Foundations of Location Based Services

Lesson 1

CartouCHe[1] - Lecture Notes on LBS, V. 1.0

Stefan Steiniger, Moritz Neun and Alistair Edwardes[2]

KEYWORDS: Location Based Services, mobile cartography, mobile mapping

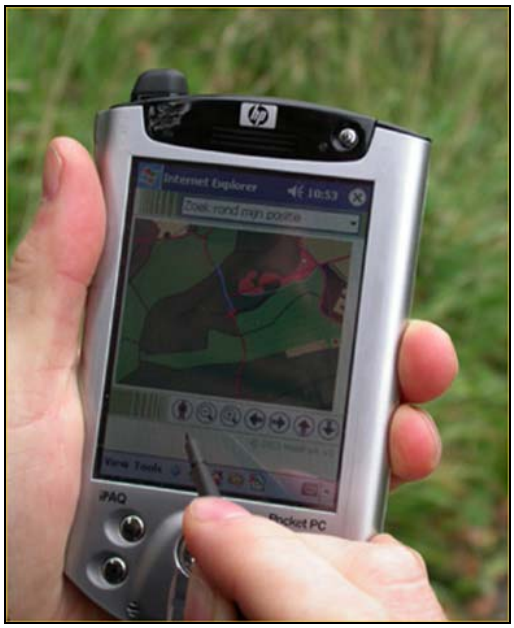
LEARNING OBJECTIVES:

After completion of the lesson you will be able to…

- identify the components and participants of LBS applications,
- describe the interaction of components,
- explain what context means, list five types of context awareness and list three levels of adaption in LBS applications.

CHAPTERS of Lesson 1:

1. Introduction
2. What are Location Based Services?
   - GIS and LBS
   - Components
   - Keywords
   - Push and Pull Services
3. How are LBSs useful?
   - User actions and goals
   - Information needs
   - Applications
4. What's special about it?
   - Context
   - Adaption
   - Privacy
   - Adaption examples
5. How does it work?
   - Services request processing
   - Mobile devices
   - Mobile networks
   - Mobile positioning
   - Architectural requirements
   - Service types – OpenLS
   - Data provider



A Location Based Service delivering a map of the environment and the position of the hiker.

[1] Project CartouCHe – Cartography for Swiss Higher Education. www.e-cartouche.ch

[2] Stefan Steiniger, Moritz Neun and Alistair Edwardes are with the GIS Divison, Department of Geography, University of Zurich, Winterthurerstrasse 190, CH-8057 Zurich (Switzerland); e-mail: {sstein, neun, aje}@geo.unizh.ch.

1 Introduction

Mobile phones and the Internet have revolutionized the communication and with it the lifestyle of people. An increasing number of mobile phones and Personal Digital Assistants (PDA) allow people to access the Internet where ever they are and when ever they want. From the Internet they can obtain on one hand information on events (cinema, concerts, parties) and on the other hand information on places (city maps, restaurants, museums, hospitals).

Let us consider the example that somebody wants to take a dinner in a restaurant and is therefore searching a restaurant in the Internet. A useful approach to prevent that one gets as search result every restaurant web-page on the world one could restrict the search by adding further search criteria. A good choice is the city where the mobile user is (position), the actual time (evening) or a special type of restaurant (Chinese or Greek).

Such kind of restaurant search with respect to position and time can be done by use of a Location Based Service (LBS). Thus, one can define that:

LBS Definition 1:

> LBSs are information services accessible with mobile devices through the mobile network and utilizing the ability to make use of the location of the mobile device. (Virrantaus *et al*. 2001)

A similar definition for LBS is given by the international OpenGeospatial Consortium (OGC, 2005):

LBS Definition 2:

> A wireless-IP service that uses geographic information to serve a mobile user. Any application service that exploits the position of a mobile terminal.

These definitions describe LBS as an intersection of three technologies (see Figure 2). It is created from New Information and Communication Technologies (NICTS) such as the mobile telecommunication system and hand held devices, from Internet and from Geographic Information Systems (GIS) with spatial databases (Shiode *et al*. 2004).

From a historical point of view location based information are not a new thing which came up with the invention of mobile phones. Espinoza *et al*. (2001) emphasize that position specific information is also transported on one hand in a person-to person communication by post-it notes and graffiti. On the other hand methods to locally inform a mass-audience are posters (e.g. of concerts in the town) or simply traffic signs, which submit navigational information. These communication forms are usually one way communications. LBS give the possibility of a two way communication and interaction. Therefore the user tells the service provider his actual context like the kind of information he needs, his preferences and his position. This helps the provider of such location services to deliver information tailored to the user needs.

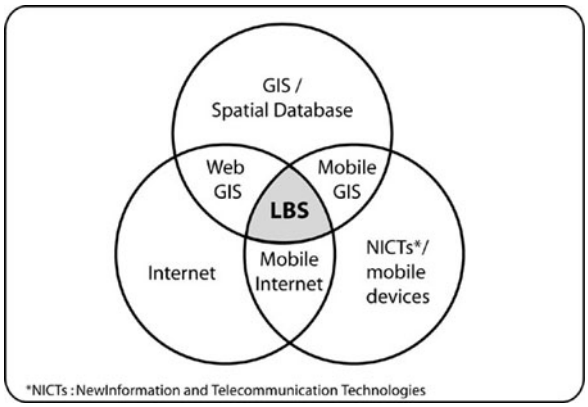


Figure 2. LBS as an intersection of technologies (Brimicombe 2002).

In the following four chapters we will try to answer the mayor questions which may appear if somebody likes to know what Location Based Services are:

- What are Location Based Services?
- How is it useful?
- What is special about it?
- How does it work?

2 What are Location Based Services?

In the following sub sections some major characteristics and definitions on LBS will be given. We will discuss the relation between GIS and LBS and give some Keywords which are useful to describe the LBS Technology. Later the basic LBS components are introduced shortly. Finally we will explain what a *Push* and a *Pull Service* is.

2.1 The relation of GIS and LBS

Figure 2 of the Introduction shows that GIS and LBS have some particular similarities. Such common features are the handling of data with positional reference and spatial analysis functions (LBS-services) which give answers to questions like:

- "Where am I",
- "What is near by?" or
- "How can I go to?".

But LBS and GIS have different origins and different user groups as described by Virrantaus *et al.* (2001). They analyse that Geographic Information Systems have been developed during several decades on the basis of professional geographic data applications. Whereas LBS were born quite recently by the evolution of public mobile services. With respect to user groups, GIS can be seen as traditional "professional" systems intended for experienced users with wide collection of functionality. Furthermore GI-Systems require extensive computing resources. In contrast, the LBS are developed as limited services for large non-professional user groups. Such LBS applications operating with the restrictions of mobile computing environment like low computational power, small displays or battery run time of the mobile device.

Nota bene: If you don't know what Geographic Information Systems (GIS) are, have a look on this GIS e-learning Project www.GITTA.info

2.2 LBS Components

If the user wants to use a location based service different infrastructure elements are necessary. In Figure 3 the five (4+1) basic components and their connections are shown:

- **Mobile Devices:** A tool for the user to request the needed information. The results can be given by speech, using pictures, text and so on. Possible devices are PDA's, Mobile Phones, Laptops, ... but the device can also be a navigation unit of car or a toll box for road pricing in a truck.
- **Communication Network:** The second component is the mobile network which transfers the user data and service request from the mobile terminal to the service provider and then the requested information back to the user.
- **Positioning Component:** For the processing of a service usually the user position has to be determined. The user position can be obtained either by using the mobile communication network or by using the Global Positioning System (GPS). Further possibilities to determine the position are WLAN stations, active badges or radio beacons. The latter positioning methods can especially used for indoor navigation like in a museum. If the position is not determined automatically it can be also specified manually by the user.
- **Service and Application Provider:** The service provider offers a number of different services to the user and is responsible for the service request processing. Such services offer the calculation of the position, finding a route, searching yellow pages with respect to position or searching specific information on objects of user interest (e.g. a bird in wild life park) and so forth.
- **Data and Content Provider:** Service providers will usually not store and maintain all the information which can be requested by users. Therefore geographic base data and location infor-

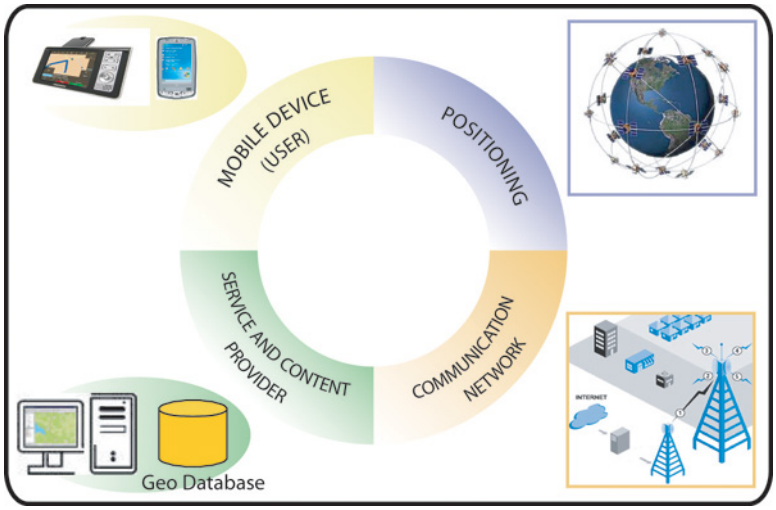


Figure 3. The basic components of an LBS: User, Communication Network, Positioning, Service Provider and Content Provider.

mation data will be usually requested from the maintaining authority (e.g. mapping agencies) or business and industry partners (e.g. yellow pages, traffic companies)

For a more detailed discussion on the components see Section 4 “How does it work” and subsequent sections.

2.3 LBS Keywords

LBS applications can be characterized by a number of keywords and related questions:

- **Mobile User:** Who or what is mobile? The mobile object can be a person or a device like a car navigation system. (see further *How is it useful?* and Reichenbacher (2004))
- **Mobile Activities:** What Questions and Problems have users? Such questions do emerge from the user actions: locating, navigating, searching, identifying, event check. A further question with respect to actions is the (spatial) scope of activities. According to Reichenbacher (2004) we can distinguish three types of spatial scope:
    - Macro scale: Do I need an overview?
    - Meso scale: What is reachable for me?
    - Micro scale: Where am I?
- **Information:** What is needed to answer a user question and how is it done? A model of information retrieval is needed to answer the user questions. Such an information process model contains a model of possible questions, defines Queries of geographic base data and location information data, and specifies possible answers. Figure 4 shows the cartographic information process if a user asks for positions of shops or restaurants close to his position.
- **Search and Spatial Analysis:** Which methods and algorithms are suitable for real-time information query in the Internet and spatial data analysis? Further question are: ”How to integrate data and information of different scale, quality, data types, prices?" "How is the data availability and actuality?"
- **User Interface:** Is a person using a PDA or mobile phone or something else? How can the user or (navigation) system formulate his needs and can make them more concrete after obtaining an overview?
- **Visualisation:** How is the information, returned from LBS, communicated to the user? Speech,

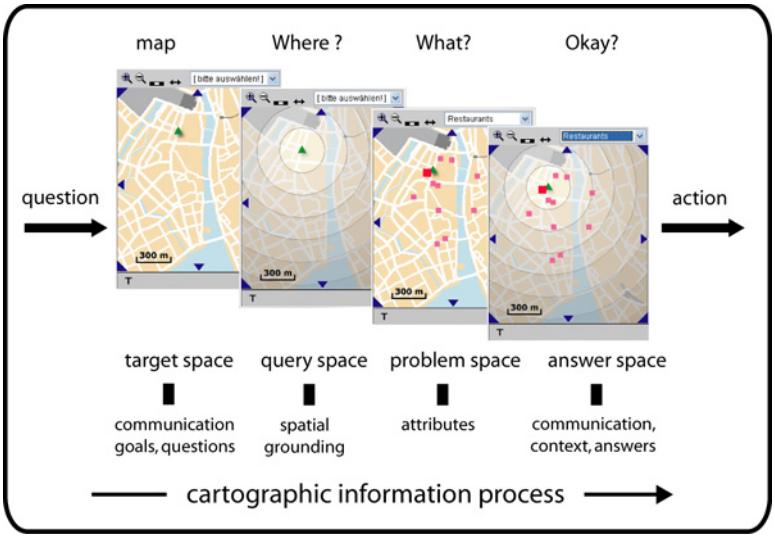


Figure 4. Question and answer model of the cartographic information processes adapted from Heidmann (1999).

text, pictures, pictograms, maps, lists,..

- **Technology:** How are service requests and data transferred between user and service provider? Where are the data stored? Which services are provided? Which positioning technology is used? ..etc.

These questions and characteristics will be considered in more detail in the following sections.

2.4 Push and Pull Services

In general one can distinguish two different kinds of location services considering if information is delivered on user interaction or not:

Pull services deliver information directly requested from the user. This is similar to call a website in the Internet by fill in its address in the web browser-address field. For pull services a further separation can be done into **functional services**, like ordering a taxi or an ambulance by just pressing a button on the device, or **information services**, like the search for a close Chinese restaurant (Virrantaus *et al.* 2001).

Push services deliver information which are either not or indirectly requested from the user. Such push services are activated by an event, which could be triggered if a specific area is entered or triggered by a timer. An example for an indirectly requested service is a news service subscription which contains event information with respect to the actual city. A not requested service could be advertisement messages if a specific area in a shopping mall is entered or warning messages if weather conditions change (e.g. hurricane warnings). Since push services are not bound on previous user interaction with the service, they are more complex to establish. Here, the background information like user needs and preferences have to be sensed by the push system.

2.5 Self Assessment

Try to identify elements of the LBS keywords (Mobile Users, Activities, Information, Interface, Visualisation and Technology) for the following application:

- A car driver want to go to the next gas station using the car navigation system.
- A student likes to know what and where his next lecture is, before going to lunch in the cafeteria

2.6 Summary on LBS Basics

In this chapter we gave a very short introduction to Location Services:

- We showed that LBS has its roots in GIS technologies, communication technologies and the Internet with all its information.
- We made clear that LBS consists of five basic components: 1. Mobile Devices, 2. Positioning, 3. Communication Network, 4. Service Providers and 5. Content Providers, whereas one can group the last two into one component. These components will described in more detail in the following sections and lessons.
- Apart from the components we gave a number of keywords which carry on to questions we should consider if we want to analyse mobile applications.
- Finally we explained how push and pull services can be distinguished. Pull services sent information on user interaction (asking for the next restaurant) and push services deliver information without user interaction (advertisement in a shopping mall, weather warning).

3 How are LBS's useful?

Where am I? Where are my friends? What is here around me?

The idea behind LBS is to answer these and other questions. If designing LBS the user's needs on information have to be met in order to make the services useful.

Figure 5. Where am I?

When individuals find themselves in an environment with which they are unfamiliar, their behaviour and needs are largely predictable, whether in their own country or abroad, in a vehicle or on foot. People need to find somewhere to eat, perhaps a pharmacy, somewhere to obtain cash, a taxi stand, and so on. When abroad, there are additional requirements: finding the local tourist attractions, getting around, locating a hotel and a foreign exchange. When driving, there may be other requirements, such as help with finding a route through an unknown city or details of breakdown services. Today, an ill-prepared traveller (who does not consult the Internet, buy a guide book, pick up information at the hotel or airport check-in, book in advance, etc) wastes a lot of time, and will not receive much help from his or her mobile phone. (Dru *et al*. 2001)

This Section will first clarify what typical user actions are and what type of information therefore is needed. Second usefulness of LBS is shown by giving some examples of LBS which are already operational or will be soon.

3.1 User Actions

User Actions and Goals

An activity is a sequence of actions conducted by a human being aimed at achieving a certain objective (Nardi 1996). Such an objective could be to solve a problem or a task. In mobile situations objectives are for example orientation, finding persons or finding the way to an object.

Activities during mobility, will often have spatially related actions embedded. These actions result out of user questions or desires. Reichenbacher (2004) identified five elementary mobile actions with respect to user needs on geographic information. The most obvious question is to know where the user himself is with respect to somebody or something else **(locating)**. Users may search for persons, objects or events **(searching)** and they ask for the way to a location **(navigating)**. Other questions ask for properties of a location **(identifying)** or they would try to look for events at or nearby a certain location **(checking)**. It should be noted that checking uses not only geo-information but involves also time, since it refers to state of entities or events as well.

Table 1 relates the elementary mobile actions with the questions they try to answer and further to basic geospatial operations that are used. The operations, also called *location service types*, will be explained in Section 5.6.

Information for searching, identifying and checking

The two basic actions locating and navigating mainly rely on geospatial information. Searching, identifying and checking however need a bigger variety of different information. Additionally to the geospatial information also other types of information are needed:

- Comprehensive **static information** are mainly contents such as a yellow pages. Such information stays constant over a while and could of course also be retrieved via other media (book, newspaper, map, TV, internet, etc.).
- **Topical information** that may change while the user is on the move. In such a case the information checked previously from other media may no longer be valid. Examples of such topical information are traffic information, weather forecasts, last-minute theatre ticket deals, or online chat. In addition to topical information, the users will need guidance on how to proceed in the changed situation. For instance, a train schedule as such can be obtained elsewhere but once on the move, the user will need information on delays and estimated arrival times.
- Additionally **safety information** has key importance, e.g. actual information on the state of the roads or hiking trials, weather changes, danger of falling rocks, etc. Car drivers or boaters also need information in emergency situations, e.g. roadside help in a situation when the car breaks down.
- Far too often users are seen as passive information consumers. However, letting the users participate and provide their opinions and recommendations could enhance many services with

	Action	Questions	Operations
	**orientation & localisation** locating	where am I? where is {person|object}?	positioning, geocoding, geodecoding
	**navigation** navigating through space, planning a route	how do I get to {place name| address| xy}?	positioning, geocoding, geodecoding routing
	**search** searching for people and objects	where is the {nearest | most relevant | &}{person | object}?	positioning, geocoding, calculating distance and area, finding relationships
	**identification** identifying and recognising persons or objects	{what | who | how much} is {here | there}?	directory, selection, thematic/ spatial, search
	**event check** checking for events; determining the state of objects	what happens {here | there}?	

Table 1. User activities (Reichenbacher 2004).

personal information. An example therefore would be notes on good places to go on mushroom foray.

In general users wish to maintain control over information content, delivery (pull/push, text/picture/video) and personal privacy and security. Security issues are shortly discussed in Section 4.2 on context.

3.2 Examples of LBS Applications

Categories of Location Service Applications

There exist a broad range of different location based services. The first figure in Table 2a gives an overview on the main categories of LBS applications. This listing does not claim to be complete and is certainly growing over time. For some application fields, namely navigation, information, advertising & billing and games & leisure, additionally information on the *positional accuracy needs*, the *environment* and the *service type* (push or pull service) are shown as graphics in the Table 2b.

Table 2a - LBS application categories

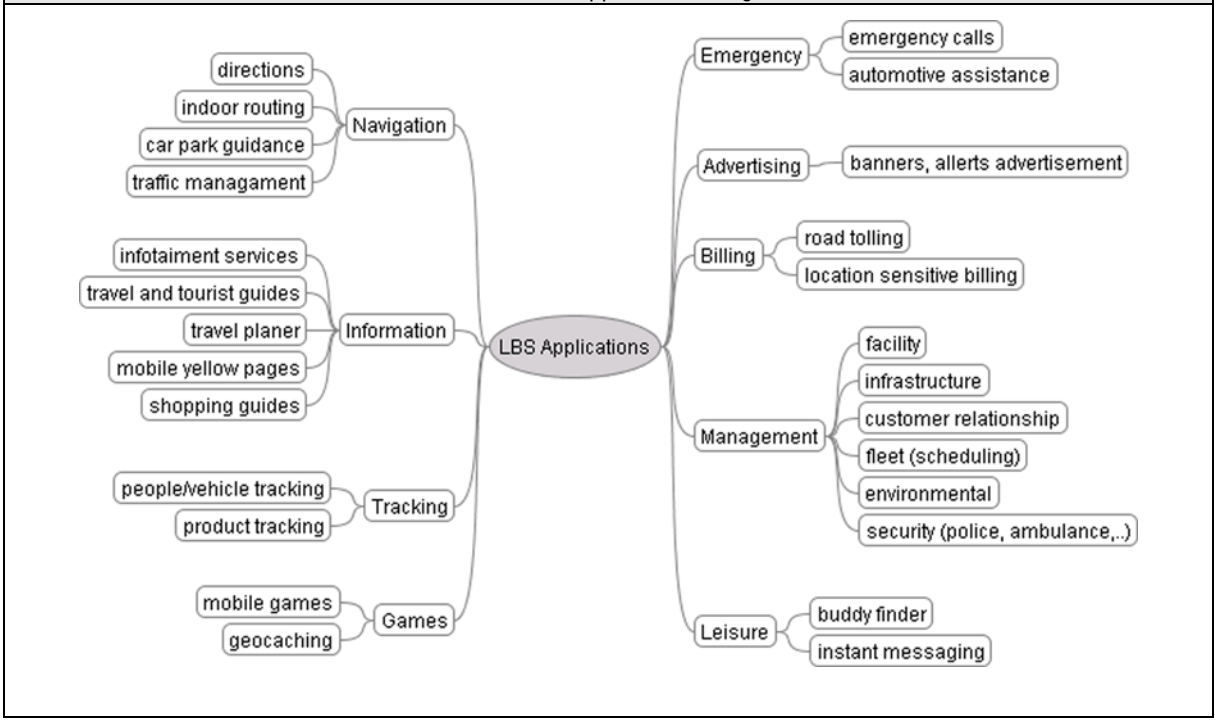
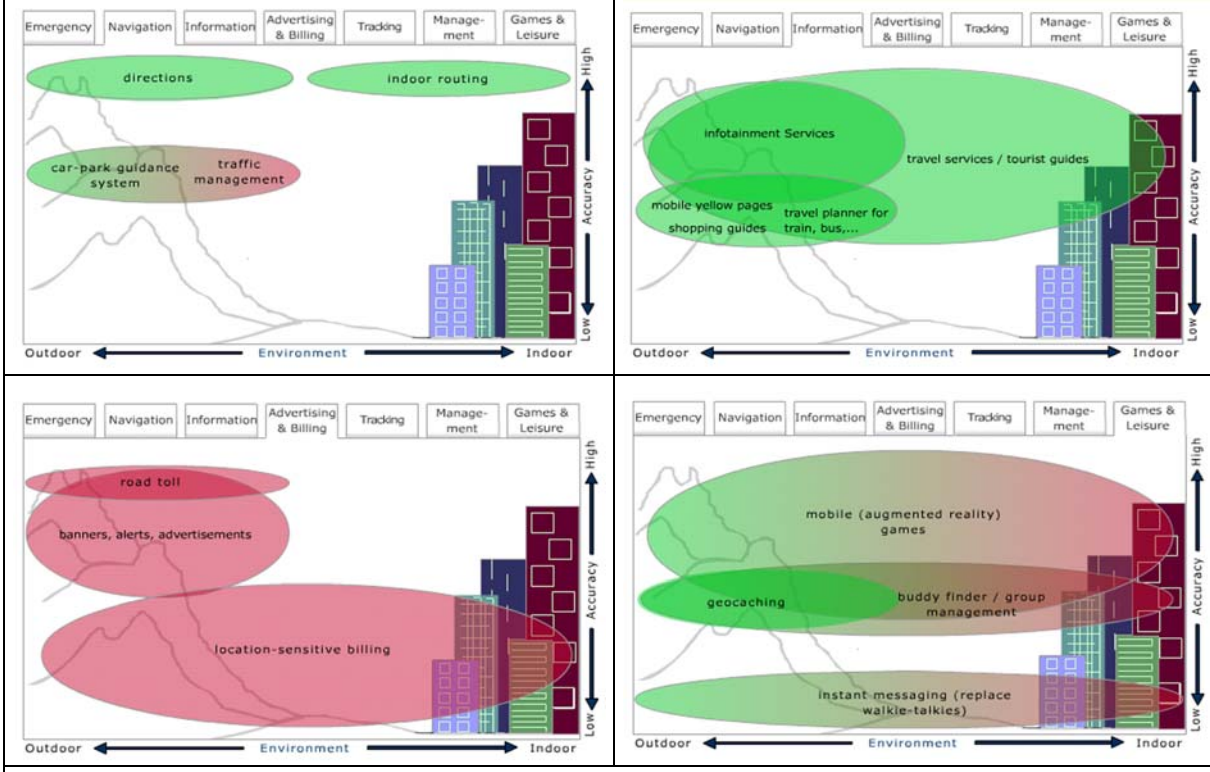


Table 2b – Properties of a selection of LBS applications



High positional accuracy denotes an accuracy within 50 meter while a low accuracy is worse than 300 meter. Red: push service, Green: pull service.

Application Examples

A - Emergency Services

One of the most evident applications of LBS is the ability to locate an individual who is either unaware of his/her exact location or is not able to reveal it because of an emergency situation (injury, criminal attack, and so on). E.g. motorists are often unaware of their exact location when their vehicle breaks down. With the exact location automatically transferred to the emergency services the assistance can be provided quickly and efficiently. This category includes public and private emergency services for both pedestrians and drivers. While public emergency services for calling out fire-fighters, medical teams, etc., are currently being mostly regulated by public organisations the emergency roadside assistance for drivers appears to be one of the most promising of the assistance services in terms of operator revenue.

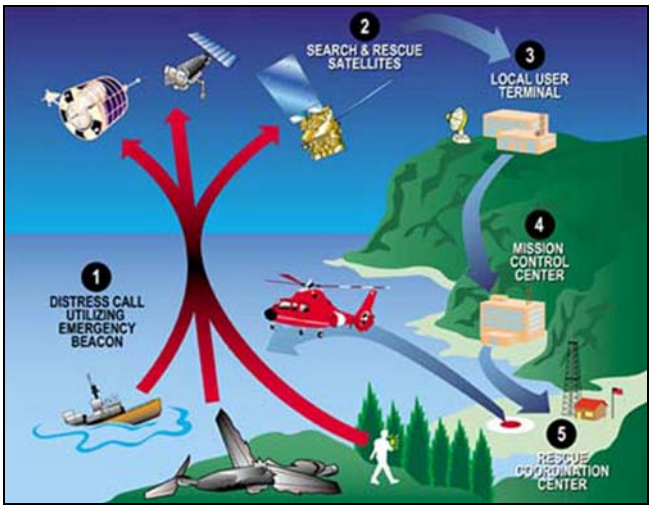


Figure 6a. COSPAS-SARSAT System Overview (NOAA Satellite and Information Service, 2005).

Example: SAR – Search and Rescue: This exam-

ple is probably one of the oldest examples for a location based emergency system. Radio beacons e.g. on marine vessels or small personal beacons transmit radio signals in the case of an emergency. The systems range from small beacons with only normal radio signals (as homing signal for rescuers or to geo stationary satellites) up to beacons which transmit their actual GPS position via satellite to the emergency services. (Figure 6a)

Figure 6b. Car Navigation (Tomtom, 2005).

B - Navigation Services

Navigation services are based on mobile users. Needs for directions within their current geographical location. The ability of a mobile network to locate the exact position of a mobile user can be manifested in a series of navigation-based services.

Example - Navigation service: By positioning a mobile phone, an operator can let the user know exactly where they are as well as give him/her detailed directions about how to get to a desired destination. In most of the current car navigation systems, other information than routing functionalities and the road databases are not in the mobile device. The user gets the pre-calculated route via the mobile network connection (see Figure 6b).

C - Information Services

Finding the nearest service, accessing traffic news, getting help with navigating in an unfamiliar city, obtaining a local street map – these are just a few of the many location based services. Location-sensitive information services mostly refer to the digital distribution of information based on device location, time specificity and user behaviour. The following types of services can be identified within this category.

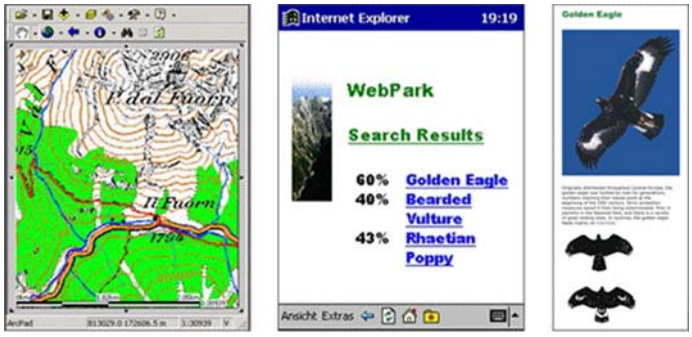


Figure 6c. WebPark LBS with presentation of habitats of different plants and animals (Edwardes *et al*. 2003).

Example - Travel services / tourist guides: Services such as guided tours (either automated or operator-assisted), notification about nearby places of interest (monuments etc.), transportation services, and other services that can be provided to tourists moving around in a unfamiliar environment (city, national park – see Figure 6c).

D - Tracking and Management Services

Tracking services can be equally applicable both to the consumer and the corporate markets. One popular example refers to tracking postal packages so that companies know where their goods are at any time. Vehicle tracking can also be applied to locating and dispatching an ambulance that is nearest to a given call. A similar application allows companies to locate their field personnel (for example, salespeople and repair engineers) so that they are able, for example, to dispatch the nearest engineer and provide their customers with accurate personnel arrival times. Finally, the newfound opportunity to provide accurate product tracking within the supply chain offers new possibilities to mobile supply chain management (m-SCM) applications (Kalakota and Robinson 2001).

E - Billing Services

Location-sensitive billing refers to the ability of a mobile location service provider to dynamically charge users of a particular service depending on their location when using or accessing the service.

F - Outlook - Augmented Reality

In the next decade, researchers plan to pull graphics out of the phone or computer display and integrate them into real-world environments. This new technology, called augmented reality, will further blur the line between what's real and what's computer-generated by enhancing what we see, hear, feel and smell.

Other than in virtual environments, in augmented reality, the user can see the real world around him, with computer graphics superimposed or composed with the real world. Instead of replacing the real world it is supplemented. So called "see-through" devices, usually worn on the head, overlay graphics and text on the user's view of his or her surroundings.

Figure 6d. Augmented Reality
(How Stuff Works, 2005).

3.3 Summary

This section has provided some knowledge on user action and a lot of application examples. You should finally know the five types of user **actions**: locating, searching, navigating, identifying and checking and the corresponding questions like "Where am I?" or "Where is...?".

Further you should be able to give examples on the four **information types** of static, topical, safety and personal information.

To describe a given LBS application you should remember that this can be done in terms of

- application area (e.g. navigation, emergency, information, etc.),
- positional accuracy needs,
- application environment (indoor/outdoor), and
- delivery type (push and pull services).

4 What's special about it?

Location-based services are different from more conventional paper and internet based media (guides, directories, maps etc.) because they are **aware of the context** in which they are being used and can **adapt** their contents and presentation accordingly. There are many different types of context, some of the most commonly considered are location, time and task. These relate to

- where the user is,
- when they are using the service and,
- what they are using the service for.

However considerations such as *how old the user is*, *if its raining* or *who the user* is with can be equally as important. Location-based services can respond to these types of context in different ways. They might filter information, for example by only retrieving restaurants within 10 minutes walk of a user's location, or they might present information in such a way that its relevance to a users context is enhanced, for example by using different map symbols for restaurants that are currently open compared to those that are closed.

In this section we shall look at what context is and how it can be used to distinguish LBS application.

4.1 What is context?

Context is any information that can be used to characterise the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application. This can include the user and applications themselves (Dey 2001). Various researchers have attempted to

classify the different kinds of contexts that are relevant to a user when accessing an information service. For example, Schilit *et al.* (1994) emphasize three important aspects of context: where you are (spatial context), who you are with (social context), and what resources are nearby (information context). But Schilit *et al.* (1994) adds that one has also to take into account technical aspects like communication band-width, network connectivity, speed of user and further the social situation or weather conditions. Further classifications are given by Abowd *et al.* (1999), Chen *et al.* (2000); Dey (2001) and Mitchell (2002).

Nivala *et al.* (2003b) developed a classification with specific reference to mobile services that are map-based. They give 9 types of context shown in Figure 7 and explained below:

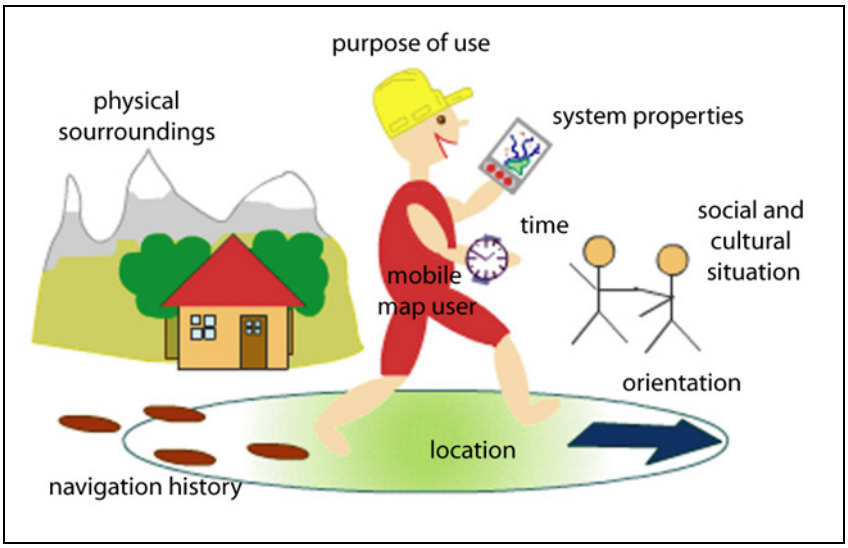


Figure 7. Different types of context after Nivala et al. (2003b).

Mobile map user: The identity of the user is important to allow the service to consider such issues as:

- Their age and gender, for example children are unlikely to be interested in knowing about bars and pubs
- Their personal preferences, for example which language they want the service to be in
- Who their friends and colleagues are, if they wish to socialize and collaborate

Location: The location is the most commonly considered element of context. It allows information and services to be localized. A user's location can be absolute, for example describe by a geo-referenced coordinate, or relative, for example a room inside a building

Time: Time can refer to the instantaneous time of day or longer intervals such as morning, afternoon or evening, day of the week, month, season of the year etc. In an entertainments service time might be used to determine if an event was still valid, for example a concert or a venue is open.

Orientation: The orientation of the user is important to determine the direction a user is heading in and thus what is in front, behind and to either side of them. In a tourist guide this might be used to determine what historical building the user is facing. In a navigation service it is important to check the user is heading in the right direction.

Navigation history: Navigational history allows the users to see where they have been and what they have seen and done. This can be useful in navigation to orientate a user while they're are moving and allow them to backtrack if they get lost. It can also help to build up a profile of the what the user is interested in, enhancing the provision of relevant information.

Purpose of use: The purpose of use is defined by the activities, goals, tasks and roles (e.g. a ranger or a tourist) of users. Different types of usage require different

- Types of information,
- Types of presentation, for example maps, text or speech, and
- Modes of interaction

Social and cultural situation: The social situation of a user is characterised by their:

- proximity to others,
- social relationships and,
- collaborative tasks

For example a user might want to 'follow the crowd' to find popular venues for example bars, exhibitions, talks, or alternatively avoid others if they're are looking for wilderness areas, or they may just want to know where their friends are.

Physical Surroundings: The physical surroundings includes such things as the lighting level or how much ambient noise there is. For example For example direct sunlight will make screens more difficult to read requiring the contrast to be adjusted

System Properties: This relates to the computer infrastructure the user is employing. What type of device they are using and what are its capabilities (e.g. touch screen, colour or black and white etc.). If they have access to a continuous internet connection or if it is only intermittent. The bandwidth of the connection. The quality of the positioning information, e.g. the GPS coverage.

4.2 Adaption – How do services respond to context?

Systems that can dynamically change their behaviour because of context have been termed variously; reactive, responsive, situated, context-sensitive and environment directed (Abowd *et al.* 1999). However, the term adaptive has become the most commonly used in mobile cartography (Reichenbacher 2004).

Adaption can take place at four different levels (Reichenbacher 2003):

1. **Information level:** the content of the information is adapted. Examples include filtering information by proximity to a user or changing the level of detail of information according to tasks (Timpf *et al.* 2003).
2. **Technology level:** Information is encoded to suit different device characteristics (e.g. display size and resolution, network and positioning availability). For example using auditory driving instructions for users with mobile phones or maps for users with PDAs.
3. **User interface level:** the user interface is adapted. For example automatically panning and re-orientating a map as the user moves about.
4. **Presentation level:** the visualisation of the information is adapted. For example restaurants that are more relevant to a user's preferences in price and taste are shown with more crisp icons and those less relevant use more opaque ones.

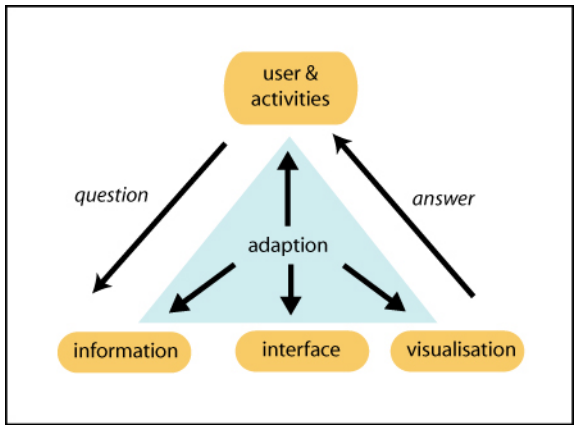


Figure 8. Levels of adaption for mobile technologies after Reichenbacher (2004).

4.3 Privacy

The sensing of context helps to deliver tailored information for a specific user, for instance to a visitor of a National Park as described by Nivala *et al.* (2003a). Such a park visitor could be interested in places where mushrooms did grow in the last years or where the next campfire location is. On the other hand context sensing rises many privacy concerns if people are tracked by their position or by analysing their preferences and action history. Such history analysis on one hand helps business applications to get a perfect customer model but can on the other hand raise user fears. Thus, context sensing is closely related to user security and privacy. To reduce user fears the user should be always informed about the information which is collected and the security of data transfer. Further, LBS user should have an option to decide if context based service features are turned on or off. A more exhaustive discussion of privacy is given in the "Geoslavery" article from Dobson and Fisher (2003).

Figure 9. Example search results from the CRUMPET project with respect to personal preferences (Schmidt-Belz et al. 2003).

4.4 Examples

A - Adaption to user preferences

Adaption has been applied in practise in a number of varied and novel ways. In the CRUMPET project (Schmidt-Belz *et al.* 2003) researchers looked at how tourists could benefit from the provision of sightseeing information. They adapted the information content according to the context of the users' personal preferences for different types of information and their current location. (Figure 9)

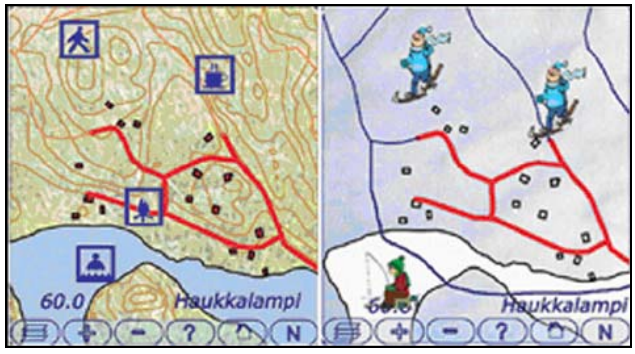


Figure 10. Maps adapted to for the GiMoDig project (Nivala et al. 2004).

B - Adaption to seasons of a year and to user age

In the GiMoDig project (Nivala *et al.* 2003a,b) researchers used the contexts of the user, the time of year and the purpose of use to adapt the content and presentation of maps. For example icon styles were varied according to the age of the user, and different recreational activities were shown at different times of the year. (Figure 10)

C - Adaption to location and social context

Persson *et al.* (2002) and Burrell *et al.* (2002) both looked at how location and social context could be used to help guide new students on a university campus. Their systems adapted the information contents according to

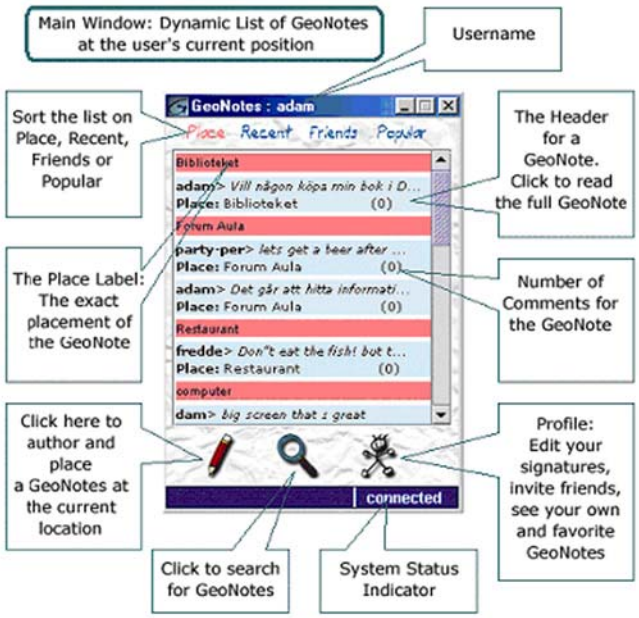


Figure 11. A virtual note (Persson *et al.* 2002).

location, time of day and social relationship between students and student groups. The contents consisted of virtual notes left by students at locations anywhere in the university, which would pass on information, experiences and preferences about what goes on where and when at that note's location. (Figure 11)

D - Adaption to system context

Chalmers *et al*. (2004) used the system context to adapt the content and presentation of information. They designed a cat-and-mouse type multiplayer game where players could use dead spots in the network and GPS coverage to hide from other players. (Figure 12)

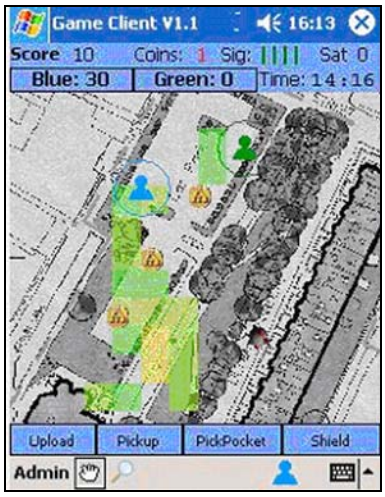


Figure 12. A seamful game (Chalmers *et al*. 2004).

4.5 Self Assessment

Describe relevant contexts and how a service might be adapted to them in the following scenarios.

- Navigation - You want to create an information service to assist people navigating. Describe the kinds of context that affect a person trying to get about, how they affect the planning and undertaking of a journey, how they might change during travel. Suggest different ways to adapt a service to consider these contexts so that the users can get efficiently and safely to their destination.
- Nature lover - You want to provide an information system to visitors of a nature reserve for birds. List the different types of context that might effect a bird-watcher in such an area and suggest how the service might be adapted to help them observing and identifying different species of birds
- Student - you want to provide an information service to help students with their studies, for example finding books and finding a place to sit at one of the university libraries. List the different types of context that might be relevant to a student and how the contexts change during the day. Suggest ways a system could be adapted to consider these.

4.6 Summary

This chapter tried to show you that **context awareness** makes LBS applications very special compared to other information technologies. From Figure 7 you can extract different types of context the users watch (time), the people in the background (social context), the arrow on the ground indicating the walking direction (orientation) or the footprints as a metaphor for the user action history.

The second section of the chapter shows you how context can be used by **adaptation**. Apart from the examples you could play with a second animation and explore adaption by moving the pointer of the clock or the distance slider. You should finally know that adaption can take place on four levels: information, technology, user interface and the kind of presentation.

5 How does it work?

The basic components necessary to use and provide LBS services have been listed in the chapter one: *"What are LBS?"*. These technical basic components are: devices, communication network, positioning technologies, Types of Services and Data. In this chapter we will give some basic information on these components and their interaction.

5.1 LBS service request processing

Considering the example of searching a Chinese restaurant the information chain from a service request to the answer will be described in the following and is illustrated in Figure 13. The information the user

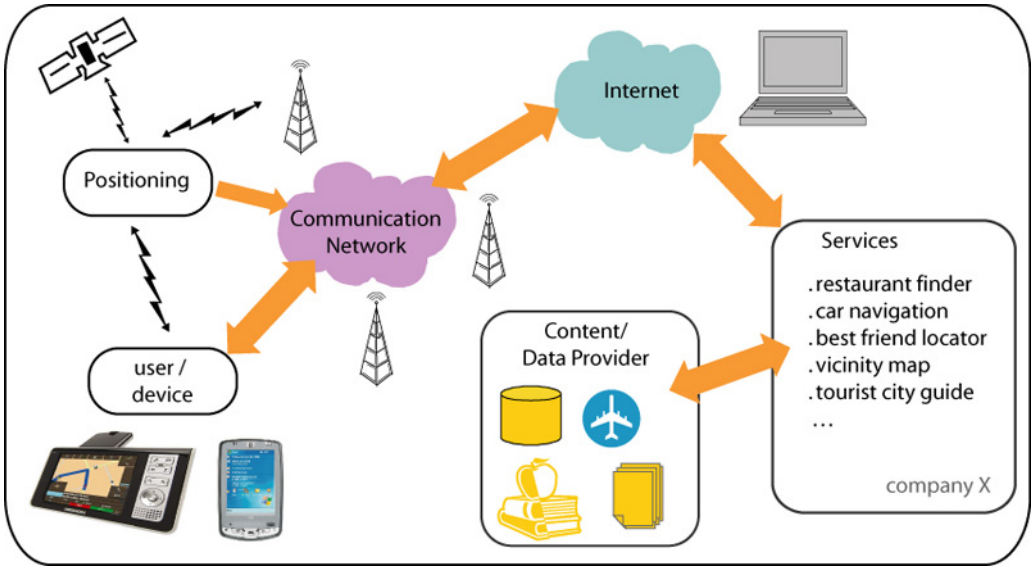


Figure 13. LBS components and information flow.

want is a route to a Chinese restaurant near by. Therefore the user expresses his need by selecting the appropriate function on his mobile device: e.g. menu: position information => searches => restaurants => Chinese restaurant.

1. Now if the function has been activated, the actual position of mobile device is obtained from the Positioning Service. This can be done either by the device it self using GPS or a network positioning service. Afterwards the mobile client sends the information request, which contains the objective to search for and the position via the communication network to a so called gateway.
2. The gateway has the task to exchange messages among mobile communication network and the internet. Therefore he knows web addresses from several application servers and routes the request to such a specific server. The gateway will store also information about the mobile device which has asked for the information.
3. The application server reads the request and activates the appropriate service - in our case a spatial search service.
4. Now, the service analyses again the message and decides which additional information apart from the search criteria (restaurant + Chinese) and user position is needed to answer on the request. In our case the service will find that he needs information on restaurants from the yellow pages of a specific region and will therefore ask for a data provider for such data.
5. Further the service will find that information on roads and ways is needed to check if the restaurant is reachable (e.g. sometimes a restaurant on the other river side might not be reachable since no bridge is near by).
6. Having now all the Information the service will do a spatial buffer and a routing query (like we know from GIS) to get some Chinese restaurants. After calculating a list of close by restaurants the result is sent back to the user via internet, gateway and mobile network.

The restaurants will now be presented to the user either as a text list (ordered by distance) or drawn in a map. Afterwards the user could ask for more information on the restaurants (e.g. the menu and prices), which activates a different kind of services. Finally if he has chosen a specific restaurant he can ask for a route to that restaurant.

5.2 Mobile Devices

Devices

The applications presented Chapter 2 “How is it useful?” emphasise that very different types of LBS applications exists and show further that LBS users can be persons or machines. In dependence on *skills of a user to handle electronic devices*, the *storage capabilities* of a device, the *user need* of applying several services or fulfilling only a specific task a broad range of devices exists. Based on the latter device property LBS devices can be distinguished into **single purpose** and **multi purpose** devices.

A **single purpose device** is for instance a car navigation box, a toll box or a emergency remote for old or handicapped people. As well part of that category are devices which call service engineers or rescue teams. But also more advanced systems like augmented reality systems - which might be used by a state inspector for bridges and other buildings - belong to it.

Multi purpose devices will be used by a broad number of people and will be part of our everyday life. Such devices can be mobile phones, smart phones, Personal digital Assistants (PDA’s) but also Laptops and Tablet PC’s.

Figure 14. Different mobile devices.

Limits

If we especially look on the multi purpose devices like mobile phones and PDA’s one has also to speak about the limits of such devices. Most of them have small *computing and memory resources* which restricts spatial search calculations, routing operations and the creation of a user specific “mobile” map. Therefore such operations are done on a service server which sends the results to the user. Further limits are given by *battery power, small displays and weather influences* on usability (sun makes things showed on a display hardly visible). Also in terms of sending and receiving data there is still a lack on broadband *access to communication networks*. A non technical challenges for such small devices is for example the design of user interface to support user interaction with respect to hardware and software.

Some of the technical problems like computing resources are more or less contemporary and will proba-

bly solved within the next years. Further points on limits of mobile devices with a focus on mobile cartographic applications will be discussed in Lesson 2 on LBS Techniques.

5.3 Wireless Mobile Networks

As already seen in the previous section the wireless communication networks transfer user data and service request messages from the mobile terminal to the service provider and further the requested information back to the user. A possible second task is to use the network to obtain the user position. Common wireless networks today can be classified by two means. One classifier is the *network range* which is also induced by the network's purpose and the physical limitations of radio waves. The other classifier is the *networks topology*, whether the network consists of a large infrastructure of mostly im-mobile network-nodes and the mobile clients access only the nodes or the clients form an "Ad-Hoc" network by being the nodes themselves. (Figure 15).

Since the classification with respect to the covered area is preferred we will discuss this one below. A useful classification here is done into *Wireless Wide Area Networks* (WWAN) - e.g. GSM and UMTS, *Wireless Local Area Networks* (WLAN) -e.g. IEEE 802.11, and *Wireless Personal Area Networks* (WPAN) - e.g. Bluetooth (Figure 15).

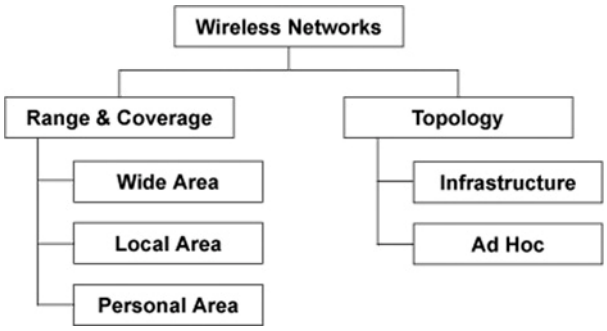


Figure 15. Classification of mobile networks.

Common to WWAN and WLAN is the principle of a mobile terminal and a base transceiver station. For WWAN a structured network (backbone) of such base stations is necessary. Since every base station covers a specific area does call such network types also cellular networks. Usually the network cells for WWAN overlap only by small portions.

Wireless Wide Area Network cells covering distances of 100 meters up to 35 km (Figure 16). The used frequency spectrum is usually not free, which means it has to be licensed, but can also not used by somebody else. Since the first generation networks (analogue G1) were intend for voice communication only the transferred data rates are quite low (4.8 kbps). The Global System for Mobile (GSM) and General Packet Radio Service (GPRS) are network types of the second generation (digital G2) which can transfer higher data rates (GSM: 9.6 –14 kbps; GPRS: 20-115 kbps). But these rates are still insufficient with respect to multimedia applications. For this purposes new 3rd Generation networks are currently build up. In Europe these wideband system is called UMTS (Universal Mobile Telecommunica-

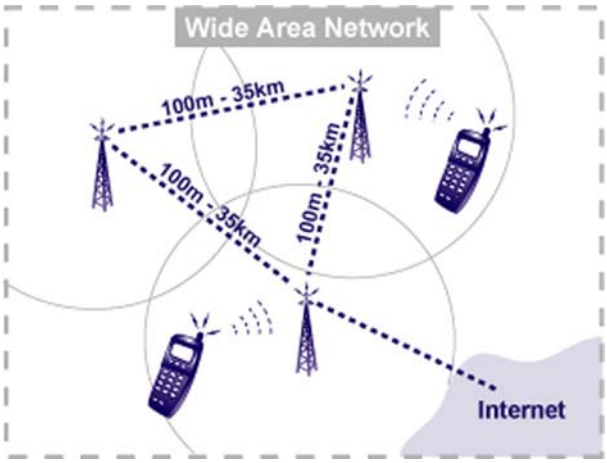


Figure 16. Wireless Wide Area Network.

tion System) and can reach data rates up to 2 Mbps. The development on faster networks and higher data rates is already in process as an announcement for a 3.5G network by NTT DoCoMo for 2006 demonstrates (NTT DoCoMo 2005). Comparing existing GSM and UMTS techniques the latter network type needs much more base stations. Further the radius of UMTS cells is not constant since the coverage depends on the number of mobile clients and used data rates. A disadvantage of UMTS are higher network costs compared to G2 networks. Advantages of UMTS apart higher data rates are better data security (128bit encoding) and also better positioning capabilities (Hoffmann 2002).

Wireless Local Area Networks covering distances between 10 m to 150 m (300m outdoor, see also Figure 17). They use the unlicensed spectrum and provide much higher data transfer rates (100 Mbps) than WWAN. Since WLAN technology emerged as extension to Computer LANs the network is specialized on data transfer. Mobile stations connected by WLANs can use simple infrastructures with Access Points (APs) instead of Base Stations or can connect to one another directly in ad hoc mode (Krishnamurthy *et al*. 2004).

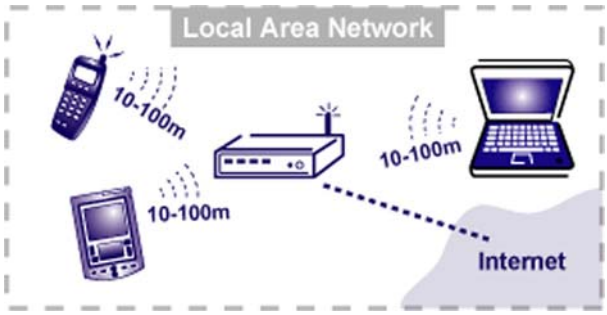


Figure 17. Wireless Local Area Network.

Wireless Personal Area Networks provide short range connectivity e.g. for digital cameras or headsets. The covered area radius is about 10m but will increase up o 100m in future. The used frequency spectrum is unlicensed and data rates are about 0.5 Mbps, thus in between WWAN and WLAN. These devices connect and disconnect as needed and have therefore a so called ad hoc topology. Most WPANs are based on the Bluetooth standard. Advantages compared to WLAN are voice support and security issues (Mäs 2003).

In consequence Krishnamurthy and Pahlavan (2004) state that WLAN and WPAN are better suited for information services with high granularity (e.g. details of a room) and better suited for consumer portal services (navigation in a shopping mall or museum). In the opposite WWANs are likely to support large scale services like fleet management, safety, telematics and are therefore useful for smaller set of information services. More introductory information on wireless networks can be found in Krishnamurthy and Pahlavan (2004) and Schiller (2003).

Network technology		Average range	Data Rate (Mbps)	frequency domain
WWAN	GSM (G2)	base station distance 100m-35km	0.009-0.014	~ 900 MHz, licensed Spectrum
	GPRS		0.160	
	UTMS (G3)		2.0	
WLAN	Ultra-Wideband	10m	100	~ 2.4 & 5 GHz, not licensed Spectrum
	IEEE 802.11a	50m	54	
	IEEE 802.11b	100m	11	
WPAN	Bluetooth	10m	1	~ 2.4 GHz, not licensed Spectrum
	HomeRF	50m	10	
	IrDA (infrared)	1-1.5m, needs line of sight	1-16	not licensed spectrum

Table 3. Properties of different wireless network technologies.

5.4 Positioning methods and Accuracy

In the previous Section 5.1 , which describes the general information workflow, a *position service* has been introduced to obtain the user location. We will now have a more detailed view on positioning methods.

If we do not consider the manual input of the position as a location method a general classification of positioning methods can be done into two groups: The first group is called **network-based positioning**. Here a tracking and evaluation of the user location is done by using the base station network (see in the figure image . Therefore the mobile device sends either a signal or is sensed by the network. The second positioning group is called **terminal-based positioning**. Here, the location is calculated by the user device itself from signals received from base stations. The most famous example for a terminal-based sys-

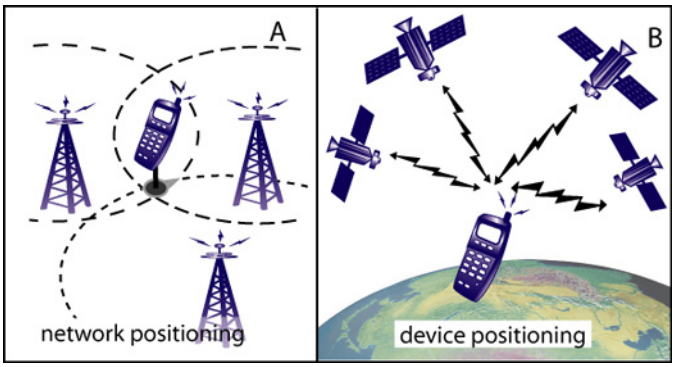


Figure 18. Types of mobile positioning.

tem is the use of the Global Positioning System (GPS). The base stations for the GPS system are the GPS-satellites (see image B in the Figure). Finally a third group of positioning techniques emerges from combination of network and terminal positioning techniques.

The basic principles for the calculation of the user position, valid for all groups, are:

1. Base Stations have a known position.
2. Information from a signal is transformed into distances (N.B.: this is not valid for Angle Of Arrival, AOA).
3. Calculation of position by using the obtained distances to the base stations (e.g. arc intersection in picture C of the figure)

The following basic techniques are often used for positioning, mostly in combination:

Cell of origin (COO), **location signature**, **location beacons**: The cell id is usually the identifier of the nearest base station, e.g. a mobile phone antenna. With this technique the position is known in a defined circle or cell around the base stations known position. Beacons, e.g. infrared, ultrasound or RFID, are used mostly indoors. Here beacons have an identifier id or transmit their exact position to the mobile device which is in reach.

Time of Arrival (TOA): As electromagnetic signals move with light speed. Knowing the speed and the time difference between sending and receiving the distance can be computed. Light speed is approx 300’000km/s thus the runtimes are very short and exact timers are needed. The same principle can also be used for slower signals like ultrasound.

Time Difference of Arrival (TDOA), **Enhanced Observed Time Difference** (E-OTD): these techniques do also compute the distance by measuring the runtime, but in difference they use therefore the time difference between the signals of usually three different base stations. Thus having signals from different

neighbouring base stations the position can be triangulated. In the case of TDOA the calculation of the position is done by the network provider, in the case of E-ODT it's done in the mobile device.

Angle of Arrival (AOA), **Direction of Arrival** (DOA): by using antennas with direction characteristics the angle of arrival in the mobile device can be detected. Because of a moving mobile device this is not very exact. Another possibility is that many base stations have segment antennas (usually 2-4) which divide the circum-circle of the base station in segments of 90, 120 or 180 degrees.

The currently two most common position technologies are the already mentioned GPS and the position evaluation using the Cell-ID from the nearest base transceiver station, a network method. Whereas GPS delivers a very accurate position (accuracy up to 5m) does the Cell-ID deliver a very coarse position (accuracy between 100m to km). Especially GPS is (currently) a outdoor positioning method. To obtain indoor positions with high accuracy, as needed for instance in museums or shopping malls, localisation methods based on WLAN, Bluetooth or infrared technologies should be applied.

In general it is important to note that the position technology and its accuracy influences the application of different location based services (see also application examples in Chapter 2). Figure 19 shows a number of positioning methods with their accuracy and their applicability to indoor and outdoor user activities. As a rule over the thumb one can say on one hand that network positioning is useful for LBSs where precision is not critical. Here, the Figure below shows the usually lower positioning accuracy of network methods. On the other hand the terminal based positioning is to recommend for LBSs where precision is important: e.g. dispatch, driving directions or billing (Lopez 2004).

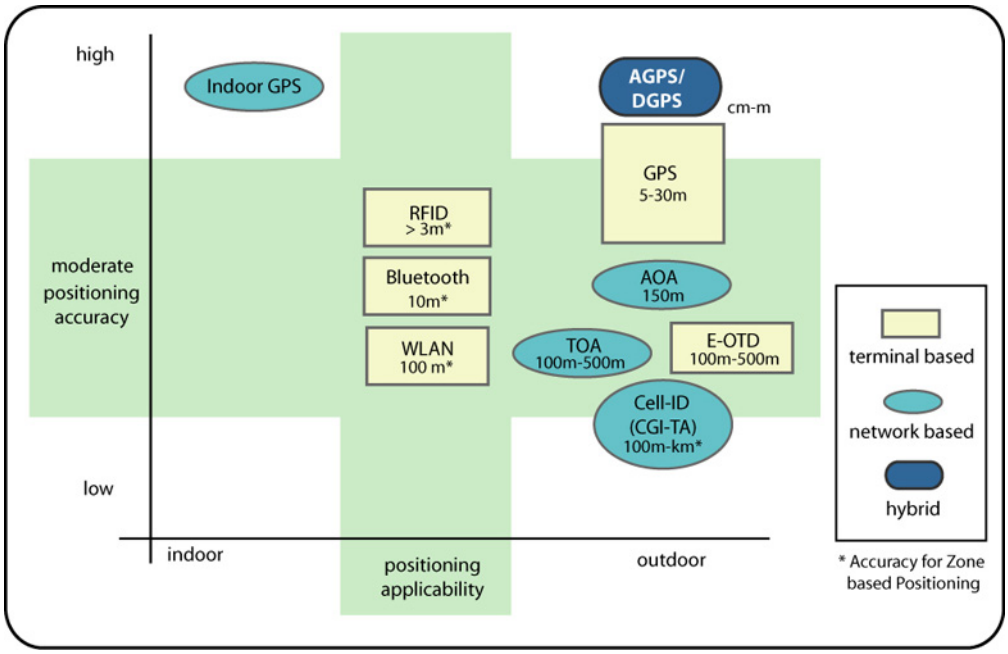


Figure 19. Positioning methods, accuracy and application. (AGPS: Assisted GPS, AOA: Angle of Arrival, TOA: Time of Arrival, E-OTD: Enhanced Observed Time Difference).

5.5 Requirements of an LBS architecture

Derived from the user actions, different requirements on the LBS system architecture emerge. Further different types of services are offered by companies to satisfy the needs. Whereas types of services will be described later we will start with the requirements on LBS.

In opposite to Geographic Information Systems which are usually desktop or client server applications with a limited number of users, do LBS provide access and information to dozens of users. Lopez (2004)

lists the following capabilities of LB-Services that usually exceed the general requirements on static GIS use:

- **High Performance**: Delivering answers in sub-second if querying information from internet and databases.
- **Scalable architecture**: Support thousands of concurrent users and terabytes of data.
- **Reliable**: Capable of delivering up to 99.999 percent up-time.
- **Current**: Support the delivery of real-time, dynamic information.
- **Mobile**: Availability from any device and from any location.
- **Open**: Support common standards and protocols (HTTP, Wireless Application Protocol - WAP, Wireless Markup Language - WML, Extensible Markup Language – XML, Multimedia Markup Language – MML).
- **Secure**: Manage the underlying database locking and security services.
- **Interoperable**: Integrated with e-Business applications such as Customer Relationship Management, Billing, Personalization, and wireless positioning gateways.

These requirements lead to a complex LBS architecture involving a number of players. These Players include hardware and software vendors, content and online service providers, wireless network and infrastructure providers, wireless handset vendors and branded portal sites. Only common specifications and agreements among these players do ensure a user satisfying offering and deployment of services.

5.6 Mobile Services – Open Location Services (OpenLS)

In the previous sub sections we discussed requirements and necessary components of LBSs. To realize a Location Based Service a number of different players ranging from technology providers to data providers have to be involved. This includes hardware and software vendors, content and online service providers, wireless network and infrastructure providers, wireless handset vendors and branded portal sites. To ensure that all the different technologies and devices work together common standards for interfaces and description have to be defined. Such standards with respect to LBSs have been set up by the International Standard Organisation (ISO) and by the Open Geospatial Consortium (OGC). Whereas ISO 19119 provides a general service framework and ISO 19101 gives a classification of geographic services, has the

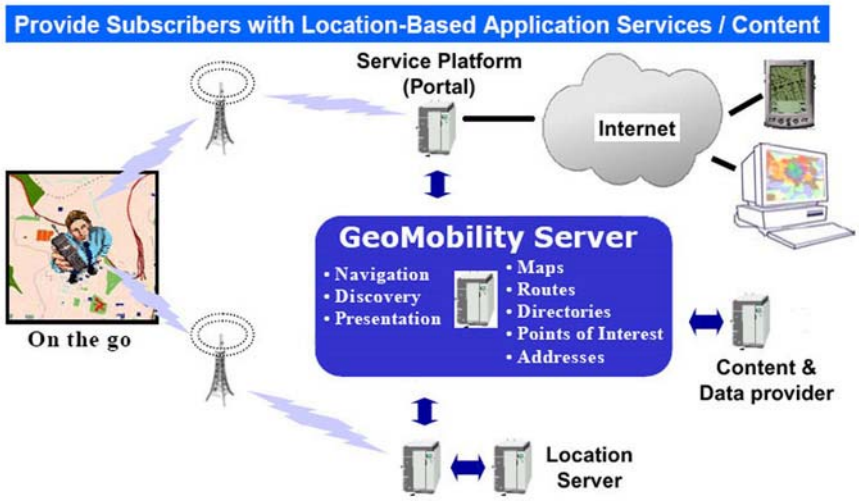


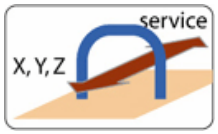
Figure 20. The role of the GeoMobility Server.
Modified version from OGC OpenLS Specification 1.1, 2005 (Open Geospatial Consortium 2005).

Open Geospatial Consortium released a specification for *Open Location Services* (OpenLS - Open Geospatial Consortium 2005). OpenLS defines core services, their access and abstract data types which form together a framework for a open service platform, the so called *GeoMobility server*. The server acts as application server and should proceed and answer core service requests. The role of this server is pictured in the Figure 20. It should be noticed that service requests to a GeoMobility server can be send from a mobile user, from Internet users but also from other application servers.

The core services defined in the OpenLS 1.1 specifications (Open Geospatial Consortium 2005) include five service types:

Directory Service (spatial yellow pages): This service provides subscribers with access to an online directory to find the nearest or specific place, product or service.

- Example 1: “Where is the Red Dragon Chinese Restaurant?”
- Example 2: “Where are Chinese Restaurants?”
- Example 3: “Where is the nearest Chinese Restaurant to my hotel?”
- Example 4: “Which Chinese Restaurants are within 500m of my hotel?”



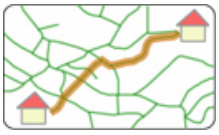
Gateway Service: This is the interface between the GeoMobility Server and the Location Server from the Positioning Service (see the Figure). It is useful to request for the current location with different modes (e.g. multi or single terminal, immediate or periodic position).

Location Utility Service (Geocode/ Reverse Geocode): This service performs as a Geocode by determining a geographic position, if a place name, street address or postal code is given. It also performs as a reverse Geocode by determining a complete, normalized place name/street address/postal code, for a given geographic position.

- Example 1: Given an address, find a position.
- Example 2: Drive to an address (position).
- Example 3: Given a position, find an address.
- Example 4: "Where am I?"

Presentation Service: This service renders geographic information for display on a Mobile Terminal. An OpenLS application may call upon this service to obtain a map of a desired area, with or without map overlays that depict Route Geometry, Point of Interest, Area of Interest, location, position and/or address.

- Example 1: Joe User wants to see where his house is located on a map.
- Example 2: Planning a family road trip, Joe User wants to see how get from his house in Calgary, Alberta, to the hotel he has booked in San Diego, California.



Route Service: This service determines a route for a subscriber. The user must indicate the start point (usually the position acquired through the Gateway Service, but this could also be a specified location, e.g. their home for a planned trip), and the endpoint (any location, like a place for which they only have the phone number or an address, or a place acquired through a search to a Directory Service). The subscriber may optionally specify waypoints, in some manner, the route preference (fastest, shortest, least traffic, most scenic, etc.), and the preferred mode of transport. The returned routing information can be textual, in a presentation code (describing turns and distances) or a geometry, useful for a map.

These mentioned services are core services, that means different providers will implement further services for their customers. Examples therefore are real-time traffic information, event guides and friend finders.

5.7 Content and Data Providers

The types of data needed can be very different and depend on the kind of services offered, that means on its global or specialized application character (Figure 21).

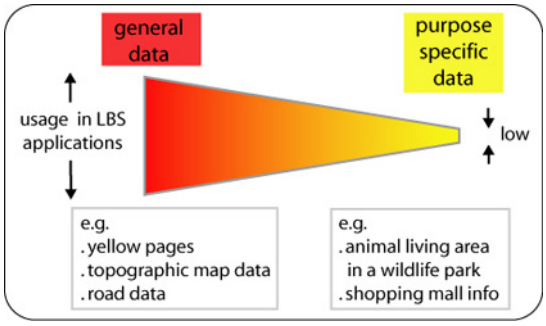


Figure 21. Types of data for mobile services and manifold of application.

Purpose Specific LBS Applications are for instance services which help localizing handicapped people or services provided by a national park. For the first example of handicap people monitoring only the position and mapping data is necessary (to see in a better way the position of the patient). Further the monitoring service could introduce own risk zones where an alert is activated if the patient enters the zone. For the second example of a national park LBS again some background data for positioning information is useful. Such mapping data could be obtained from the country mapping agencies. Other national park services will be probably based on information about species living in the park (What is it? and Where to find?). Here, a certain amount of data will be in the park own information data bases. Additional information on "What is it?" could be provided by an electronic encyclopaedia system of a publishing company.

General LBS Applications are offered by telecommunication providers like NTT DoCoMo, Telecom, Vodaphone, AT & T or specialized companies, which provide their services to user of different telecom networks. Examples of these general data are shown in the Figure 22 below.

Considering the core services types of the previous sub section we can allocate different data providers:

- *Directory Service:* Yellow Pages provider with local, national and international focus; transportation companies (rail and bus); Internet search services (e.g. Google.com, Yahoo.com); Internet consumer information services (Ciao.com) and Personal Websites (restaurant website, company website); electronic libraries like Wikipedia (www.wikipedia.org); weather services; entertainment and news information services; and so forth.
- *Gateway Service:* positioning services / position providers.
- *Location Utility Service:* provider of postal data (National Post Agencies) and street data (NAVTEQ, Tele Atlas).
- *Presentation Service:* aerial and satellite photo provider (National Space Agencies, National Surveying Agencies) and map provider (National Mapping Agencies, mapping companies and publishers).
- *Route Service:* street data providers (NAVTEQ, Tele Atlas, National Road Administrations) and routing services which can be combined with presentation (mapping) services (e.g. Michelin.com, Map24.com).
- The non core service function "Friend Finder" does not necessary need external information. Here, the position of friends can be determined by using solely mobile network information. In contrast, other services like "Real-Time Traffic" information could be directly exchanged between specialized data provider and user, without needing any additional data sources and processing, after obtaining the location from a positioning service.

The integration of the data - so called data conflation - from the mentioned different providers needs the definition of suitable data exchange formats and interfaces. The data conflation will be one of the challenging tasks for the next years.

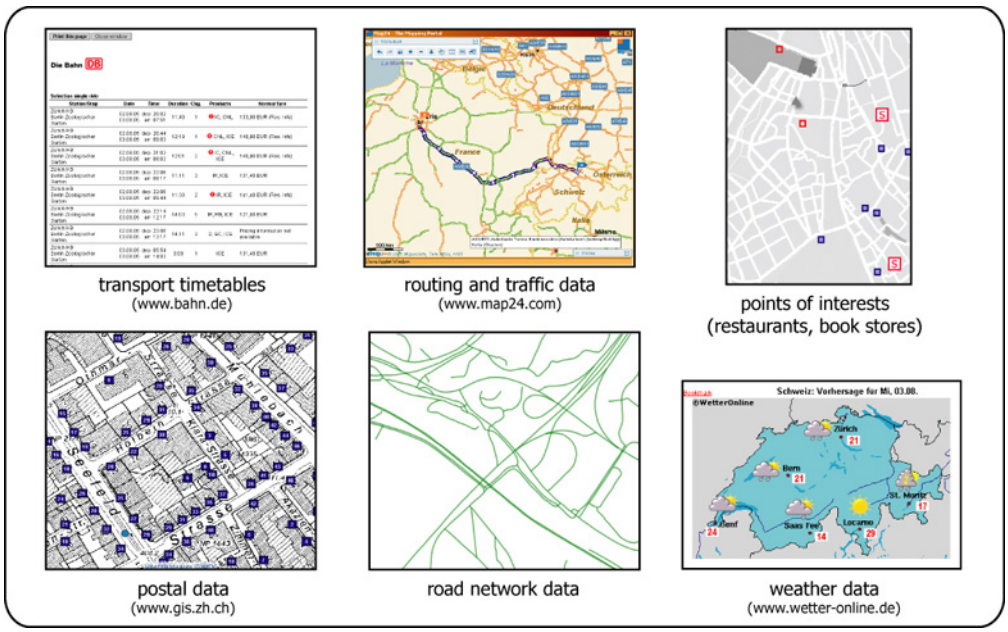


Figure 22. Data from different data providers for location services.

5.8 Summary

This unit presented on one hand the processing chain of a service request and on the other hand some basic knowledge on the five components of LBS. Considering the different components you should know..

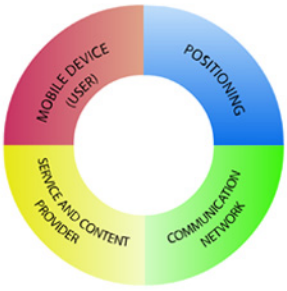
- that we can distinguish between **single** and **multi purpose devices** and further be able to list some device types, e.g. mobile, toll box, PDA, navigation unit
- that can be classified with respect to the **area of coverage** and that we distinguish between WWAN, WLAN and WPAN
- that the location of a mobile user can be determined using either **network-based positioning** or **terminal based positioning** methods. Further you should remember that the basic principle of position calculation is based on the intersection of distance-circles around base station

Figure 23. Five LBS Components, whereas we distinguish two provider types.

- that data for LBS applications may be classified into **purpose specific** and **general data**. And you should be able to list some data type - e.g. yellow pages, topographic data, road data or shopping mall information.

6 Summary on Lesson 1

Location Based Services will become more and more part of our everyday life. First services are already provided for mobile phone users like friend finders, weather information or city event boards. Other location services like road tolling for trucks or fleet management are also already operational LBS business applications. In this lesson we defined first what Location Services are and presented afterwards some fundamental characteristics of such services:



Five LBS Components

- We saw that the LBS architecture consists of **five basic components**: Mobile Devices, Positioning, Communication Network, Service Providers and Content Providers. These components have been shortly discussed in the last subsection of the lesson. Further we gave an example how these components act together in the processing chain of a service request sent by a user.
- In the second section we presented **user actions** and questions from which the types of services (operations), needed by users, emerge. Five types of actions have been identified: locating, searching, navigating, identifying and checking.
- **Context awareness** has been emphasised as a major feature of LBS technology. Therefore context has been defined and 9 types have been listed and visualized (e.g. location, time, social situation, system, etc.).


Context

- Using context in an LBS application has been introduced as **adaption**. Four levels of adaption have been identified (information, technology, user interface and presentation) and effects could be discovered in an interactive tool.
- Finally a long list with LBS application examples has been given and four properties to **characterise an application** are presented: the application area (e.g. navigation, emergency, information, etc.), positional accuracy needs, application environment (indoor/outdoor), and delivery type (push and pull services).

Since this lesson does present only the basics on LBS the further lesson will give some closer insight into the characteristic, partially with a specific focus on map presentations of results received from a Location Service. However, user actions and goals as well as context will be issues of the Lesson *Designing Maps for LBS*. But context will also play a role in a further lesson on *Solutions for small screen map design*.

5. Acknowledgements

Major parts of the work have been accomplished and are financed as part of project CartouCHE – Cartography for Swiss Higher Education, a Swiss Virtual Campus Project (project id: 3083). The Authors like to thank the following persons for contributions: Barbera Lenz and Harald Steinmann; and for useful hints: from ETH Zurich: Olaf Schnabel, Regula Stopper, Lorenz Hurni; from FHB-Basel: Susanne Bleisch, Stephan Nebiker; and from University of Zürich: Joel Fisler, Robert Weibel.

6. References

Abowd, G., Dey, A., Brown, P., Davies, N., Smith, M. and, Steggles, P., 1999. Towards a Better Understanding of Context and Context-Awareness. In: Hans-Werner Gellersen, ed. *Lecture Notes In Computer Science*; Vol. 1707. London, UK: Springer-Verlag, 304-307. (Download)

Brimicombe, A. J., 2002. GIS - Where are the frontiers now?. In: *Proceedings GIS 2002*., Bahrain, 33-45.

Burrell, J. and Gay, G.K., 2002. E-graffiti: evaluating real-world use of a context-aware system. *Interacting with Computers*, 14(4), July, 2002 (Special Issue on Universal Usability), 301-312. (Download)

Chalmers, M. and Galani, A., 2004. Seamful interweaving: heterogeneity in the theory and design of interactive systems. In: *Proceedings of the 2004 conference on Designing interactive systems: processes, practices, methods, and techniques.*, (ACM DIS), August 01-04, 2004, Cambridge, MA, USA. New York: ACM, 243-252. (Download)

Chalmers, M., Bell, M., Hall, M., Sherwood, S., and Tennent, P., 2004. Seamful Games. In: *Adjunct Proceedings of 6th Int. Conf. on Ubiquitous Computing.*, UbiComp 2004 - Demonstrations Proceedings, Sept 7-10, 2004, Nottingham, England. . (Download)

Chen, G., and Kotz, D., 2000. Technical Report: *A Survey of Context-Aware Mobile Computing Research.* Dept. of Computer Science, Dartmouth College, TR2000-381. (Download)

Collins, P., Shukla, S., Redmiles, D., 2002. Activity Theory and System Design: A View from the Trenches. *Computer Supported Cooperative Work*, 11, 55-80. (Download)

Dey, A., 2001. Understanding and Using Context. *Personal and Ubiquitous Computing.*, 5(1), 4-7. (Download)

Dobson, J.E., Fisher, P. F., 2003. Geoslavery. *IEEE Technology and Society Magazine*, 22 (1), 47-52.

Dru, M-A., Saada, S., 2001. *Location-based mobile services: The essentials.* Alcatel Telecommunications Review, first quarter, 71-76. (Download)

Edwardes, A., Burghardt, D., Weibel, R., 2003. WEBPARK – Location based Services for Species Search in Recreational Areas. In: *Proceedings of the 21st International Cartographic Conference.* Durban, South Africa. (Download)

Espinoza, F., Persson, P., Sandin, A., Nyström, H., Cacciatore. E. and Bylund, M., 2001. GeoNotes: Social and Navigational Aspects of Location-Based Information Systems. In: Abowd, Brumitt and Shafer, ed. Ubicomp 2001: *Ubiquitous Computing.*, International Conference, September 30 – October 2, Atlanta, Georgia. Berlin: Springer, 2-17. (Download)

Heidmann, F., 1999. *Aufgaben- und nutzerorientierte Unterstützung kartographischer Kommunikationsprozesse durch Arbeitsgraphik: Konzeptionen, Modellbildung und experimentelle Untersuchungen.* Herdecke: GCA-Verlag.

Hoffmann, M., 2002. Mehrseitig sichere Location Based Services – Endgeräte, Übertragungstechnik und Anwendung. *Geoinformation mobil.*, 75-84.

How Stuff Works, 2005. *How Augmented Reality Will Work* [online]. (Download)

Kalakota, Robinson, 2001. XXX

Krishnamurthy, P., Pahlavan, K., 2004. Wireless Communications. In: Karimi, H. A., Hammad, A. (eds.) *Telegeoinformatics*. CRC Press, 111-142.

Lopez, X., 2004. Location-Based Services. In: Karimi, H. A., Hammad, A., ed. *Telegeoinformatics*. CRC Press, 171-188.

Mäs, S., 2003. *Konzeption und Implementierung eines multimedialen Location Based Services für mobile Endgeräte.* (Diploma).

Mitchell, K., 2002. *Supporting The Development of Mobile Context-Aware Systems.* Ph.D. (Download)

Nardi, B. A., 1996. *Context and consciousness: activity theory and human-computer interaction.* Cambridge, MA: MIT Press.

Nivala, A.-M., Sarjakoski, L. T., 2003a. Need for context-aware topographic maps in mobile devices. In: *Proceedings of ScanGIS 2003*, Espoo, FI. , 15-29. (Download)

Nivala, A-M., and Sarjakoski, L.T., 2003b. An Approach to Intelligent Maps: Context Awareness. In: *The 2nd Workshop on 'HCI in Mobile Guides'*, in adjunction to: MobileHCI'03, 5th International Conference on Human Computer Interaction with Mobile Devices and Services, September 8th, 2003, Udine, Italy. (Download)

Nivala, A-M. and Sarjakoski, L. T., 2004. Preventing Interruptions in Mobile Map Reading Process by Personalisation. In: *Proceedings of The 3rd Workshop on 'HCI in Mobile Guides'*, in adjunction to: MobileHCI04, 6th International Conference on Human Computer Interaction with Mobile Devices and Services, September 13-16, 2004, Glasgow, Scotland. . (Download)

NOAA Satellite and Information Service, 2005. *COSPAS-SARSAT System Overview* [online]. (Download)

NTT DoCoMo, 2005. *Internet information on mobile networks.* [online]. Available from: http://www.nttdocomo.com/corebiz/network/index.html [Accessed 22 August 2005].

Open Geospatial Consortium (OGC), 2005. *Open Location Services 1.1.* .

Persson, P., Espinoza, F., Fagerberg, P., Sandin, A. and Cöster, R., 2002. GeoNotes: A Location-based Information System for Public Spaces. In: Kristina Höök, David Benyon and Alan Munro, ed. *Readings in Social Navigation of Information Space.* Berlin: Springer, 151-173. (Download)

Reichenbacher, T., 2003. Adaptive Methods for Mobile Cartography. In: *Proceedings of the 21st International Cartographic Conference ICC: Cartographic Renaissance*, 10-16th August 2003, Durban, South Africa. , 1311-1321. (Download)

Reichenbacher, T., 2004. *Mobile Cartography - Adaptive Visualisation of Geographic Information on Mobile Devices.* (PhD). (Download)

Schiller, J. H., 2003. *Mobile Communication.* Addison Wesley.

Schilit, B., Adams, N. and, Want, R., 1994. Context-aware computing applications. In: *Proceedings of IEEE Workshop on Mobile Computing Systems and Applications.* 1994, Santa Cruz, California. , 85-90. (Download)

Schmidt-Belz, B., Laamanen, H., Poslad, S., Zipf, A., 2003. Location-based mobile tourist services - first user experiences. In: *Proceedings of ENTER 2003. Int. Congress on Tourism and Communications Technologies.*, 2003, Helskini, Finland. Heidelberg, Berlin: Springer Computer Science. (Download)

Shiode, N., Li, C., Batty, M., Longley, P., Maguire, D., 2004. The impact and penetration of Location Based Services. In: Karimi, H. A., Hammad, A., ed. *Telegeoinformatics*. CRC Press, 349-366.

Timpf, S. and Kuhn, W., 2003. Granularity Transformations in Wayfinding. In: C. Freksa, W. Brauer, C. Habel and K.F. Wender (eds). *Spatial Cognition III. Lecture Notes in Artificial Intelligence*. Berlin-Heidelberg: Springer Verlag, 77-88. (Download)

Tomtom, 2005. *Car Navigation* [online]. (Download)

Virrantaus, K., Markkula, J., Garmash, A., Terziyan, Y.V., 2001. Developing GIS-Supported Location-Based Services. In: *Proc. of WGIS'2001 – First International Workshop on Web Geographical Information Systems.*, Kyoto, Japan. , 423–432.

6.1 Some books on LBS

Karimi, H. A., and Hammad, A., 2004. *Telegeoinformatics.* CRC Press

Meng, L., Zipf, A. and Reichenbacher, T., 2004. *Map Design for Mobile Applications.* Heidelberg, Springer Verlag.

Reichenbacher, T., 2004. *Mobile Cartography - Adaptive Visualisation of Geographic Information on Mobile Devices.* (Ph.D.). http://tumb1.biblio.tu-muenchen.de/publ/diss/bv/2004/reichenbacher.html last accessed: 01/2006, München, Verlag Dr. Hut.

Schiller, J. H., and Voisard, A., 2004. *Location-based services*. Morgan Kaufmann Publishers.

Schiller, J. H., 2003. *Mobile Communication.* Addison Wesley.