Geoinformation Systems
17 July- 15 August 2003
by **Lund University GIS Centre**
for **The Øresund Summer University**

Introduction to Location-Based Services

by Neil Chan
Undergraduate
Dept of Electronic Enginerring,
The Chinese University of Hong Kong

supervised by Dr. Lars Harrie
Lund University GIS Centre

ABSTRACT

Location-Based Services (LBS) are services that based on locations of people. It is a hot topic in the subject of wireless communication and GIS. This article tries to give an elementary introduction to LBS. It explains what is LBS, the technology involved, its applications and other noteworthy issues.

INTRODUCTION

What is location-based service (LBS)?

Location-based services (LBS), also known as location services, mobile location-based service, wireless location services, is an innovative technology that provides information or making information available based on the geographical location of the user.

This new technology is giving a great impact to how we live and do businesses. Knowing the physical position of a user at any given time can be a huge potential to application service providers. This service allows mobile users (MUs) use services based on their position or geographic location.

Why is location useful?

LBS is a service trying to find out the answer to "WHERE", e.g. "Where am I?"; "Where is the restaurant?"; "Where are the target customers of our company"; "Where is my friend John?", etc.

Location is so important to human lives that is essential to how people organize their surroundings. It is of essential value that we can readily exploit to model reality.

With today's advanced telecommunication and information technology, people in different market sectors, such as business, consumer and government, can handle their surroundings at any time and any place.

How is LBS used?

Apparently, location-based service can show its full potential through mobile/wireless usage. The development of LBS is initially driven by emergency assistance application (discussed in later section), but it is found that such technology of locating users within a wireless network has noteworthy commercial application. For example, LBS application could involve the following aspects:

- People Tracking and Finder
- Driving Directions
- Information Directory Service
- Advertising

- Location Based Billing

Further discussion on application of LBS will be included later in the report.

FCC E-911 MANDATE

FCC E-911 Mandate is an early and still main driving force of LBS development. Therefore, it is worth mentioning this mandate here.

In 1996, there was continuous usage of cell phones. In the US, there was increasingly high number of emergency calls being made from cell phones where the caller was not able to describe their location. The US Federal Communications Commission introduced the wireless Enhanced 911 (E911) rules, the goal is to

> *"seek to improve the effectiveness and reliability of wireless 911 service by providing 911 dispatchers with additional information on wireless 911 calls."[1]*

E911 provides dispatchers with the location of callers and their phone number. This is also known as ANI/ALI - automatic number information and automatic location information.

The program is divided into two parts - Phase I and Phase II. [1]

- Phase I (deadline on 4/1/98) requires carriers, upon appropriate request by a local Public Safety Answering Point (PSAP), to report the telephone number of a wireless 911 caller and the location of the antenna (base station) that received the call.
- Phase II (deadline on 10/1/2001) requires wireless carriers to provide far more precise location information, i.e. to provide an emergency 911 caller's cell phone location to PSAP to within 100 meters 67% of the time.

The requirement of Phase I was achieved. However, no major carrier (e.g. Nextel, Sprint, the GSM portions of AT&T Wireless and Cingular's networks) was able to meet the deadline of Phase II requirement on 1st October 2001. Temporary waivers and extensions of time were granted by the FCC. Some companies have received heavy fines and the FCC is raising the pressure for compliance. [1]

Many technical problems remain in E911. Fortunately, the goal to complete the requirement of E911 within 2003 is promising. For instance, AT&T Wireless claimed in July that their development succeeded in satisfying the E911 Phase II requirement [2]. There is no doubt that E911 mandate should be able to be

implemented as fast as possible, since statistics reveals that more than 50 percent of all US 911 calls now are being made from wireless phones. [3]

Although E911 cannot achieve a 100% successful completion at the moment, the mandate is still receiving major attention as the driver of LBS for emergency services. In fact, efforts are made worldwide to meet the requirement similar to E911 mandate. For example, the European Union is working on its equivalent mandate - e112. [4]

TECHNOLOGY IN LBS

Location based services involve a lot of technology. To be successful, an LBS technology has to provide an accurate location, as well as suitable information for users required by the corresponding service, with minimal expenditure including establishing infrastructure and overhead.

Positioning Technology

The most important technology is of course the positioning technology, the way to find out the location of a mobile device accurately. Due to the unique characteristics of the cellular environment, it is a great challenge to locate the object precisely. Many advanced methods are used for positioning. Here are some of the examples:

1. *Satellite-Based Technology*
    - *assisted GPS*
    - *Galileo*
    - *GLONASS*
2. *Network-Based Technology*
    - *angle of arrival (AOA)*
    - *time of arrival (TOA)*
    - *time difference of arrival (TDOA)*
    - *hybrid methods*

Satellite-Based Technology

Compare to other method, it has been quite long that satellites are used to determine locations.

GPS

The most popular technology in this stream is the Global Positioning System (GPS). GPS is maintained by 24 satellites and a few ground stations located around the equator. GPS finds out the location based on the concept of Trilateration, a fundamental geometric principle that allows people to find one location if its distance from other known locations is known. GPS is proved to be accurate and useful enough for many years. However, it is not good enough for LBS uses. The main problem is that to use GPS, the mobile device should be in sight of those satellites. This is hardly possible in indoor environment or urban areas with tall buildings, where LBS is mainly used. GPS is not accurate and fast enough for demanding LBS uses. Since it cannot provide locations as precise as street level, and it could take several minutes to achieve an accurate location under undesirable environment.

Assisted GPS (AGPS)

Assisted GPS (AGPS) is developed to compensate the weakness of GPS. This is a hybrid of mobile technology and GPS. It makes use of local wireless network. The assistance information derived from wireless network is used to help to find the location. The strengths of AGPS include much faster location acquisition than conventional GPS, more sensitive to signals from GPS satellites, excellent accuracy. The main drawback is such approach could be expensive to end-user, as the handsets must be integrated with GPS functions. New handsets or upgrade of handsets are needed.

Network-Based Technology

Besides using satellites, a location of a mobile device can be determined in accordance with its cell site. Coverage of a whole network is divided into cells. The area covered by a cell is called cell site and each cell site has its unique cell ID. The network coverage in this cell site is provided by a cell tower, i.e. a base station. Signals between the mobile device and cell towers can be utilized in positioning technology.

Network-Based positioning technology applies different methods of triangulation of the signal from cell sites serving a mobile phone. Some popular methods are:

Cell of Origin (COO)

The mobile network base station (BTS) cell area is used as the location of the mobile device. Positioning accuracy generally depends upon the size of the cell. Accuracy may be as close as 150 meters in urban areas with the deployment of cell sites, or as far off as 30 kilometers away from the target where base stations are less densely concentrated.

Its main advantages are that speed of response in getting a location is fast (typically around three seconds) and that as no handset or network upgrade is required.

COO is a technology that is widely deployed in wireless networks today. This scheme is used to meet Phase I requirement of E911 mandate.

Time of Arrival (TOA)

The difference in time of arrival of a signal from a mobile device to three BTSs is used to calculate the location. This system requires a synchronization of the cellular network, using GPS or atomic clocks at each BTS.
It is more accurate than COO, but with longer speed of response of around 10 seconds.

Angle of Arrival (AOA)

This system requires a complex 4 -12 antenna array at each of several cell site locations. These antenna arrays can work together to determine the angle (relative to the cell site) from which a cellular signal originated. When several cell sites can each determine their respective angles of arrival, the mobile device location can be estimated from the point of intersection of projected lines drawn out from the cell site at the angle from which the signal originated.

The main drawback is the system suffers from distortion of the wavefront of the cellular signal such as multipath. Another problem is that existing cell site antenna are not suitable for angle of arrival.

Enhanced Observed Time Difference (E-OTD)

E-OTD systems operate by placing location receivers or reference beacons, overlaid on the cellular network as a location measurement unit (LMU) at multiple sites geographically dispersed in a wide area. The time differences of arrival of the signal from each BTS at the handset and the Location Measurement Unit are

calculated. The differences in time stamps are then combined to produce intersecting hyperbolic lines from which the location is estimated.

E-OTD schemes offer greater positioning accuracy than cell of origin, between 50 and 125 meters, but have a slower speed of response, typically around five seconds, and require software modified handsets, which means that they cannot be used to provide location specific services to existing customer bases.

Application Technology

In many cases, position accuracy is not the most important consideration of LBS application. Other elements are also essential for a well-developed LBS application in the view of technology. The following two are some of these elements:

Geographic data

Geographic data is a must for LBS to function. It provides the data to render man made structures like road network, geocoded customer addresses and buildings and terrains like mountains and rivers. GIS is also used to manage point-of-interest data such as location of gas stations, restaurants, cinema halls, etc.
The quality or types of Geographic data needed is dependent in the type of service to be provided to the user. The Geographic data needed should be updated and rich to be able to cater to various demands of LBS.

Communication system

Messaging is required to convey the location to the control center and provide the service needed. The choice of communication will depend on the level of service needed, the inclusion of voice communications and the relationship between channel occupation and cost.

To cater for these requirements, various IT technologies are used, such as Java, XML and spatial database. Many parties all over the world are making efforts to develop LBS, which results in differences in technological standards. To have a healthy LBS development, standardization is needed so that technology can be used cross platform. Worldwide groups, such as Open GIS Consortium (OGC), are working to develop publicly available geoprocessing specifications, supporting interoperable solutions that "geo-enable" the Web, wireless and location-based services, and mainstream IT.[5]

APPLICATION

The market potential of LBS application can be huge. It can be used in a lot of situation. Currently, there are two main development, emergency service and commercial application.

Emergency service

As mentioned before in E911 mandate, LBS can be used to locate the mobile phone that makes an emergency call.

LBS can further assist emergency issue in many ways. Imagine a fire accident takes place; the followings are what LBS can do: [6]

- After receiving the emergency call and getting know of the location, the emergency control center can immediately ask the police/emergency cars which are nearest to the emergency location for help.
- Emergency cars can reach the location in shortest time by letting LBS find the fastest route between its location and the accident location.
- To find hydrant in a mazy environment as fast as possible, fire fighters can use LBS and GIS application to find out the distribution of surrounding hydrants and how to reach for them.
- By using similar technique to find hydrants, fire fighters can monitor continuously whether there are flammables/explosives nearby and avoid entering these districts. Different explosives, such as a barrel of flammable chemicals, a pipeline of radioactive material or a standing pool of oil, have different explosive properties. A real-time GIS analysis can be performed to examine different levels of dangers in every place.

Commercial Application (m-commerce)

The commercial sector is very optimistic towards LBS. Due to its mobile property, the sector uses “mobile-commerce (m-commerce)” to describe commercial LBS. Estimates form industry analyzed wireless LBS at $4 billion by 2004 in the US and at $30 billion worldwide. They also labeled location-based services as the "killer app" for mobile data applications and services and believed that thin-client, location-relevant services will dominate the mobile e-commerce and consumer wireless data markets [7]. Here are some examples of m-commerce:

Route Guide

This service is suitable for travelers. Users have access to information that is relevant and useful based on their current location, a predefined location, or their destination. A user can set up predefined locations. For examples, a user may pre-select the airport and hotel that they are traveling to get driving directions in between.

Push/Pull Advertising

"PULL" means services that utilize the geographic position of a wireless device to derive information related to that location enable users to "pull" information to them wherever and whenever it is needed. For example, a user can pre-define a list of products he/she wants to buy in his/her mobile device. The mobile device receives information from nearby stores that carry the products that the user wants, and notifies the user when he/she is near a shop that carries the specific items he/she is looking for. These applications largely reduce the time spent in searching for desired items, at the same time help the vendors to build strong connections with customers.

"PUSH" refers to location services that utilize the position of the wireless device to qualify the holder as a potential customer or recipient of a service. For example, by knowing locations of users, seller can deliver advertisements to their nearby target customers. GIS tools used extensively in target marketing can be useful for profiling consumer's spatial behavior so that promotions may be tailored to derive maximum value.

Friend Finders

This service allows users to find the locations of their friends or family. The service automatically notifies the user when a selected person (who also has a mobile device with LBS) is nearby or has entered into a specified area. Such service can be used as personal child security, i.e. to notify a parent when a child has arrived at home, school, or other specified location.

Location Sensitive Billing (LSB)

This service allows wireless carriers to offer customised calling plans based on where subscribers use their handsets. Subscribers who have unique geographic rate zones can make and receive lowercost calls at home, at the office, or at other desired locations.

When an LSB subscriber makes or receives a call, LSB compares the location of the subscriber to his or her unique set of rate zones to determine if he or she is

within a preferential calling area. If the subscriber is within one of the preferred rate zones, that information is made available to the billing system, and the subscriber is then billed for the call at the preferred rate.

LSB rate zone assignment is performed by the carrier's Customer Care personnel through the LSB Web Provisioning interface. If LSB is configured accordingly, subscribers can assign their own rate zones from their handset or from the Internet.

The LSB Administrator can vary the radius of each rate zones and create exclusion zones within the market territory. Exclusion zones prohibit subscribers from creating lower-rate zones in locations such as high-revenue producing areas or poor coverage areas.

PROBLEMS

As LBS is technology/business in development stage, lots of problems are awaiting solutions. Here are some of the examples,

Technical Improvement

Location accuracy is still the main issue to combat. While different parties are trying different ways to deal with location determination and data manipulation, they should work together to come up with unique standards and specifications.

Privacy

The ability of constantly monitoring the position of an individual in real time is a critical privacy concern. One may disclose lots of information about his/her private life. Mobile users can be tracked without knowing it, which may lead to dangerous consequences. Some location privacy laws are established to restrict the use of information from LBS. Details include businesses can only use location information according to user's wishes; businesses should seek permission from users to expose their information to third parties; users should be notified the collection of their information [8]. However, further efforts should be paid from wireless operators and service providers to prevent location information from being stolen and used illegally.

CONCLUSION

Location-based services are so attractive that they can cover all walks of life. However, current LBS are growing slower than expected. Many problems like accuracy, privacy, security, customer requirement have to be addressed.

It should be understood that there is no single universal solution to LBS. Each service comes with its own set of requirements. The positioning accuracy, data manipulation and presentation are significantly determined by business considerations, service requirements and infrastructure. With all the appropriate infrastructure to support these tailored and well- marketed applications, LBS can finally become a revolutionary and profitable tool in human lives.

References

1. FCC: Enhanced 911 (E911) -- http://www.fcc.gov/911/enhanced/
2. "AT&T Meets Phase II Deadline" -- http://www.wirelessweek.com/index.asp?layout=documentPrint&doc_id=122274
3. Wireless 911 Information -- http://www.911dispatch.com/911_file/phaseII_chart.html
4. TimesTen for Location-Based Services Solutions -- http://www.timesten.com/telecom/appLBS.html
5. Open GIS Consortium (OGC) -- http://www.opengis.org/
6. "Location-Based Services And Topology" by Jim McGeough -- http://spatialnews.geocomm.com/features/geomode2/index2.html
7. The Location-Based Services Channel -- http://www.wirelessdevnet.com/channels/lbs/
8. "Privacy and Location-Based" by Euro Beinat -- http://www.geodan.nl/nl/geodan/nieuws/pdf/GeoInformatics_sept_2001_LBSandPrivacy.pdf
9. LBS Portal: Everything about Location-Based-Services -- http://www.lbsportal.com/
10. Java Location Services Home -- http://www.jlocationservices.com/

11. "Where's the Value in Location Services?" by Harry Niedzwiadek -- http://www.jlocationservices.com/LBSArticles/HN.Where%27s%20the%20Value%20in%20Location%20Services.pdf
12. E-911 Resources... Feature Articles -- http://www.wirelessdevnet.com/e911/articles.html
13. GIS in Location-Based Services, ESRI -- http://www.esri.com/industries/locationservices/index.html
14. "More About Location-Based Services" -- http://www.mobile-and-wireless.com/Articles/Index.cfm?ArticleID=26732
15. "Wireless Location Positioning based on Signal Propagation Data" By Jim McGeough -- http://www.wirelessdevnet.com/library/geomode1.pdf
16. "Carrier Choices in Location" by Mario Proietti -- http://www.technocom-wireless.com/pdf/GPS-Mar02_TechnoCom.pdf
17. GeoMode -- http://www.geomode.net/
18. MapInfo -- http://www.mapinfo.com/