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DEVELOPING GIS-SUPPORTED LOCATION-BASED SERVICES FOR M-COMMERCE: DREAM OR REAL CHANCE

Abstract

Mobile networking us developing and proliferating at high speed. Many estimates say that the number of mobile telecom subscribers will exceed 1 billion in the year 2003. Among the terminals deployed, there will be hundred of millions of Internet-enabled ones making Mobile Internet a reality for the big masses. The terminals and/or the mobile networks are now able to determine the position of the terminal on the earth with more and more precision. This is the bases for the new class of services called Location Based Services (LBS). The paper discusses this new emerging application area that some people consider the central novel application class of Mobile Internet. We discuss the business models, technology and standardization trends, as well as unsolved/unclear problems like privacy issues and global service provision architecture for roaming customers. A large portion of the paper is devoted to the question, how existing Geographic Information Systems (GIS) and the data hosted currently by them could be used in the context of LBS. We analyze their properties and relate them with the needs of LBS. We also present our pilot system that is based on XML-encoded vector format for city maps and runs on Java-enabled mobile PDAs and smartphones.

Keywords: Location-based services, mobile networks, GIS, 3rd generation networks

Introduction

The mobile phones have revolutionized the communication and drastically affected to the life style of the modern nomadic people. The voice capabilities of the mobile phones are currently augmented with data capabilities of increasing speed. The small size mobile terminals – mobile phones and PDAs – are converging and evolving into Personal Trusted Devices (PTD), which allows users to access Mobile Internet services and run applications at any time and at any place. The telecommunication industry estimates that by 2003 there will be about 500 million Internet-enabled mobile terminals in the world. The number of these mobile Internet-enabled terminals is expected to exceed the number of fixed line Internet users around 2003[1]. The rapidly growing population of PTD users generates huge markets for related services, offering new attempting opportunities for business.

The inherent features of PTDs are their high portability and personal nature. They are used for storing and accessing information at any time wherever the users go. The continuous availability of the device and the emerging capability of the terminals and/or the mobile network infrastructure to position the terminals on the earth allows new types of spatio-temporal real-time services that are called Location-Based Services (LBS). LBSs are services accessible with PTDs through the mobile network and utilizing the ability to make use of the location of the terminals. Major part of the future Mobile Internet services is expected to be LBSs.

The development of LBSs for mobile terminals got a strong impetus when US Federal Communications Commission (FCC) set the Wireless E911 Rules, initially in

September 1999, requiring that it should be possible to locate all of the mobile phones for emergency purposes with the accuracy of about 100 meters in 67 % of the cases. Quickly the more general potential of determining the location of mobile terminals was realized in the business environment and the emphasis of the LBSs development has moved to value-added services.

LBS business is still in early and evolving stage. Japanese operators[2] have offered special services (like tracking children/demented people) a few years and since 1999 more complicated services are emerging (like finding the phone number of the nearest taxi station, getting advertisement/information relevant in the cell user entered, finding friends in the close environment). Currently mobile service providers also in other parts of the world have introduced some basic LBSs for general public, and the number and versatility is steadily increasing.

The LBS require both the location of the terminal to be known, as well as the contents relevant to the location do be offered. The latter remains mainly in Geographic Information Systems (GIS). A GIS can be defined generally to be an information system that processes geographic data. Geographic data has the specialty of having the component of location on the earth (longitude, latitude, altitude), given either explicitly by coordinates or implicitly by another georeferenced object – this component is called as spatial data. In addition to spatial data geographic data consist of attributes; this is also the main characteristic of GIS databases, they link large amounts of attribute data files (population, buildings, enterprises, land use plans, land ownership, facilities, transportation, services, environment) to spatial data (maps). Spatial data, actually the coordinates, are a universal key with which various sets of information can be inter-related.

Even if LBSs could be considered as a subclass of GIS systems, they have different roots. LBSs are born by the revolution of public mobile services. GIS systems have been developing on the basis of professional geographic data applications. In this paper the focus is in the differences and similarities of LBS and GIS, as well as the possibilities to use the geographic data and GIS systems to support LBS and m-commerce.

The article is organized in the following way. In the next section a few typical examples of rather complicated location-based services are discussed and system requirements, architecture, and business models deduced. After that we discuss the current state of the art of GIS and relate the capabilities with the needs of LBS. Then we present the pilot system based on XML-encoded lightweight vector format developed in MultiMeetMobile project at the University of Jyväskylä, Finland, is presented. Finally, conclusions based on the discussion are given.

Location-Based M-commerce

M-commerce is a new form of electronic commerce that was born with the increasing popularization of data- and Internet-enabled mobile PTDs. Under m-commerce we understand e-commerce where the business transactions are run using mobile PTDs as terminals (in stead of PCs or other wire-line devices). LBSs are a central type of the new m-commerce applications and services, because mobility and positioning capabilities are unique for PTDs. It is generally expected that a major part of the future mobile services will be location-based.

The key questions in the emerging LBS m-commerce are business models and transactions. The new LBS business and markets are still in a developing stage, built initially by the old players who have been operation on the related fields. LBSs offer new business opportunities for these companies, but the business models, actors' positions, possibilities and revenue sharing is not yet established. The business transactions have an important role in LBS m-commerce, because it generates a new type of business environment. LBSs are, or ideally should be, operating globally (i.e. should be available everywhere), but providing at the same time locally relevant services for any customer roaming with a PTD in a particular area. They are thus "global-local" services.

Location-Based Services

In a general form the location-based services can be defined as services utilizing the ability to dynamically determine and transmit the location of persons within a mobile network by the mans of their PTDs. From the mobile users' point of view, the LBSs are typically services accessed with or offered by her/his PTD. For further analysis, let us consider two examples of LBSs: finding a suitable restaurant and ordering a taxi in a city not familiar to the person.

In a scenario for restaurant finding you want to find a "close" restaurant where to eat. Using your PTD you query for close moderately priced restaurants offering vegetable food. As a response a map is presented on your PTD, displaying your current location and location of a few close restaurants offering vegetable food. By selecting a particular restaurant symbol on the map you can get information about that restaurant, for example the contact information and a lunch offer. After choosing one, you can ask for turn-by-turn navigation instructions to guide your way along the trip to the restaurant.

In a scenario of taxi ordering you need a taxi. With your PTD you order a taxi selecting "order taxi" button in a LBS menu of your PTD and give perhaps some parameters, like how long you are prepared to wait and where you are going. After a while, a taxi arrives beside for taking you to your destination.

Restaurant finding is a “classic” example of a LBS. Taxi ordering presents a highly practical and seemingly simple, but inherently complex, service. Both of them present very common tasks, met daily basis by most of the travelling people. These examples reveal some key aspects of typical LBSs. They are intended to support suddenly “here and now” emerging well specified everyday tasks, expecting immediate solving. The services are designed to manage the tasks more easily, conveniently and efficiently. They should also be accessible anywhere and anytime, ideally globally, with a personal mobile device, PTD. The LBSs are useful for a population in large, implying potentially huge markets. The using conditions and terminal restrictions imply expectation of minimal effort from the user, fast and easy usability. When a person needs a taxi, she/he likes it to be there by a “press of a button”.

The usability of the LBSs emphasizes the importance of adaptation of the services to the users needs. This implies the need of defining personal profiles for the users within the system. In the examples the users profile can specify that she/he is pedestrian and prefers vegetable food. The storing and transmission of personal data, like the profile and the present location, highlights the questions of privacy protection and security within LBS systems. For example in the case of the taxi example the sending of the personal data, including the location, to the taxi company’s system and its handling there involves potential privacy risks.

Analysis of the examples shows the central role of the locating ability in LBSs. The mobile user has to be located in order to specify the services for her/him. In addition to mobile users own location, determinable in real-time, the services use also other location information. This location information can be either dynamic or static. Dynamic location information is information on moving target objects that can be determined and transmitted within the same system, for example other PTD users and objects like taxis, busses or pets. Objects whose coordinates do not change on earth with time have static location, i.e. they are static objects. One can connect to these objects also other non-varying information such as object type (a restaurant, a sight, a street, the parliament, etc.). The dynamic information attached to an object changes over time. Depending on how often it changes, it has either to be determined in real-time (like object's location) by the service or it can be stored along the static information in a database (like a menu of a restaurant that changes once a month).

In addition to location-based information, LBS systems utilize geographic base data. Geographic base data forms the data infrastructure needed by all of the services in some form. At first, geographic data in a form of digital map is required for information presentation as a reference material. Locations, presented through bare coordinates, do not have any information value for the most of the people. Responding to the query of finding the closest vegetarian restaurant could be answered by sending a list of WGS 84 coordinates of the "closest" restaurants. They would be, however, rather onerous to use. The location should be rather related with the current surrounding and presented e.g. graphically on a reference map. The same holds implicitly in the taxi ordering example, where the taxi company’s system have to guide the taxi to the users location based on street address, not the bare WGS 84 coordinates. Secondly, geographic data is required by LBSs for spatial query and analysis functions. This is the case even if the maps are newer shown to the users. In the restaurant example the service could utilize the street network data for determining the real distances of the restaurants from the users location in order to determine which are the closest ones, although this computation can also be done based directly on the global coordinates of the restaurants, if the latter can be found in the data source. The turn-by-turn navigation instructions, which can even be sent in a text or voice form, must, however, be calculated on the basis of the street network data. In the taxi example the geographic data is again used implicitly by the taxi company's system for selecting the "closest" free taxi and for supporting the navigation to the customer. Again, this could be done by determining taxi with shortest distance to the customer, but in the city the "closest" has more complicated meaning because the properties of the street network have to be taken into consideration (one-way streets, bridges, traffic jams, etc.). In addition to presentation and analysis, geographic data can be used also as an interface to the information. A map is easy and convenient tool for finding, selecting and accessing information and services in spatial context.

The LBSs types can be classified by their functionality and utilization of location information. The basic class of LBSs is *location-based information services*, utilizing the mobile users present location. In a simplest form it is a *positioning service*, informing the user about her/his present location (Where am I?). However, knowing the coordinates is not very useful, as noted already above. Therefore this service is usually combined with a digital map associated to the users location. This service is a *map service*. A digital map can be only a basic map on street network without any more information. When the map is augmented with an access to some point-of-interest location information, the service type becomes a *city guide service*. When the service includes capabilities to search information about real-world physical services, and perhaps a possibility to contact them, it becomes a *mobile yellow pages service*. The service may have features that support finding of the way to the specified destinations. This type of service is called *navigation service*.

Location-based functional services can be distinguished from the information services. Functional services are using the mobile users present location, but they are providing some function instead of information. The example of taxi ordering to the present location belongs to this category. Other examples are location-based fishing permit acquisition and ticket payment. Emergency and security services are also important group of functional services. They also show that in LBSs the essential feature is not that the services are actively used by the means of the PTD. The key is that the location of the PTD can be utilized by the service.

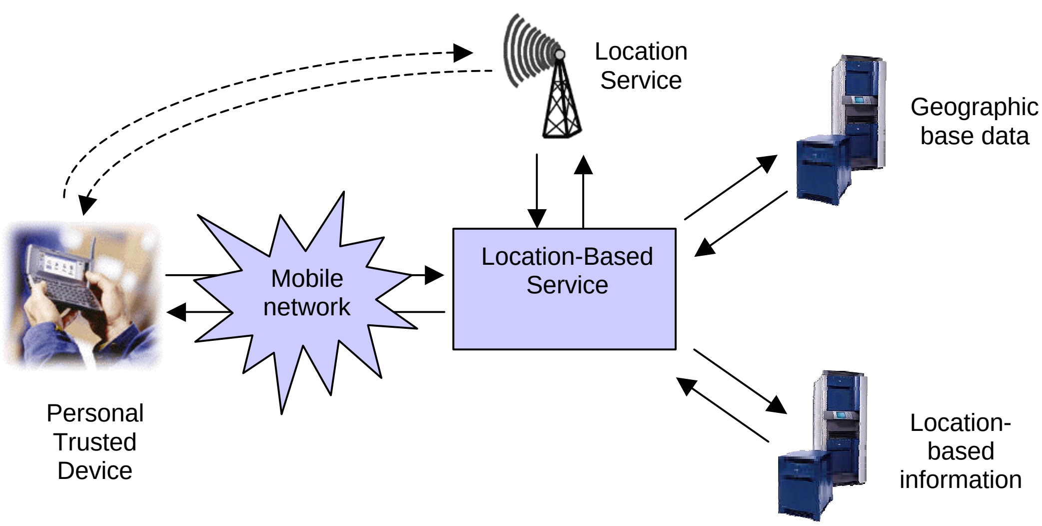
The next class of LBSs that can be distinguished from the ordinary actively used pull type of services is *location-aware services*. Location-aware services are push type of services where the user’s position or proximity to another object triggers some event or defines some condition. One examples of location-aware services is location-based marketing, where for example advertisement is send to the PTDs approaching the restaurant.

The LBSs types above make only use of the mobile users dynamic location and some other static location information. There is additionally a class of LBSs that are based on dynamic information on one or many other locatable target objects. *Finding service* is a basic type of these services (Where is X?). You can “find” an identified target, a friend, a pet, a taxi etc. When the time element is added, the question is about *tracking service*, where you can track for example a child. More developed services of this class are location-based community services allowing to find or track an identified group or specified class of targets. You can for example see where your family members are (if they allow to you to track them!). Certain types of dating services are also based on this scheme.

LBSs can of course be classified also in numerous other ways. The intended purpose and usage of the services are often used as a basis for classification. Following this scheme the classes could be for example: car navigation services, emergency services, security services etc.

LBS service architecture

Location-based services in a mobile environment are based on common service architecture principles. A general LBS service architecture for a particular geographic area is presented in below and the components are defined after that.



Personal Trusted device (PTD). A PTD is used by a mobile user to access the LBSs. Due to its personal nature, it is assumed to be associated to a specified and identifiable person. PTDs usually store personal data and they should include data security features. Personal profile can be part of the stored data. Some PTDs can also be equipped with positioning capabilities, for example GPS receiver.

Mobile network. Mobile network offers the infrastructure for the mobile telecommunication. It is operated by a Mobile Network Operator (MNO). Mobile network provides also the measurement data or supporting data needed by most of the positioning methods. Currently in the LBS system context the mobile network is a cellular network. In the near future it can be also Bluetooth or WLAN network.

Location service (LCS). LCS is a service providing the location of the PTD for the LBS services. LCS computes the location estimate based on one or more positioning methods and delivers it to the services in a form of co-ordinates in the standard WGS 84 system. The positioning can be network based (e.g. cell area), terminal based (e.g. GPS) or a hybrid solution (e.g. assisted GPS). The LCS specifications for 3G and GSM networks are standardized by the Third Generation Partnership Project (3GPP)[3]. Currently the LCS providers are usually network operators. They can be also independent service providers.

Location-Based Service (LBS). LBS are services offered for the mobile user through her/his PTD by the LBS providers. Tracking services can also be offered through fixed terminals. The different types of services were presented already earlier.

Content: Geographic base data & Location-based information. Content is the data that are used by the LBS to provide location-based information or functionality for the users. The content is in many cases offered by third party content providers. In the context of LBSs the content can be divided into two categories: geographic base data and location-based information. The division is required because these contents are different by their nature and typically they come from different sources. Geographic base data consists of the digital map data and location-based information is any information that can be associated to a particular location. Geographic data is for example a street network and location-based information the information about restaurants.

Considering real-world location-based services there are still several important questions and open problems. The expectation of ideal LBS is that it is easily accessible to a mobile user with her/his PTD at anywhere and anytime. This raises first the question, how to find the address of the local service (cf. taxi service in Rome). The current solution is basically: manually, because there is no automated support for it. Automatic solution requires in practice global directory services available in Internet or within the mobile network infrastructure. These are again special LBS that make use of the location of the terminal to determine which local service providers are appropriate in this particular case (e.g. taxi service in Rome, not in Paris, is offered). These questions are largely open and also interwoven with the business model issues; who maintains the directory services and who pays for them.

LBS business models

For the present purpose the discussion is restricted to business-to-customer commerce. However, it can be noted here that LBSs may offer also interesting possibilities for customer-to-customer business models, when the LBSs develop and become more sophisticated.

A business model can be defined as architecture for the product, service and information flows, including a description of the various business actors and their roles.[5] A business model includes also a description of potential benefits for the various business actors and sources of revenues. A general framework for LBS business model can be based on the service architecture defined in the previous section. The actors in LBS business are presented below.

Mobile user. In LBS business models, a mobile user with her/his PTD is the client. She/he is the main source of revenues in the LBS system.

Mobile Network Operator (MNO). The main role of a MNO in the LBS business is to provide the telecommunication infrastructure. In this role it has a central position in the business. In LBS systems, MNOs revenues come from the transmission of the data. They have also direct customer relationship with all of the mobile users, and along it an established billing system.

Location service (LCS) provider. LCS provider’s role is to offer the location of the mobile user to the services and the users themselves. Basing on the LCS specifications[3] a LBS provider can be independent service provider. However, in most positioning methods the LCS needs measurement data from the mobile network. Therefore LCSs are closely related to mobile networks and tied to MNOs. Currently the LCSs are mostly offered by the MNOs themselves. Independent LCS providers can still have markets in offering more flexible and precise locating. In LBS business it has to be remembered that third party LCS is not necessary in every case. The locating can be also purely terminal based like GPS positioning; this, however, requires more expensive special PTDs. The terminal based locating can also work without expensive GPS module, only requiring small modifications to the terminals;

in this case the locating still relies on the measurement data provided by the network, which is in principle in the control of the MNOs.

Location-Based Service (LBS) provider. LBS providers offer services to the mobile users. In many cases they buy or license required contents from content providers. LBS providers collect the revenues from the mobile users or from some other source. The other sources can be for example advertisements. The services can also be free for the users, for example when they support other services or marketing.

Content providers. The content providers' role in LBS system is to offer the information or other content directly for the mobile users or to the LBS providers. Thus, the content providers collect the revenues from the users or from the LBS providers. The content in LBS system contexts can be divided into geographic base data and location-based information, which are usually provided by different service providers.

In LBS m-commerce the MNOs are in an important position. For example in Japan, the MNOs, namely NTT DoCoMo, have had a key role in introducing and establishing Mobile Internet services, by its strong control over the whole system. Even if the core role of MNOs is to provide the telecommunication infrastructure, they have also got a strong hold on the services and they are currently the only network-based LCS providers. The MNOs have also an important advantage in relation to the other actors. They have a direct customer relationship with the mobile users, including billing relationship. Direct customer relationship and its management is expected to be one of the key factors in the future Mobile Internet businesses. The only thread to the present MNOs strong position in the future seems to be the emergence of the other network technologies, Bluetooth and WLAN. These technologies prevent the controlling of all wireless telecommunication, and persons locating, by the MNOs.

The content providers' position is also interesting, and at the present stage of development still somehow unclear from the business point of view. The geographic base data is quite important for many LBSs. The collection of this data is very expensive and time consuming and the quality of it is an essential feature. The data are readily collected and available for example from the national mapping organizations. Huge amounts of location-based information data are also available in many official databases. However, data pricing and copyright are questions to be solved. The data privacy, security and secrecy issues are prevalent. The questions of responsibilities about the data correctness and updating are expecting solutions. The data maintenance questions have also affect to the system architectures; is the data stored in LBS's server or is a connection built to the data providers system.

M-commerce transactions

In the present context, m-commerce transaction can be defined as any type of business transaction of an economic value that is conducted using a PTD over a mobile network. M-commerce transactions are inherently distributed, because they are always performed over a wireless link and are thus protocol-driven.

In a technical sense, m-commerce transaction refers to the following issues: a specification of an m-commerce protocol and its overall semantics; execution of the protocol and the steps launched by the protocol message exchanges at different players. The steps can be database transactions, but also real world steps like typing in a PIN or sending/receiving a digital map. The properties of m-commerce transactions are different from the traditional centralized and distributed database transactions. The same is true also for many "advanced" transaction models developed, although some known transaction models are designed for application environments with similar properties as m-commerce environment, addressing protocol issues, diverse autonomy aspects of the players, long duration of the transactions, and need to cancel the transaction in some cases.[6] Because the international banking is part of e-commerce infrastructure, these all are also present in the m-commerce environment. There are also important differences because of the peculiarities of mobile environment, the problems with e-commerce infrastructure (e.g. logistics) and security due to the vulnerability of the terminals, hostility of the environment and potential maliciousness of the players.

GIS support to LBS

In this section the possibilities of GIS to support LBS are introduced. First the main strengths of GIS are outlined and then some examples are given about the potentialities of integration of these two system types.

GIS

There are four main strengths in GIS: geographic data collection and conversions, geographic data management, geographic data analysis, and geographic data presentation.

Geographic data collection and conversions. GIS can manage different types of spatial data as well as different representations of them - not only in global geographic coordinates longitude and latitude, but in several local map coordinate systems and projections used in different parts of the world. GIS is able to receive and combine spatial input data in several forms, collected by using varying mapping and surveying methods from geodetic measurements in the field to interpretation of aerial photographs and satellite images as well as scanning and GPS positioning. In spite of good software tools conversions make a remarkable workpackage, and need special expertise in any GIS application, this part of system establishment is often underestimated.

Geographic data management. Maybe the core strength of a GIS is the ability to link spatial data and attributes, the descriptive information about the features or elements in the geographic database. The management of geographic data has been a topic for research and development for the entire short history of GIS. First solutions were simple file based systems, later on, during the 70´s, tailored network structured databases became available. The 80´s brought relational database management systems to GIS, however, not before the recent years relational database management systems have developed into spatial versions (Oracle 8i Spatial). The main problems in geographic data management are, in addition to spatial functions, the need for spatial indexing, the need for long transactions and the need for managing the geographic data quality.

Geographic analysis. Another strong field of GIS is spatial processing of data by using so-called GIS analysis tools based on developed spatial algorithms and data structures. There is much common with spatial algorithms and computational geometry, but also a lot of knowledge developed just for GIS. GIS analysis is at the moment in a big transition from simple geometry and topology based analysis tools towards more advanced computational methods called GeoComputation. In

GeoComputation the goal is to produce more advanced analysis tools for GIS based on theory, both classical and modern: mathematical modeling, optimization, simulation, statistics, fuzzy modeling, cellular automata, knowledge based systems, fractal analysis, neural computing, spatial multimedia, visualization, genetic programming.[7]

Geographic data presentation. Presentation of the results of queries to the user is the critical point when the question is about a small computer screen and geographic information. The most natural presentation of geographic information is of course a map, but in the traditional form it does not always fit on the small screen. The shortest path or other geographic information must be generalized both cartographically and also transformed into some other – for example verbal - form. However, modern GIS systems can give support for providing both source data and functionality for example knowledge based generalization and also strong theoretical basis as well as ready made tools for presentation of geographic data for a human user.[8] With the use of 3d and virtual models even more advanced visualization is possible in GIS.

Using GIS for supporting LBS

As was have seen already earlier, knowing the coordinates of a user is just a necessary condition for LBS. The other part is geographic data that links the coordinates with some other useful data. This data resides currently mostly in GIS. The data collection and conversion capabilities of existing GIS systems imply that there are large and expensively collected information contents that could be utilized for LBS business. There are two problems, however, that that must be clarified. First, the data collected into GIS is owned by NMOs, municipalities and other players and it is to a large extent unclear, at which price they are willing to sell the data for the LBS providers and how the data is made accessible. Second, it is not clear whether it would be indeed technically possible to integrate the GIS systems containing the data with the operational systems supporting LBS, although the Internet-enabled interfaces might perhaps be used. The business model used there is, however, different from the LBS business model.

Most National Mapping Organizations (NMO), which used to be responsible for traditional map production in small scales in the country, are now facing major changes. Several NMOs have developed map services both for professional and non-professional use – all known NMO web sites are listed by ITC (International Training Centre, Holland) Department of Geoinformatics and a link is available at their site (http://itc.nl/~carto/nmo/). A NMO web map system can provide an index to map products and services, it can also offer an access to digital base data sets. An example of the latter service is the Finnish Map Site service by the National Land Survey of Finland: after logging in the amount of downloaded data can be identified and the customer will receive an invoice (http://www.kartta.nls.fi/karttapaikka/eng/services/ammattilaisen.htm/).

Apart from the actual GIS containing the data, the GIS analysis functions could be used for building more advanced and efficient solutions for the LBS services functions. The long tradition of cartographic knowledge applied to modern geographic data can be used for finding solutions for geographic data presentation. The standardization work done for assuring interchange between GIS systems is turned now to support the development LBS geographic data interoperability

GIS database contents. National and municipal GIS databases all over the world include data on population, apartments, enterprises, public and commercial services.

Several databases are available on the prices of real estate and apartment purchases as well as available ones. Municipal and private facility service companies have information about ongoing projects on the streets and other infrastructure facilities. The landscape and built environment has been modeled in GIS databases and can be available even as a virtual model for visualization purposes. LBS services should not be limited to the computing of shortest path and getting the menu but the user can have information about traffic jams and accidents as well as street repairs, the best route should not be guided only by a skeleton map or textual message but it can also show a sequence of 3d views along the route or give the height profile of a biking trip. LBS service can give in-site information about the prices of flats or give you a fishing permission in real time while travelling in the wilderness, without that the user even knows the name of the lake or river.

Managing the coordinates by GIS. Most LBS applications are not only local but worldwide and we have to manage with different map projections and coordinate systems. Several hundreds of different projections are used in the world and it means a multitude of coordinate systems based on these. Different projections are necessary because of the varying shape and location of countries on the surface of the Earth as well as different needs of data accuracy. Global WGS 84 coordinates are used for GPS positioning, but for topographic mapping in small scales normally some map coordinate system based on selected projection like Universal Transverse Mercator (UTM) or Lambert projections Mercator projection based coordinates are used for nautical charts because they preserve directions best. The principal with reference systems and projections is that the best suitable is selected for every mapping purpose. The transformations between different systems are not trivial but most GIS software and developed applications do support them. Transformations make a significant and interesting field in global-local LBS system development, because the PTD's position is always given in WGS-84 coordinates, but the data often in local coordinates. The need for effective computational methods is evident in order to utilize the existing enormous and valuable geographic data resources.

Standardization. The main problem until the recent times has been that GIS systems have been more or less “black boxes” with very individual database structures and software architectures. Conversions between one GIS system to another have been difficult and sometimes the loss of information has been unavoidable. However, the need for openness is today so strong that different GIS vendors have established the OpenGIS Consortium (OpenGIS)[4], the purpose of which is to develop standards for spatial data modeling and processing and thus help the interoperability. Standardization is also made among ISO (ISO 211TC). OpenGIS and ISO are working in parallel. Also another progress must be mentioned, the development of spatial relational database management systems of which Oracle 8i Spatial is the first pioneer. Enabling the storage of both spatial and attribute data in the same RDBS and enabling spatial functionality for spatial queries is a big step forward and makes it possible also for LBS services to use GIS data. Developing the XML-based GML (Geography Markup Language) is also a significant attempt towards interoperability of different systems and of high importance for LBS.

The user is urged to consult Big Book on GIS (Longley et al., 1999)[9] for further information on GIS.

Pilot system

In the framework of the MultiMeetMobile project at the University of Jyväskylä, a LBS pilot system, called Multimeetmobile Location-based Service system (MLS), has been developed. MLS is a general LBS system for mobile users, offering map and navigation service accompanied with access to location-based information through the map on PTD's screen. Following the development of the mobile computing environment, MLS is based on Java and XML.

MLS utilizes XML as the core technology, in order to support interoperability between different LBS components. XML defines logical structure of information. It is platform-independent, allowing data integration from heterogeneous sources. The XML-based data flow in LBS is shown in Figure 2.

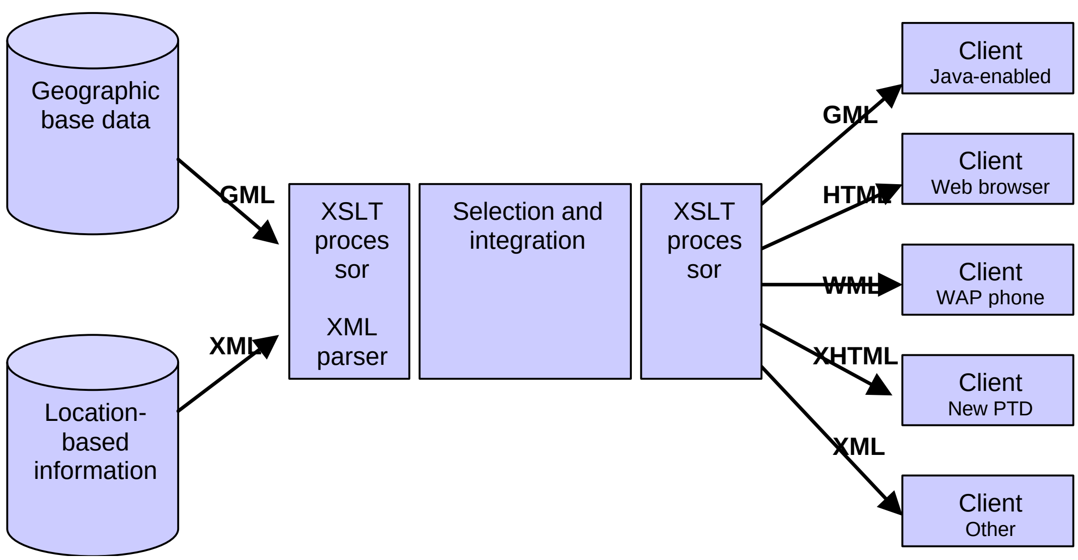


Figure 2. XML data flow in LBS system.

When content data is encoded in an XML-based format, then standard tools like XML parsers and XSLT processors can be used for extracting and transforming the needed information for the clients in an appropriate format. With the support of XML, the data from various sources, from different geographic base data and location-based information content providers, can be integrated into LBS system. LBS server is then responsible for interaction with data providers, data integration, data selection and conversion of the data into a proper format for the client.

The XML-based geographic data formats used in MLS are the standard Geography Markup Language (GML), specified by OpenGIS[4], and Geographical Mobile Markup Language (GMML), developed by the MultiMeetMobile project. Initially the reason for developing GMML was the limitation of standard GML: it does not explicitly support network topology. Network topology is necessary for many typical navigation applications, like for example route finding. Currently the most recent GML version 2.0 enables already implicit modeling of topology by XLink mechanism, and better tools for topology are promised in the future.

At the present stage MLS pilot system supports geographic data in the form of road network and location-based information on points of interest. Client-server interaction is implemented on the top of HTTP protocol. The XML-based data is transmitted in a compressed form.

The MLS client runs on any mobile devices supporting Java. Currently for example all Symbian EPOC and Microsoft Pocket PC based devices support Java, and it is expect to be a standard feature of the future PTDs. The appearance of the client application on the EPOC system is presented in Figure 3.

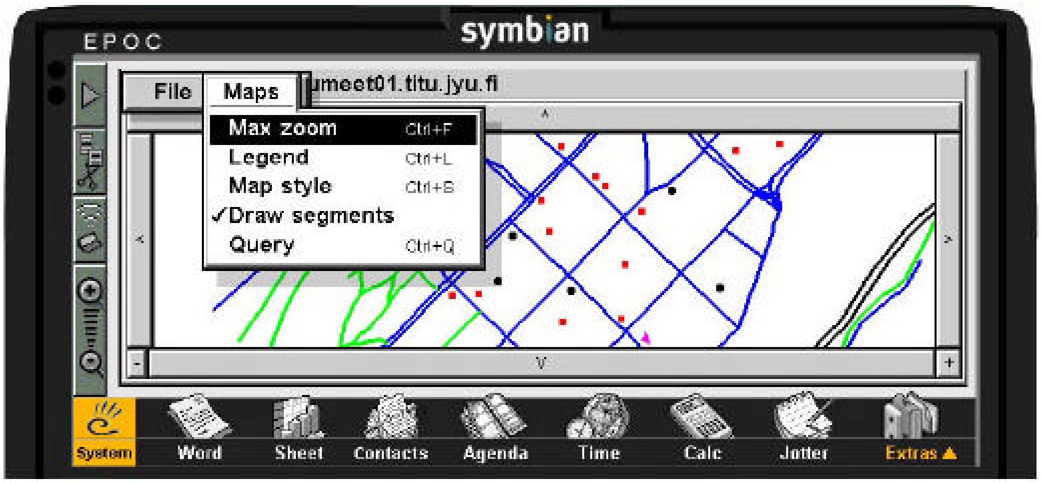


Figure 3. MLS client on EPOC system.

MLS client enables user to specify query to MLS server. After retrieving the requested geographic data from the MLS server, it is represented to the user is the form of map. The interface supports basic operations like panning and zooming and the presentation of map can be customized. The user can retrieve information about specific point of interest by pointing it.

MLS server responses to the client's query by sending an appropriate data to the client. In MLS system geographic data is managed by Oracle Spatial. The server selects the appropriate data on the basis of the client's location and other specified parameters in the query.

The design of MLS system based on the restrictions of mobile computing environment: limited memory, computing power and screen of the devices and; high cost, limited bandwidth and high latency of mobile networks. In addition the usability of the services is taken into account. For efficiency and flexibility reasons, the MLS system uses geographic vector data, instead of bitmaps to which most of the existing systems are relying on. MLS system is able to select transmit and present only the information that is relevant for the particular user at the present moment. MLS is also designed to support coherence of data. The server records what data was sent to a specific user and this knowledge could be used during handling of new requests. This can be used for example for progressive data transmission during user movement and for transaction management.

The MLS pilot system is still under development. The implemented basic features will be complemented with some more advanced features and methods. The support of transaction management on the client and more intelligent data selection tools are the features under construction at the present time. A research and development of geographic analysis and search functions in the distributed client-server environment is also going on.

Conclusions – GIS supported LBS, be it achieved and what added value it might give

Location-based services have been introduced in the recent years into mobile telecommunication networks. Currently, one can speak about first generation of services. They are almost solely based on the capability of the mobile network to determine the base station serving the terminal. The accuracy of this method depends largely on the cell size and several more fine-grained methods for finding the position of a terminal (Personal Trusted Device, PTD) have been standardized. The accuracy of the methods varies from about ten meters (Assisted GPS) to several hundred meters or even kilometers (cell-id).

We discussed in this papers the especially the relationship of LBS and GIS. Functioning LBS need clearly partially the same functionality as GIS offers (like spatial queries, use of topological data structures and need for intelligent presentation methods). Further, any reasonable LBS needs the geographic data stored in GIS. Also, the GIS and LBS fields have common interests like standardization for interoperability, need for more efficient computation and the limitations of data transfer capability. In these common problems LBS being a driving force will significantly also support GIS for development.

GIS databases make a self-evident resource for LBS further applications. Not being limited to the location but offering spatial and attribute data on almost any sector of human life, GIS systems can also promote new services. The main strength of GIS is the coordinate based integration possibility what enables, without limits, the combination of any set of data.

Although GIS and geographic data in general are a necessity for LBS, it is not evident that the current GIS systems actually containing the geographic data would be tightly integrated with systems offering LBS operationally. This is for business model, performance and technical integrability reasons. Still the GIS technology could perhaps be used to provide the services, but geographic data enabled database servers could as well contain and provide the actual services.

Some actors offer GIS services in Internet. These are not directly applicable with the mobile terminals, because of small displays and lack of other resources. It rather looks that the services must be adapted to PTDs. In paper we describe our pilot system that makes evident that vector maps can be presented and manipulated on PDA-level devices. When more and more terminals become Java-enabled, this approach will most probably become more popular.

GeoComputation promises a lot new for geographic analysis. Already there are several methods and approaches which can be used in developing server application for LBS for m-commerce. Advanced spatial data structures and algorithms will serve developers of network based applications. LBS and GIS can co-operate also in this computational field for finding the best approaches.

It seems very clear that LBS providers should be seriously interested in GIS and geographic information science. Innovations are most often created when several fields of science meet and feed each others with completely different approaches and knowledge. LBS and m-commerce is probably most interested in the economic value of innovations – geographic information science will get the best benefit if the huge geographic data sources will become into a real, profitable use.

Car navigation systems have been on the market place for quite some time. They have been largely GPS based. There is an emerging trend of convergence of the car navigation systems and PTD-based navigation systems. Car manufacturers are currently pushing LBS from their perspective (Internet-enabled cars).

The most problematic unsolved issue for LBS seems currently the global-local nature of LBS. It is not guaranteed that the roaming user can first find the locally relevant services and second really make use of them with her PTD due to technical heterogeneity and language problems. This is a hard problem area that requires still a lot of further research organizational and business level solutions.

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