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Introduction

1.1 What are Location-based Services?

Although *Location-based Services* (LBSs) have been an issue in the field of mobile communications for many years, there exists neither a common definition nor a common terminology for them. For example, the terms *location-based service*, *location-aware service*, *location-related service*, and *location service* are often interchangeably used. One reason for this dilemma might lie in the fact that the character and appearance of such services have been determined by different communities, especially the telecommunications sector and the ubiquitous computing area.

The *GSM Association*, which is a consortium of 600 GSM network operators, simply defines LBSs as services that use the location of the *target* for adding value to the service, where the target is the "entity" to be located (and this entity is not necessarily also the user of the service). This abstract definition raises of course the question of what a concrete added value is. The GSM Association (2003) presents three examples where the added value is given by the filtering of information (for example, selecting nearby points of interest), showing the location of a target on a map, or automatically activating the service when a target enters or leaves a predefined location. Another similarly abstract definition of LBSs is given by the *3rd Generation Partnership Project* (3GPP), which is an international federation of many national standardization authorities aiming at providing the specification for GSM and UMTS: an LBS is a service provided by a service provider that utilizes the available location information of the terminal (3GPP TS 23.271). Following these definitions, most of today's LBSs are realized as data or messaging services, for example, based on the *Wireless Application Protocol* (WAP), the *General Packet Radio Service* (GPRS), or the *Short Message Service* (SMS). However, they can also appear in conjunction with traditional telephony services or future interactive multimedia services, as well as with *supplementary services* like call forwarding, freephone, charging, and televoting. Another application area is *location based* or *selective routing*, where telephone calls or data are routed depending on the subscriber's current location. This is used, for example, to route emergency calls to an emergency response agency that is close to the emergency caller's current location.

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3GPP strictly distinguishes between LBSs and *location services*. The latter exclusively deals with the localization of target persons and objects and with making the resulting location data available to external actors. A location service does not imply the processing of location data in the sense of filtering or selecting location-dependent information or performing other high-level actions (as an LBS does); it is only responsible for the generation and delivery of location data. However, with this function, location services essentially contribute to the operation of LBSs and can be regarded as an important subservice of them. Without a location service, an LBS user would have to enter location data manually, which would be a cumbersome procedure, especially when doing it by using a mobile device with limited user interface while on the move. Thus, LBSs and location services mostly appear in conjunction.

In research, LBSs are often considered to be a special subset of the so-called *context-aware services* (from where the term *location-aware service* has its origin). Generally, context-aware services are defined to be services that automatically adapt their behavior, for example, filtering or presenting information, to one or several parameters reflecting the context of a target. These parameters are termed *context information*. The set of potential context information is broadly categorized and, as depicted in Figure 1.1, may be subdivided into personal, technical, spatial, social, and physical contexts. It can be further classified as *primary* and *secondary contexts*. Primary context comprises any kind of raw data that can be selected from sensors, like light sensors, biosensors, microphones, accelerometers, location sensors, and so on (Schmidt and van Laerhoven 2001). This raw data may be refined by combination, deduction, or filtering in order to derive high-level context information, which is termed *secondary context* and which is more appropriate for processing by a given context-aware service.

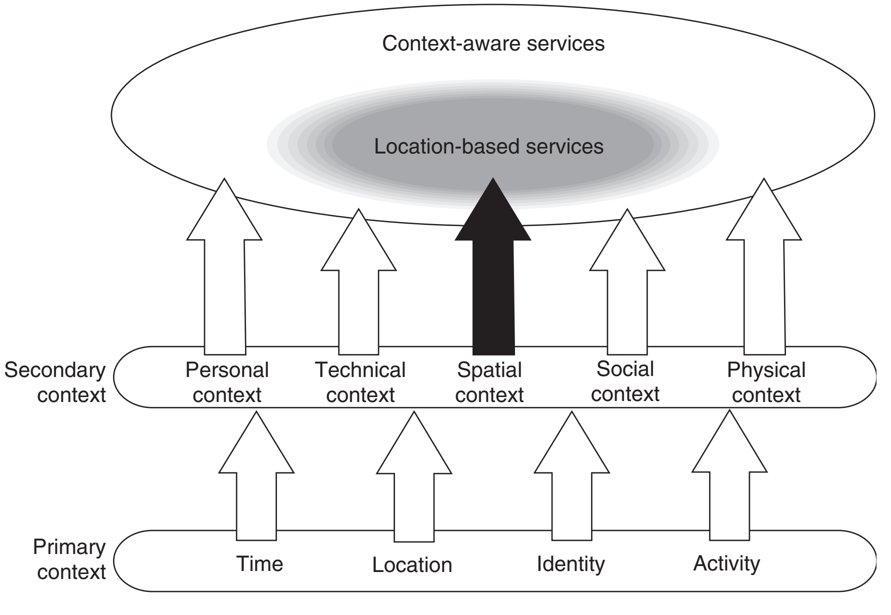

Figure 1.1 Context-aware and location-based services.

As can be derived from Figure 1.1, LBSs are always context-aware services, because location is one special case of context information. In many cases, the concept of primary and secondary contexts can also be applied to LBSs, for example, when location data from different targets are related or the history of location data is analyzed to obtain high-level information such as the distance between targets or their velocity and direction of motion. Therefore, there is no sharp distinction between LBSs and context-aware services. And, in many cases context information that is relevant to a service, for example, information such as temperature, pollution, or audibility are closely related to the location of the target to be considered. Hence, its location must be obtained first before gathering other context information. A detailed introduction to the ideas and fundamentals of context-awareness is given in Dey and Abowd (1999) and Schmidt et al. (1999).

LBSs can be classified into *reactive* and *proactive LBSs*. A reactive LBS is always explicitly activated by the user. The interaction between LBS and user is roughly as follows: the user first invokes the service and establishes a service session, either via a mobile device or a desktop PC. He then requests for certain functions or information, whereupon the service gathers location data (either of himself or of another target person), processes it, and returns the location-dependent result to the user, for example, a list of nearby restaurants. This request/response cycle may be repeated several times before the session is finally terminated. Thus, a reactive LBS is characterized by a synchronous interaction pattern between user and service. Proactive LBSs, on the other hand, are automatically initialized as soon as a predefined location event occurs, for example, if the user enters, approaches, or leaves a certain point of interest or if he approaches, meets, or leaves another target. As an example, consider an electronic tourist guide that notifies tourists via SMS as soon as they approach a landmark. Thus, proactive services are not explicitly requested by the user, but the interaction between them happens asynchronously. In contrast to proactive LBSs, where the user is only located once, proactive LBSs require to permanently track him in order to detect location events.

In order to make the idea behind LBSs more clear, the following section presents a broad range of application scenarios.

1.2 Application Scenarios

The scenarios presented here are subdivided into economical initiatives, which are carried out by operators and providers to raise the attractiveness of their networks and data services and thus to increase the average revenue per user, and public initiatives, which are introduced by governments for supporting or fulfilling sovereign or administrative tasks.

1.2.1 Business Initiatives

The main motivation for offering LBSs is to gain revenue by increasing the average airtime per user, selling location information to third parties, and offering services tailored to the special needs of mobile users. A provider may either realize and offer LBSs on its own initiative or it may enter into business relationships with other actors, for example, from trade and commerce or the automobile industry, and realize and offer services on behalf of them. These relationships are defined by more or less complex business models, which are the subject of intensive research in the areas of business sciences and consulting (see, for example, (Agrawal and Agrawal 2003)). This section presents some classical examples of LBSs, which result from such business initiatives. However, actually there is a much broader range of LBSs, which cannot be completely covered here.

1.2.1.1 Enquiry and Information Services

The simplest and so far the most widespread type of LBSs are *enquiry* and *information services*, which provide the mobile user with nearby *points of interest* such as restaurants, automated teller machines, or filling stations. Upon request, the user is either automatically located by the mobile network or, if appropriate positioning technology is missing, he must explicitly enter his current location. Furthermore, he must specify the points of interest, for example, whether he would like to receive a list of all nearby restaurants or filling stations, and the desired maximum distance between his current position and the points of interest. The request is then passed to a service provider, which assembles a list of appropriate points of interest and returns it to the user. Thus, this type of service is basically an extension of the Yellow Pages for showing only entries of local relevance. In today's networks, these services are usually accessed over SMS, WAP, or I-mode. In some cases, they are combined with navigation facilities for guiding the user to the points of interest of his choice along the shortest route.

1.2.1.2 Community Services

Community services enable users that share common interests to join together in a closed user group (*community*) and to interact among each other via chat, whiteboards, or messaging services. In the recent years, the WWW has created various occurrences of these services supporting a broad and heterogeneous range of communities in such areas as cooking, traveling, family, computer, and eroticism. What is common to most of them is that users have to fix their nicknames, age, gender, domiciles, and other personal data in profiles that are matched against each other in order to support the mutual detection of users with similar interests. A very popular category is the so-called *Instant Messaging*, where users can assemble a buddy list of their favorite acquaintances. If a user is registered with the service, he can observe which of his buddies is also on line and can immediately enter into contact with him. This feature is commonly referred to as the *presence* feature.

Like for many mobile services, a breakthrough in mobile community services has not yet taken place, the reason for which is certainly the lack of convenient user interfaces for mobile devices. However, their extension with location-based features represents an obvious way to make them popular in mobile networks too. Typical functions are to show a user the current location of his buddies or to alert him if one of his buddies stays close by. Location-based community services are much more sophisticated and more difficult to realize than, for example, the enquiry and information services presented earlier. They require a permanent tracking of their members and sophisticated mechanisms for saving their privacy. The different characteristics of mobile community services and the chances they provide for users as well as for mobile operators are discussed in Fremuth et al. (2003).

1.2.1.3 Traffic Telematics

The area of traffic telematics aims to support car drivers with a set of manifold services relating to their vehicles. It includes but is not limited to navigation, the automatic configuration of appliances and added features within the vehicle, diagnostics of malfunctions, or the dissemination of warning messages. The most widespread application so far has been navigation, which is enabled by *On-Board Units* (OBU) installed in the cars. On the basis of the current location, which is derived via GPS (Global Positioning System), the OBU guides the driver to the desired target by giving either vocal instructions or displaying the route graphically. The guidance is based on map material that is loaded from a local CD/DVD-ROM inside the OBU. More sophisticated versions of these systems are equipped with GSM/GPRS units and can thus keep the driver up-to-date with information from a remote server, including information on, for example, the latest traffic jams, weather conditions, and road works. On the basis of this information, it becomes possible to recommend alternative routes. The navigation services can be combined with several useful features. For example, Scharf and Bayer (2002) present a system that includes a number of services around parking lots, ranging from registering and tariffing parking lots, guiding the driver to the reserved lot, and the exchange of parking lots among drivers.

A hot topic in research is the wireless intervehicle communication, which relies on short-range communication technologies like WLAN or Bluetooth and which enables the exchange of warning messages, local traffic situations, or the position of filling stations in an ad hoc manner. The content of the messages originates from different sources, above all from sensor technology inside the vehicles. Data delivered by these sensors is subsumed under the term *floating car data* and comprises such parameters as the vehicle's speed, direction, and position. To derive high-level information, for example, like the aforementioned traffic situation, the floating car data must be refined in several steps and maybe even combined with the data received from other vehicles, before disseminating it to nearby vehicles. Intervehicle communication is a complex matter, which poses a number of strong requirements on the systems' reliability, security mechanisms, routing protocols, and positioning technologies. It is usually not considered to be a classical LBS, but adopts a number of similar technologies and mechanisms. The interested reader can get additional information from the works of Enkelmann (2003), Lochert et al. (2003), and Kosch et al. (2002).

1.2.1.4 Fleet Management and Logistics

While traffic telematics is concerned with supporting single, autonomous vehicles, fleet management deals with the control and coordination of entire fleets of vehicles by a central office. Typical target groups are freight services, public transportation, and emergency services. Location-based systems for fleet management are able to request the position of vehicles, display it on a map, determine the distance between different vehicles of a fleet as well as between a vehicle and its destination, and so on. On the basis of this information, the central office can dynamically delegate new orders and predict the arrival time of deliveries at the destination.

LBSs can also serve to support each form of logistics. As stated in Jakobs et al. (2001), the distribution of goods is no longer about moving cargo from A to B, but a complex process including sorting, planning, and consolidation of goods along a supply chain, which is usually composed of a sequence of different means of transportation. With the technologies of LBSs, it becomes possible to support faster transportation, different transportation modes, and the development of fallback scenarios in case of failures.

1.2.1.5 Mobile Marketing

Mobile marketing is a new kind of sales approach that helps manufacturers and service agencies to promote their products and services by interacting with consumers through their mobile devices. The contact with a consumer is usually established by using technologies such as SMS, *Multimedia Messaging Service* (MMS), or WAP, where the first one is the most popular "media channel" till date. Unlike conventional campaigns in television, newspapers, and journals, mobile marketing enables to select the target group of a certain product or service very accurately by evaluating the user profiles that reflect a customer's interests in products and services and possibly even his buying patterns in the past. In addition, it enables a high degree of interactivity between consumers and the agencies carrying out a campaign.

The consequent step forward is to make mobile marketing location-based in that the consumer is provided with information about products and services of local relevance. For example, a consumer might be informed about the special offers of a shop by sending a message to his mobile device just at the moment he is passing the shop. This message might contain information about products or services available on the spot as well as additional benefits like coupons or allowances. However, it must be stressed that mobile marketing in general and the location-based version in particular will only gain acceptance if consumers do not feel harassed by incoming advertisement messages, which turns out to be a very serious problem with the E-mail service in the Internet. Advertisement messages should be delivered to a consumer only if they are in accordance with his interest profile, and it must be possible to conveniently cancel a subscription either permanently or temporarily. For advertisement messages that are delivered depending on the user's location, it must also be guaranteed that they do not distract the user while carrying out activities that need concentration such as car driving, for which appropriate mechanisms, either in the network or in the mobile devices, are yet to be developed. Further information about location-based marketing can be found in Ververidis and Polyzos (2002).

1.2.1.6 Mobile Gaming

In recent years, mobile devices have developed from rudimentary mobile phones to sophisticated mobile computers with high-resolution multicolor displays, high-speed processors, and several megabytes of storage. Hence, devices with these capabilities can not only be used for making phone calls, but they are also very attractive to be used as mobile consoles for playing games, which are either preinstalled or which can be dynamically loaded over the air from a service provider against a fee. A very popular application is the interactive games that allow remote users to share the same session and to enter into a real-time competition, for example, in a football game or a race. The games are accessed via the mobile device and the data needed to organize and maintain a distributed game session are communicated over a cellular network.

Another occurrence is the location-based mobile games, where the virtual and real worlds merge and the current locations of users become an essential aspect of the play.

An example is *Can you see me now?*, where on-line players have to catch professional players who run through real city streets, and the on-line players are equipped with a mobile device for tracking the runner and communicating with the game server (Benford et al. 2003). In Japan, another popular game is *Mogi*, where players have to cruise the streets of a city to collect virtually hidden treasures. The mobile device indicates the hiding places of treasures on a map, and the players have to move to this place in the real world as fast as possible before the treasure is collected by another player. For a comprehensive and thorough introduction to the business and technical aspects of the mobile entertainment industry, see the publications of the EU project mGain (2003).

1.2.1.7 Value-added Services

Value-added or *supplementary services* are terms originating from the traditional telecommunications domain and refer to enhancements of basic services, especially speech telephony (see (Magedanz and Popescu–Zeletin 1996)). More prominent examples are *call forwarding*, *freephone*, *split charging*, and *televoting*. Actually, positioning capabilities of a network can also be seen as a value-added service as they are, in many cases, offered as enhancements to other services. However, they can also serve to enable a more intelligent and flexible use of conventional supplementary services. For example, location-based call forwarding (or selective routing) means that incoming calls addressed to a user's mobile device are automatically rerouted to a nearby fixed terminal. Some operators have also implemented location-dependent charging and allow their customers to determine a so-called *homezone*, that is, a certain geographic area of some size from where they can make calls at special tariffs or even free of charge. Location-based supplementary services like these are predominantly based on proprietary solutions developed by the operators for marketing purposes. Unlike any other (supplementary) services in the telecommunications sector, they are not subject to standardization currently.

1.2.2 Public Initiatives

In many countries of the world, governments and authorities have recognized the potentials of new communication systems such as the Internet and use them for supporting and fulfilling sovereign and administrative tasks. Obviously, the new technical possibilities for tracking and locating people by mobile communication systems have inspired many governments to think of new services for various national purposes, ranging from fighting against crime and emergency services to collecting tolls. While some of these initiatives go along with legal mandates that require network operators to implement the required functions, others may be realized through the so-called *public-private partnerships*, that is, contracts between the government and operators, which have been negotiated according to the rules of free market economy. Although these initiatives do not fall into the category of conventional LBSs (and, in most cases, are hardly experienced by the citizens as such), the underlying mechanisms are nevertheless the same as those used for LBSs. Therefore, public initiatives in the aforementioned areas turned out to be very important driving forces for a broad commercial introduction of LBSs. In the following section, the most important examples of national activities in this field are reflected.

1.2.2.1 Enhanced Emergency Services

Emergency services represent a very obvious and reasonable application area where the deployment of location technology makes sense. In many cases, persons calling a so-called *emergency response agency* (e.g., police, fire) are unable to communicate their current location or they simply do not know it. While in many cases the address of a caller can be easily determined when the emergency call is made over the fixed telephone network, rescue workers are faced with serious problems when locating callers from mobile networks. This is worse, for example, in the United States, where about 50% of all emergency calls are increasingly made from mobile phones.

To cope with this problem, the *Federal Communications Commission* (FCC) in the United States passed a mandate in 1996 that obligated mobile operators to locate the callers of emergency services and to deliver their geographic position to the so-called *Public Safety Answering Point* (PSAP), the office where emergency calls arrive. According to the emergency number 911 in the United States, this mandate is known as *Enhanced 911* (E-911). The mandate also defines an accuracy standard that goes far beyond what is possible with the standard mechanisms of location management in cellular networks and therefore requires enhancement of existing network infrastructures. To give operators enough time for these enhancements, the FCC ruled that the introduction of E-911 be carried out in two phases:

- **Phase I.** In the first phase of E-911, it was required to derive a caller's location from the coordinates of the serving cell site from where the emergency call has been made. Typical 2G networks like GSM were designed for cell radii of several tens of kilometers (although in urban areas typical cell radii were in the range hundreds of meters), and hence the accuracy of this location technology was rather poor. In addition, the operators were obligated to forward the caller's telephone number to the PSAP, a feature called *Automatic Number Identification* (ANI) , thereby allowing the PSAP to call back if the call is unintentionally interrupted. Phase I was scheduled to be completed by April 1998.

- **Phase II.** The second phase ruled that the operators be able to locate a caller accurately within 50 to 100 m in 67% and 150 to 300 m in 95% of all emergency calls, depending on the location technology used. As this accuracy standard was hard to meet by the cell-based approach mentioned earlier, complex enhancements on the network infrastructure became necessary. The E-911 mandate required the operators to begin the network enhancements not later than October 2001 and to finish them by December 2005. By this point in time, network operators must meet the aforementioned accuracy standard in their whole coverage area.

While all operators in the United States had no problem in meeting the deadline of Phase I, they were and still are faced with serious problems with the realization of Phase II, and that is why the FCC changed the conditions of Phase II several times and postponed the deadline. One reason for the problem was that many operators decided at a very early stage to implement premature positioning technology. When making the first field trials, it soon became apparent that especially in rural areas the prescribed accuracy standard was missing. As a result, one operator after the other decided to switch to alternative positioning technologies, thereby missing the initial deadline of Phase II, which ruled the starting of network enhancements by October 2001. However, it was common consensus in the meantime that all participants, not only the operators but also the FCC, had dramatically underestimated the complexity of positioning technology, which was very unproven when the FCC issued the E-911 mandate in 1996.

The introduction of enhanced emergency services is also an issue in many other countries. The EU launched activities for *Enhanced 112* (E-112) in 2000 and founded the *Coordination Group on Access to Location Information for Emergency Services* (CGALIES) (see (CGALIES 2002)). The intention of this group is to investigate and prepare for the introduction of location-based emergency services in all countries of the EU and to coordinate investments and implementation details among all actors involved in this initiative. However, the commitments for operators are less restrictive than in the United States. For the time being, the EU has merely issued a recommendation defining several features of E-112, but has neither fixed a schedule for an introduction nor defined any accuracy standards so far. Rather, the operators are required to merely locate emergency callers as accurately as possible. In Asia, the situation is very different. While many countries have not passed any regulatory arrangements so far, in Japan and Korea the counterpart of the American E-911 is expected to go into operation around 2005 or is even already available in some regions.

1.2.2.2 Toll Systems

In many countries, drivers have to pay tolls for using roads, for example, highways and streets in cities as well as tunnels and bridges. It is common practice, for many hundreds or even thousands of years, as long as people have to pay tolls anyhow, that the access to chargeable roads is controlled by the local staff on the spot and that the toll has to be paid to this staff either directly before or after passing the road. Many countries are still practicing this approach. Alternatively, in some countries the drivers have to buy vignettes that are valid for a certain duration of time, usually a month or a year. While the former approach causes horrible congestions on the roads, which is bad as the traffic volume is permanently increasing, the vignette suffers from the fact that a driver cannot be charged depending on the covered distance.

To cope with these problems, many countries have launched activities that aim at recording the usage of roads and collecting tolls electronically. Some systems developed so far require that each vehicle is equipped with an OBU, which exchanges data over the air with fixed control stations located along the roads. The data transfer is usually based on infrared or microwave and happens exactly at the moment a vehicle passes a control station. In other systems, control stations take a picture of passing vehicles and electronically analyze the license plate number by image recognition.

Unfortunately, each country having installed such a system or planning to do so has followed its own design decisions, and that is why often the systems of different countries are incompatible with each other, that is, OBUs cannot be deployed across national boundaries. Even the EU, which usually leaves out no efforts to harmonize everything (ranging from the size of eggs and tomatoes to more fundamental aspects such as a common currency) has not managed to coordinate the toll activities in its member states. As a result, Italy, Austria, Germany, and the United Kingdom, to name only a few, are building up or just operating proprietary systems. Nevertheless, the EU has recognized this necessity and founded a coordination group that prepares a stepwise migration path from existing systems toward a common, Europe-wide toll system, which, however, is expected to go into operation not before 2007.

While Austria has successfully launched its toll system in 2004, Germany experienced massive problems a year prior to this while trying to establish such a system for charging trucks on highways. In contrast to Austria, where the system works on the basis of microwaves as described earlier, the German government favored a satellite-based system: the OBU in a truck detects the usage of highways via GPS and determines the covered distance. The resulting data is then passed for billing purposes to a toll center via a public GSM network. In addition, hundreds of control bridges were installed on German highways in order to take pictures of trucks without OBUs for analyzing their license plate numbers. When the system was to be launched in August 2003, it turned out that the 210,000 OBUs that had just been installed in trucks suffered from profound defects. Because this was only one of many flaws, the system could not go into operation before January 2005, but even when it became operational, it had only a reduced functional range.

1.3 LBS Actors

LBSs are an interorganizational matter. Many actors are participating in the operational and nonoperational realization of LBSs. Generally, an *actor* is here defined as an autonomous entity like a person, a company, or an organization. An actor adopts one or several roles, which characterize either the functions it fulfills from a technical point of view or the impacts it exerts on LBSs from an economical or regulatory point of view. Accordingly, the roles listed in Figure 1.2 are classified into operational and nonoperational roles.

The operational actors are represented by the roles of the LBS provider, the user, the target, the network operator, the position originator, the location provider, and the content provider. Actors operating in these roles are cooperating during the execution of an LBS and request or provide subservices of the LBS. Each of them maintains a technical infrastructure ranging from single mobile devices (users and targets) to server farms (LBS, location, and content providers) and large-scale, complex cellular networks (network operators). The interaction between these roles during service operation happens over reference points consisting of protocols and connectivity services offered by various networks. Often, the technical realization of reference points is determined by *Service Level Agreements* (SLAs), which are adopted between the participating actors for fixing quality of service and accounting conditions.

Apart from a few exceptions, nonoperational actors are not engaged in the technical operation of LBSs. Rather, they have an indirect impact in that they dictate the economical or regulatory circumstances of LBS operation or influence it by the definition and adoption of technical standards. For example, trade and commerce may be interested in utilizing LBS technologies for mobile marketing and may authorize developers or service providers for creating adequate applications, and the automobile industry is specifically interested in furnishing their vehicles with appliances for navigation and fleet management. On the other hand, the government may have a direct influence in that it strictly regulates the utilization of location data by law, either for saving the privacy of individuals or vice versa, for purposes of lawful interception. Furthermore, the appearance of LBSs also strongly depends on the availability of standards from the responsible standardization committees, and on the acceptance and adoption of these standards by the vendors of network infrastructure.

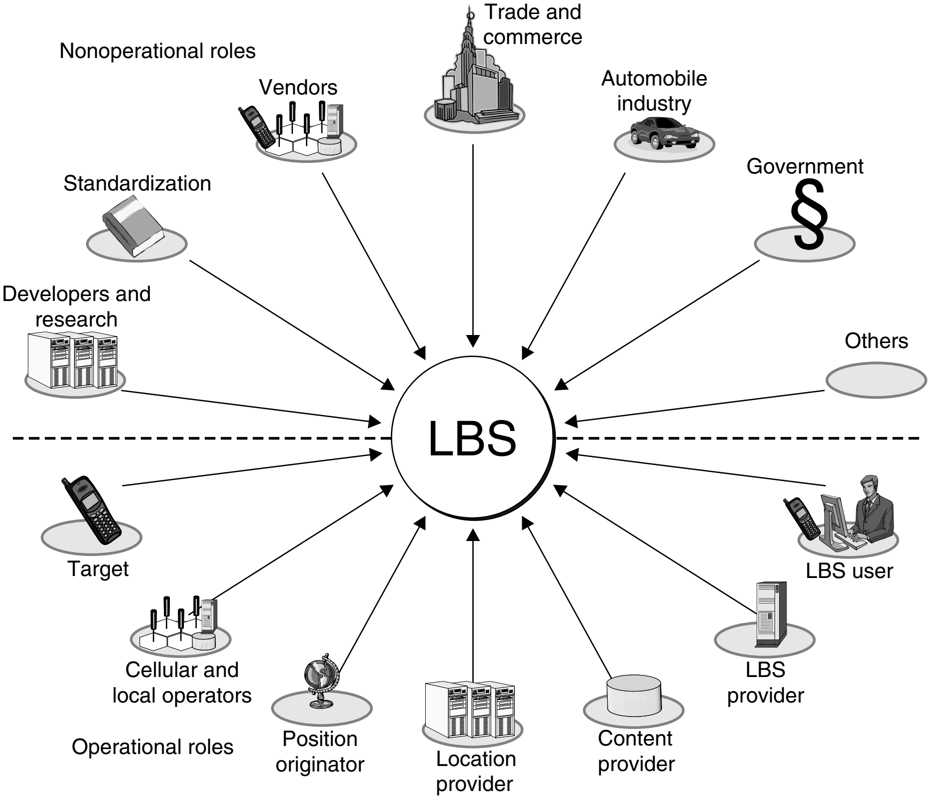

Figure 1.2 Roles for LBSs.

Finally, it should be mentioned that operational actors also affect nonoperational aspects, which especially holds for network operators, and significantly decide about success or failure of a certain technology.

Apart from standardization committees (which will be presented in the next section), the focus of this book is on the operational actors. In later chapters, their interaction will be explained by means of a supply chain, and the corresponding subservices, APIs, and protocols will be introduced.

1.4 Standardization

The acceptance and success of LBSs is essentially based on the availability of appropriate standards, which fix the interfaces, protocols, and APIs for supporting the cooperation between the actors introduced before and during LBS operation. Without the existence of standards, these actors would have to communicate over proprietary protocols and technologies, which would prevent competition, open service markets, and success of LBSs in general. Standards are considered and adopted by vendors and manufacturers of mobile network equipment and mobile devices as well as by the developers and programmers of applications and services. They guarantee a seamless interworking between equipment and software originating from different sources and in this way enable the use of services that are technically independent of a certain operator or provider. For example, the success of GSM was significantly determined by the possibilities of global roaming between different networks, which would not have been possible without the existence of international standards and their adoption by hundreds of mobile operators worldwide.

The technical realization and appearance of LBSs is mainly determined by the standardization works of the following consortia and committees:

- **3GPP and 3GPP2.** The *3rd Generation Partnership Project* (3GPP) is an international collaboration of several national standards bodies and focuses on the production of technical recommendations and reports for GSM and UMTS (3GPP Web site). In the context of LBSs, the work of 3GPP is of major relevance for positioning technologies in and with cellular networks and related location services. 3GPP specifications are continually being enhanced with new features. These enhancements are structured and coordinated according to *releases*. Today's GSM/UMTS networks are mainly operated on the basis of Releases 98 and 99, while work on Releases 4, 5, and 6 is still in progress. If not otherwise stated, descriptions in this book refer to Releases 99, 4, and 5. The *3rd Generation Partnership Project 2* (3GPP2) is a similar collaboration (3GPP2 Web site). It consists of North American and Asian standards bodies and deals with the specification of cdma2000 networks and related technologies.

- **OMA and Parlay.** The *Open Mobile Alliance* (OMA) and the *Parlay group* are collaborations of mobile operators, device and network manufacturers, information technology companies, and content providers (see (OMA Web site) and (Parlay Group Web site)). Their aim is less on the development of network solutions, but rather on the delivery of technical specifications for application-level and service frameworks. OMA is primarily concerned with the creation of end-consumer platforms like WAP or the emerging push-to-talk services, while Parlay develops open APIs for enabling third party service providers to access network functions of operators. Both groups support the development of LBS applications by providing protocols and APIs for the exchange of location data between different actors.

- **IETF and W3C.** In the past, the development of LBSs was primarily motivated by the telecommunications sector. However, with increasing mergers of classical telecommunications and Internet-based services, the necessity for supporting location-related technologies has also been recognized by consortia like the *Internet Engineering Task Force* (IETF) and the *World Wide Web Consortium* (W3C) (see (IETF Web site) and (W3C Web site)). These groups develop solutions that form the basis for specifications of the consortia mentioned earlier and specify special protocols for integration of location data into Internet or Web-based applications.

- **OGC.** The *Open Geospatial Consortium* (OGC) focuses on the specification of open standards for geospatial and location-based applications (OGC Web site). It is developing a broad range of standards for location languages, the transformation between different formats of location representation, the support of spatial databases and Geographic Information Systems (GIS), and middleware solutions for supporting the rapid creation and deployment of LBSs.

The specifications and standards produced by these consortia will be extensively covered and explained throughout this book.

1.5 Structure of this Book

This book is organized into three parts, thereby covering the diverse demands and interests of different target groups of readers like students and lecturers, professionals as well as developers.

The first part deals with the basic fundamentals the LBS operation relies on. It starts with an overview of different categories of location information in Chapter 2. A special focus of this chapter is on spatial reference systems, including coordinate systems, datums, and map projections, which are of importance for interpreting the results of positioning methods and for the processing of location information. The latter aspect is then covered in Chapter 3, which gives an insight into the principles and working of spatial databases and GISs. They are used for relating the positions and locations of target persons with geographic content, for example, in order to compose routing information or to find nearby points of interests. The chapter explains the underlying data models and shows how to represent spatial objects and topological relationships and how to query them. Chapter 4 explains the fundamentals of wireless communications, which are required for understanding the principles behind positioning in later chapters. It provides an overview of the basics of radio signals, introduces their representation in the frequency and time domain, and shows how to transfer data over a wireless link by the use of modulation and demodulation. Furthermore, the chapter describes the different phenomena radio signals are exposed to during their propagation, and finally gives an overview of multiplexing and multiple access schemes. The last chapter of the first part gives a general introduction into the working of cellular networks and location management.

The second part of the book is dedicated to positioning. Because it is a very complex matter and can be realized in several ways and by numerous, very different methods and systems, this part starts with an introduction to the fundamental aspects of positioning in Chapter 6. This chapter at first identifies the parameters measured during positioning, the general procedures, as well as the required infrastructures, and provides a scheme for classifying positioning methods according to different criteria. Subsequently, it introduces the basic positioning methods, which are proximity sensing, lateration, angulation, dead reckoning, and pattern matching. Finally, the chapter concludes with an overview of range measurements as needed for lateration and of error sources that may affect the accuracy of position fixes. The following chapters then deal with the implementation of positioning in the different systems. Chapter 7 introduces positioning by satellites, including the Global Positioning System (GPS), Differential GPS, and the future Galileo system. Chapter 8 explains positioning in and with cellular networks and covers the methods standardized by 3GPP for GSM and UMTS networks, among them Enhanced Observed Time Difference (E-OTD), Uplink Time Difference of Arrival (U-TDoA), and Observed Time Difference of Arrival (OTDoA). Furthermore, it illustrates how to increase accuracy and reduce latency of GPS by support of GSM/UMTS signaling, which is referred to as Assisted GPS, and provides an overview of positioning methods in cdmaOne and cdma2000 networks. The chapter concludes with a comparison of the cellular methods presented. Finally, Chapter 9 concludes the second part with an overview of positioning in indoor environments, including WLAN fingerprinting, RFID technology, and GPS indoor receiver technology.

The third part covers the operation of LBSs. Chapter 10 highlights interorganizational matters in that it identifies the different roles of actors participating in LBS operation and presents different scenarios of their interaction along a supply chain. After that, the chapter gives an overview of different querying and reporting strategies for exchanging location information between these actors. Of important concern when realizing interorganizational LBSs is the privacy protection of individuals, for which the chapter introduces the concepts of privacy policies and anonymization. Chapter 11 then deals with the concrete realization of the general concepts presented earlier. It highlights the working of location services in GSM and UMTS networks and explains different approaches and protocols for gathering location data and making it accessible for an LBS. A special focus is on the realization of emergency services, which is demonstrated by means of E-911 from the United States. Chapter 12 deals with middleware concepts for supporting the rapid creation and deployment of LBSs. As there is a lack of corresponding implementations and products in this field, it identifies at first the basic requirements and demands of an LBS middleware, and then presents available specifications and discusses their pros and cons. Finally, the third part and the book conclude with an outlook for the next generation of LBSs in Chapter 13.