurant location and booking
- Store locating applications helping users to find the desired services
- Telematics-based roadside assistance (e.g., OnStar from General Motors)
- Personal content and messaging (Live Chat with friends)
- Mobile Yellow Pages provide local information
- Information Services (News, Stocks, Sports)
- E911: (Wireless carriers provide wireless callers' numbers and locations.)

Generally, LBS services can be classified into three general categories: telematics LBS, Internet LBS, and wireless LBS (Telc).

Telematics LBS is the integration of wireless communications, vehicle monitoring systems, and location devices. Telematics LBS applications include automated vehicle location, fleet tracking, online navigation, and emergency assistance. For example, a trucking company can track all their fleet, proactively warn about traffic ahead, and estimate the arrival time. Commercial LBS providers are beginning to offer important management applications that help direct vehicle fleets and ensure optimal usage of key assets. Telematics LBS is a multibillion dollar service industry and is currently the largest segment of the LBS market (Telc).

Internet LBS provide Internet users the services relevant to their specified locations. Because they use a user-specified location instead of the user's current location, no positioning technology is required. For example, one can find turn-by-turn driving direction from one location to another and search for tour information about the destination. These services are targeting applications with stationary users, relatively powerful computers, and reliable network connections. As a result, Internet LBS support sophisticated services, such as local business searching and comparison, trip planning, online virtual tours, and so forth.

Wireless LBS deliver location relevant content to cell phones, PDAs, and other wireless devices. Equipped with automated positioning technologies, MUs can query local weather, nearby traffic information, and local businesses close to them. For example, a user can search neighboring post office or coffer shop from the PDA. The wireless LBS market is currently in a nascent stage, but it will potentially become the largest segment of the LBS market. The deployment of third generation (3G) mobile network, which support handsets that are both mobile and location sensitive, will lead to more wireless LBS subscribers and more useful LBS applications.

This article focuses on the discussion on wireless LBS system, and the term LBS refers to wireless LBS in the rest of this article. It compares LBS and traditional database system, introduces existing LBS systems, and reviews the related research works. Next, it describes a representative LBS system model and explains the functionality of the LBS system. It introduces the major components, their roles, and interactions. The discussion also covers issues related to mobile devices, positioning technologies, spatial databases, location aware queries, and so forth. In particular, this article will provide a detailed review on location dependent query processing and caching. Issues such as query processing algorithms, validity region, and query result caching are discussed. Then, it foresees the new service demands, emerging applications, and trends in future LBS systems. Finally, the article provides a summary on the above discussion and concludes this article.

BACKGROUND

Compared to traditional database (DB) services, new characteristics of LBS lead to significant differences between LBS databases and traditional databases. A database in LBS is a ***spatial database*** (SDBS) (Guting, 1994), which is capable of representing, querying, and manipulating spatial data (such as point, line, and region) to efficiently process queries with spatial restrictions and support applications such as the ***geographical information system*** (GIS). An SDBS is required to handle continuously changing data, locations of moving objects, and provide location aware services to mobile users. LBS also face other research challenges (Jensen et al., 2001) in order to support the following features: nonstandard dimension hierarchies in database; imprecision and varying precision; movement constraints and transportation networks; multiresolution objects and maps in data modeling; spatial data mining on vehicle movement; and continuous location change in query processing techniques. Interested readers are referred to Jensen et al. (2001) for more details.

LBS have introduced two types of queries with location constraints. The ***location aware query*** (LAQ) is the query with certain location constraints (Seydim, Dunham, & Kumar, 2001). As a special type of LAQ, the ***location dependent query*** (LDQ) (Barbara, 1999) is the query whose result depends on querying location, that is, the mobile user's current location. For example, "Phone numbers of all McDonald's in New York City" is an LAQ, while "Phone number of the nearest McDonald's" is an LDQ. LDQ is one of the core functions of LBS. Two common types of LDQs are the ***nearest neighbor*** (NN) query, that retrieves the qualifying database object closest to the querying position, and the ***window query*** that retrieves all satisfying database objects within an axis-parallel rectangle centered at the querying position.

LDQ processing and result caching have new characteristics not observed in traditional database systems. An LDQ may have different results in different region called ***validity region*** (VR). LDQs can be answered by the cached result of the same LDQ, if the MU remains within the cached result's VR. There are several algorithms for the DB server to determine the VR for NN and window query result sets (Zheng, Lee, & Lee, 2004; Zheng & Lee, 2001). To improve the performance, in certain applications, the limited validity region for LDQ result sets needs also be considered in LDQ caching. The following section describes the LBS system model and important research issues including positioning technology, LDQ processing, and LDQ caching.

LBS SYSTEM

LBS System Model

A typical LBS system consists of four components (Steiniger, Neun, & Edwardes, 2006) as shown in Figure 1:

- **Mobile devices:** LBS users request services and receive data using mobile devices, which can be personal digital assistants (PDA), mobile phones, laptops, and vehicle-mounted devices.
- **Communication network:** The communication network can be a wireless cellular network, wireless LAN, or other type of wireless network. It transfers the users' data and service requests to the service provider and forwards the requested information back to the users.
- **Positioning component:** User's location is an essential part of the LDQ, and it can be a symbolic entity (e.g., a street address) entered by the user or a geometric entity (e.g., the latitude and longitude coordinates) automatically acquired using positioning mechanisms. The user position can be obtained either by using the mobile communication network or by using the devices equipped with Global Positioning System (GPS). Further possibilities to determine the indoor position are active badges and radio beacons.
- **Service and content provider:** The service provider offers a number of different services to the user and is responsible for the service request processing. The requested data is usually stored and maintained at separated databases.

Positioning, Querying, and Caching Issues

- **Positioning technologies:** LBS require user's location, which can be input by the user manually or acquired by the device or network automatically. A user can input his/her street address or natural area code, which represents a location using alphanumeric characters code that is shorter than the latitude/longitude equivalent. Alternatively, one acquires a user's location via device-based techniques and network-based techniques.