# LOCAL vs REMOTE INFORMATION FOR LOCATION BASED SERVICES

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Abstract: Location-based services (henceforth referred to as LBS) have emerged as an important component of m-commerce strategy. Location can determine consumers' information needs and their product and service choices. We propose and evaluate different architectures for LBS considering that service provider allocates at different locations its information. Finally, we propose some design rules that consider the trade-off between transfer delay and query database time to improve LBS response time.

## 1 INTRODUCTION

With the proliferation and widespread adoption of mobile telephony and data, service providers have been eager to exploit customer information they have acquired over time (Rao 2003).

User location has traditionally been difficult to use due to its inherent dynamism and unpredictability (in this paper we use user and customer interchangeably). With regulatory pressures and the rollout of new technologies integrated into lightweight mobile devices and terminals, location is quickly becoming an exact science. Carriers are being forced by regulators to accurately position wireless emergency calls, through E911 in the US, and E112 in the EU (Rao 2003). Agile technologies like GPS and triangulation allow carriers to zoom in further on customer activity. As these capabilities become more accessible, accurate in real-time, various service opportunities have been conceptualised (Jukic, 2003; Rao 2003).

These location-based services have emerged as an important component of m-commerce. Predictions are that LBS will generate over $32 billion in Europe by 2005 (Stafford, 2003; Rao 2003).

### 1.1 Location based services

The implementation of location technologies opens up a whole new world of services, communicating and sending messages based on the location of the user (Rao, 2003; Stafford, 2003).

A wide range of *safety* solutions open up by use of location technology: emergency alert services, like E-911 and E-112; roadside assistance; and, safety alarm.

*Location based charging* allows a subscriber to be charged different rates depending on the subscriber's location or geographic zone, or changes in location or zone. This service may be provided on an individual subscriber basis, or on a group basis. Location may be defined for business groups to include corporate campuses, work zones or business zones with different charging rates. Charging zone would be associated with the subscriber's location. When the subscriber moves to a different zone (or its mobile system anticipate this movement), the subscriber would be notified.

*Fleet and asset management services* allow the tracking of location and status of specific service group users.

*Location based information services* allow subscriber to access information for which the information is filtered and tailored based on the location of the requesting user. Subscribers may initiate Service requests on demand, or automatically



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when triggering conditions are met, and may be a singular request or result in periodic responses. Examples of location based information services are: city sightseeing, location dependent content broadcast, driving directions and navigating.

In case the service is initiated by the subscribers, he can indicate its location when requests the service. However, whenever the service is automatically initiated, location based services should locate the customer at any time and, prediction can be added in order to anticipate customer location and therefore improve customer satisfaction.

A key driver of LBS will be a degree of fit between the system's technical feasibility and the overall marketing and platforms (including PDAs and mobile phones). LBS providers will need to focus on blending software, hardware, and wireless connectivity into a plan for serving LBS content. In (Jukic, 2003) it is concluded that designing low-cost, reliable, and high-quality systems from a complex puzzle of disparate software, hardware and connectivity components presents a challenge. However, success in this area will accelerate networking effects that lead to widespread adoption, an increase in the customer base, and lower operating costs.

Three strategic considerations assume importance while choosing and deploying these technologies (Jukic, 2003). These include the range of coverage and scalability of applications; the degree of service quality that can be established and maintained at a reasonable cost; and the careful alignment of the overall technology cost with the types of services customers will pay for.

In this paper we describe two architectures for LBS: *local LBA*, where information is located at the customer's device; and, *remote LBS*, where customer requests for information to a remote server. We discuss these architectures based on developed LBS and analyse them. The analysis allows establishing in this paper a set of design rules (engineering decisions) to be taken into account when LBS is developed. Such rules will help to evaluate the degree of service and the coverage and scalability of LBS.

Firstly, we describe LBS architectures in Section 2, defining local and remote LBS. Section 3 is devoted to present a local LBS (a guided tour). In Section 4 we present some results for remote LBS. Then, we establish a set of design rules to take into account for LBS development. Finally, Conclusions and References end the paper.

# 2 LBS ARCHITECTURES

LBS is composed by a set of elements that interact together to provide a service. One of the most important components is devoted to get the customer position: location element. There are at least two different alternatives for such element (SnapTrack, 2001; Tabbane, 1997): external processing units destined to map the customers with its geographical positions (triangulation based on signal power transmission in cellular systems); or local processing devices like GPS modules (Stafford, 2003) mounted on the customer's mobile device (i.e. a PDA with a GPS module).

The knowledge of customer's location allows customizing the service for each customer. We distinguish two different approaches depending on information location: (i) the information is completely stored in the mobile device before service had been initiated; and (ii) the information is downloaded on–demand from the service provider.

We distinguish two different architectures for LBS depending on data location to provide the service. So, we have a local LBS architecture (henceforth referred as local LBS) meaning that the mobile device contains the information to provide the service (it is the case of route selection using GPS signals). And, we have an LBS using remote located information (henceforth referred as remote LBS), which requires at least the interaction between a remote server and the mobile device to transfer the information. Moreover, remote LBS can operate in two different modes: pull and push modes. The first one considers that mobile devices request the server for information (pull mode of operation), while in the other case, the server sends the information to the mobile device (push mode of operation) without announce it.

In both cases, information will be stored usually in a database and will be delivered in response to customer's requests (pull mode) or because it has been selected by the service provider for the customer (push mode).

In order to evaluate the service, we consider interactivity as the most important parameter, as exposed in (Jukic, 2003). Customers will be satisfied (good grade of service), whenever they obtain the service on time. And, probably, in such a case, customers will consider this service as a candidate to pay for.

In this paper we assume some requirements: we consider pull remote LBS and customers get from the service provider the information they requested. So, we can pay attention on the most important elements that affect the interactivity of LBS (LBS response time): information transfer time from service provider to customer.

In such a case, the parameters that limit LBS performance are the round trip time (RTT) in the network and the query time in the database (time to get the response from the database).

The RTT determines the transfer delay of the information; while the query time determines the time to process the customer's request. The query processing time depends on the database management system, the database structure and the size of the database (amount of data).

## 2.1 Impact of information location on LBS

One of the most interesting properties for LBS is the ability to capture the user interactivity. Therefore, such services should be designed taking into account the user response. The customers access the information and it should be displayed in a short period of time. In other case, the customer satisfaction will be degraded.

In order to increase user satisfaction we should pay attention to the service design. There are two possible strategies: local LBS, where the mobile system stores all the required information to deliver the service; and remote LBS, where the mobile system is able to download the information on demand.

In the first case, the limitation highly depends on the mobile device. The resource limitation imposed by a mobile device will affect LBS performance. Whenever the mobile device can store all the information and has enough processing capacity, the customer will perceive a good service (we will get a satisfied user). In this case, the LBS response time will be short. However, resource limitation in mobile devices is very common, therefore designs should be optimised. Moreover, local LBS restrict service operation to the local information stored in the mobile device, which can reduce user interaction with the service provider.

For remote LBS the database that stores the information must be remotely accessed, and the documents to be transferred can be of very different sizes. There is not a storing problem, but the size affects proportionally information transfer delay.

Moreover, transfer delay can be increased due to congestion problems in communication networks (some QoS guarantees should be ensured to provide predictable LBS). Remote LBS require interaction between customer and service provider, improving customer profile gathering for service provider.

Table 1 resumes some parameters that should be considered in LBS design.

Table 1 : Parameters for LBS design decisions.

| | ***local LBS*** | ***remote LBS*** |
|---|---|---|
| *DB size* | Limited | Unlimited |
| *Document size* | Limited | Unlimited |
| *Query delay* | < 1 s | < 1 s |
| *RTT* | not applicable | < 200 ms |
| *Congestion* | not applicable | possible |
| *Bandwidth* | not applicable | limited |

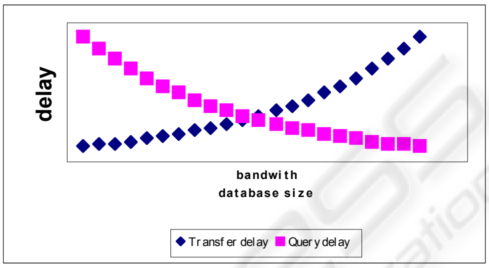


Figure 1: Trade-off between local and remote LBS.

From the consumer point of view, LBS response time highly depends on the maximum delay to get the service. In our case, there are two delay sources: the network and the database. The relation between the bandwidth and the query delay we figure that should be similar to figure 1.

As database size increase, database response time will increase. This situation is more problematic for resource limited devices as it is usually the case for local LBS. In other case, bandwidth limits transfer delay (RTT should be taking into account but we concentrate the explanation on the above parameters). And remote LBS will be limited by network performance and document sizes. The greater the document size or the lower available bandwidth, the greater the transfers delay.

As we illustrate in figure 1, there is a trade-off between bandwidth and database response time that should be considered in the design of each LBS. The main object of the paper is to obtain such relation (figure 1), because it allows deciding the LBS architecture depending on the working point of our system.

We will illustrate such considerations presenting developed local and remote LBS, with the main goal to help customer to visit the outdoor Botanic garden of the University. In the first case, the information is stored in the customer mobile device and in the other case the information is transferred through Internet as web pages.

# 3 LOCAL INFORMATION LBS WITH GPS LOCATION

In this section we describe a particular local LBS. The service provides customers a guided visit to the outdoor Botanic Garden of our University. There are different green zones in the campus, each one dedicated to a different continent or to a specific country. So, we have the European garden, the American garden, the British garden, etc. with trees original from such geographical parts of the world.

Now, the University offers a paperback *Green guide* containing the description of the different zones and information (text and images) about trees for each zone.

We have developed a local LBS using a PDA (Compaq iPAQ H3970). The PDA is equipped with a GPS module (CompactGPS from Pretec) that locates customer with a maximum error of 6 meters. The PDA stores a database with the whole information about the Botanic Garden. The goal of the LBS is to locate the customer and provide information about its position on the campus and about the trees next to the customer. That is, the local LBS provide the *Green guide* on a PDA. The customer to get the same information as the contained in the book can use this portable device. But, it is a more flexible than a book because information can be easily updated in the PDA, while a book requires a new edition.

The local LBS we have developed has the interface presented in figure 2. We use an aerial campus photo as background image and locate the customer on it. The customer is represented by the dot on the image.

In a similar way, the local LBS contains information about the trees: location, general information (common name, technical name, family, original country, etc.) and its photography. Such information is stored in a database on the PDA. Note that this application should be considered as local LBS, because all the information to provide the service is contained in the mobile device.


Figure 2 : Green guide LBS interface

In addition to service location and tree description, the local LBS provides other services as the possibility to select a predefined route through the campus to visit the Botanic garden. The local LBS contains some audio components that apply to warn the customer about the name of its location area, when a border between areas is crossed.

It is very easy to conclude in this case, that LBS can provide more powerful, flexible and customized services to customers.

## 3.1 GPS customer location

We use a GPS module (CompactGPS) to locate the customer. We verify its location precision by comparing the position it provides and the geographical UTM coordinates given by SITNA a Geographical Information System of the Navarra Government (SITNA, 2003).

We select a set of points in the University and measure its position with the GPS module several times and in different weather conditions. We show that the GPS module requires 4 minutes in average to give the first position, using, in general, a lower number of satellites than the available ones at the measurement instant. Precision location is around 9 meters in the 94,28% of the cases, as expressed by the fabricant. Moreover, we have verified, as expected, that we obtain greater position errors for test points next to buildings. However, the average position error is around 6,24 m, which is enough for our application, mainly because tree concentration places in the Botanic garden are not next to buildings.

GPS module and PDA interact through the NMEA 0183 protocol to get customer location in WGS-84 (World Geodetic System) coordinates.

These coordinates correspond to a point in the geodetic reference ellipsoid. Next we summary the conversion process from WGS-84 to UTM coordinates.

Our local LBS requires two steps after it gets the WGS-84 coordinates from the GPS module.

First, the LBS transforms them to the local ellipsoid using the Helmert transformation with 7 parameters (Hartum ellipsoid with Postdam datum – ED50, which is the reference for Europe). This transformation introduces an error. In our case, this error does not introduce a significant customer location error. We have measured an average error of 0.0539 m and a maximum error of 0.5759 m.

Finally, the local LBS projects the coordinates to obtain the UTM coordinate.

## 3.2 Local information architecture

Our local LBS contains information about the outdoors Botanic garden of the University. This information is stored in a database grouped in a set of tables.

We structure each area of the park (British park, Europe park, etc.) in a set of square regions (RegID) associated with a region name (RegName) and define its location giving the UTM coordinates of a diagonal (VInfLeftX, VInfLeftY, VSupRightX, VSupRightY). Each tree belongs to a family (FamilyName) it is distinguished by an identifier (FamilyID), and it is located at a given region with coordinates (X_UTM, Y_UTM).

Local LBS provided from a PDA, a resource limited device, can be limited by the query database time. Figure 3 shows how the value of this parameter grows, in our case, with the number of registers stored in the database (database size).

In addition, there is an information scalability problem, because the bigger the database, the greater LBS response time.

In order to overcome the above scalability problem and, consequently, to reduce the possibility of service degradation we develop an adaptive caching system for the local LBS. The cache is part of the database where database views are stored. The database view is the result of a query stored in the database.

This technique allows to reduce the local LBS response time, because data selection has been done previously (figure 4). This technique is useful, whenever the service will use often some configured selections.

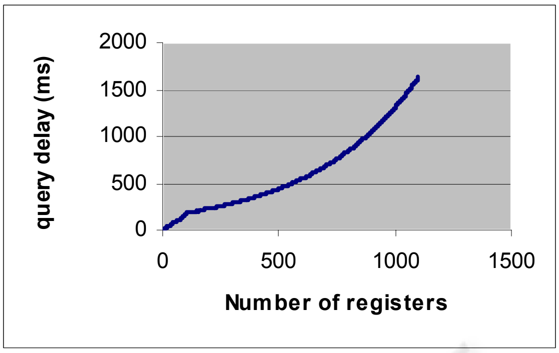


Figure 3 : Database query delay.

Then, in our case and based on the service to be offered by the local LBS, we have configured some views for each campus area.

However, we cannot store locally all possible views due to resource limitations in the customer device but we can store the sentences to build them up. The next step is to execute appropriates sentences depending on customer profile.

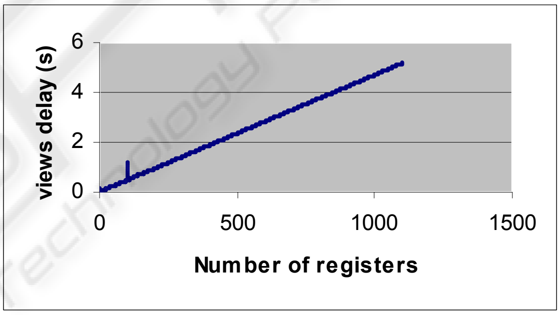


Figure 4: Views access delay for local LBS.

The caching system adapts itself using customer location as its profile. So, the local LBS select the sentences to build up the active views depending where the customer is located. In fact, the customer mobile device stores at least the views of the two regions: the region where customer is located and its neighbour region.

The local LBS automatically adapt the contents of the database to store such views without customer intervention. This technique reduces drastically the local LBS response time, as depicted in figure 4, compared with query delay time.

# 4 REMOTE INFORMATION LBS WITH GPS LOCATION

Now, we use the application in a web framework. The application sends customer's location to the remote LBS server. It responds with an HTML page containing the information depending on customer location.

In this case, we use a script to convert the GPS module output into the geographical coordinates of the customer. Such information is transferred to the service provider that returns the contents of the corresponding URL. This html page contains the new position of the customer and trees position next to the customer to locate them on the background photography; or information about the above trees.

The remote LBS, in this case, has the advantage that minimize the amount of local memory, because all the information is contained in the web page.

The limit will be the transfer delay of web pages. Such pages can be optimised in size but most of the time is required to transfer images.

Figure 5 shows the transfer delay for several tests we have done over a wireless network to transfer web pages located at different URLs in Internet. In the experiments customer has assigned a fixed bandwidth in the local network. Packet transmission through the backbone (Internet) is done in a best-effort way.

We show the delay function for different bandwidth and page sizes (figure 5) using the Internet as the backbone network. As performance measure we consider the web page download time, because it influences directly customer satisfaction.

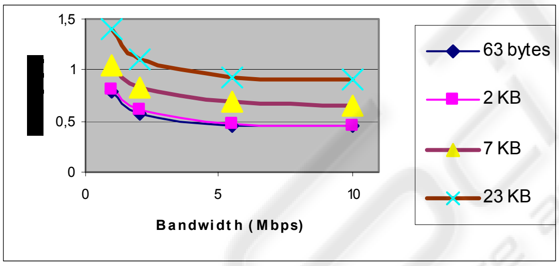


Figure 5: Transfer delay for remote LBS.

In figure 5 can be shown that increments for customer's bandwidth do not implies directly a reduction in the page transfer delay. So, bandwidth increase cannot be the best solution to provide a quality predictable remote LBS. Moreover, for each document size we obtain a minimum delay, which is limited by the RTT of the packet delivery connection (it must be taken into account that packets are transmitted in both directions, because it is a TCP/IP connection).

## 5 REMOTE VS LOCAL INFORMATION LBS

We have described and analysed, in previous sections, two different applications to illustrate the effect of information location in LBS. The results can be summarized in the next figure (figure 6). In this figure can be showed the trade-off we have found between the query database delay and the transfer delay.

Whenever the customer has a wide enough bandwidth, there are not any problems to provide remote LBS. However, it should be considered the round trip time of the network, because it restricts the interactivity. Moreover, remote LBS can be affected by network congestion problems, which are mainly unpredictable.

On the other side, local LBS are very interesting whenever the application requires a low amount of information accessible in a short period of time. For example, it is the case of a little database. But most of the applications includes of a lot of information to be useful for different customers. For example, a route selection application is sold with maps from all the country but each customer will use a small part of the whole information.

Figure 6 shows the delay the customer must wait to get a document from Internet and from the database (abscises are in logarithmic scale).

In addition, it is showed that a database, for our PDA mobile device, with a set of 150 registers provides a query delay similar to the minimum measured transfer delay through Internet.

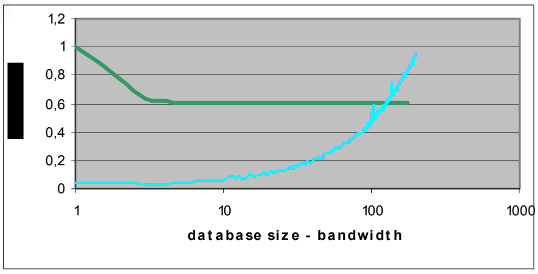


Figure 6: Local vs remote LBS trade-off.

## 6 CONCLUSIONS

In this paper we present the architecture of local and remote information LBS, and evaluate them based on practical applications.

We have found a trade-off between the query processing time and the network transfer delay as the most important factors to be considered in the design of LBS. Finally, we propose some design rules and a novel LBS architecture that improves service response time.

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