MUGGES

D1.2: STATE OF THE ART ANALYSIS

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1. EXECUTIVE SUMMARY

The MUGGES project proposes the usage of GNSS Technology as a driver of the Mobile User-Generated social service paradigm, which represents a very clear current trend of business innovation. The MUGGES project will develop the basic components and market-ready MUGGES applications, also called mugglets, in order to enable the provision, remote discovery and access of information from a mobile device to a mobile device, by means of the "location" attribute of context as key service and content characterization.

A full evaluation of the components and business models brought forward by MUGGES, i.e. social mobile location-aware user-generated services, will be carried out through a trial. This trial will remain open after the project ends, providing a long-term behavioural assessment on the adoption of the GNSS-based Technology for the proposed mobile exploitation scenarios, where location clearly adds value. The subsequent analysis of the data will provide valuable information for the widespread deployment of this innovative type of mobile GNSS-based solutions in Europe in further steps [1].

The final goal of MUGGES project is to design and trial the deployment of a set of new innovative social location-aware mobile *user-generated services* using GNSS-based "intelligent tagging" as the key driver for widespread adoption. MUGGES will definitely contribute to the GALILEO objectives by demonstrating that there is a great mass market potential for Location Based Services in Europe and that the technology is mature enough to deliver real benefits to users [1].

The project Task 1.2 "State of the Art Analysis" is one of the tasks within the first work package "User Needs Analysis" (WP1). WP1 serves as a common starting point for the project and its goal is to establish the foundations of the project, focusing on the definition of the use cases and scenarios, business models and system and trial architecture. The Task 1.2 aims to describe and analyze the different approaches to user created Location Based Services, focusing on user-created services initiatives and location-based mobile services. In this task an assessment of the current state of technology regarding positioning is also elaborated with special emphasis on integration of heterogeneous location models and semantic positioning [1].

Task 1.1 and Task 1.2 serve as a starting point for WP1 and accordingly for the MUGGES project. These tasks are accomplished from scratch without taking into account any other task and their outcomes are the input for task 1.3 and 1.4 so that the results from task 1.2 will be used for the definition of the overall system architecture in Task 1.3 and for the development of the possible business models in task 1.4.

The present deliverable is broken down into the following chapters:

- Chapter 2: This chapter introduces the document to the reader.
- Chapter 3: This chapter includes a description of Location Based Services from a general point of view, focusing on the different types of LBS, what the players involved in LBS are and finally analyzing the necessary components for the use of a LBS.
- Chapter 4: This chapter deals with user created services by describing the different types and components. Furthermore, the importance of context in this kind of services and their lifecycle is analysed at the end of the present chapter.
- Chapter 5: This part of the deliverable is focused on physical/geometric location and presents an elaborated state of the art analysis and a comparison about different positioning technologies by gathering these technologies in three main points, i.e. indoor location methods, Network based location methods and GNSS technologies.

- Chapter 6: This chapter is about semantic location. Nowadays, location information can be represented not only using a coordinate reference system but combining that geometric representation with location descriptions.
- Chapter 7: The purpose of this chapter is to outline and describe the standards and protocols regarding positioning and location from a general point of view. Another purpose to this chapter is to integrate the existing protocols.
- Chapter 8: This chapter includes a brief explanation about the influences and links between MUGGES project and a set of projects whose outcomes can be used as an input for the development of MUGGES project.
- Chapter 9: This final chapter reports the conclusions inferred from the results of the previous chapters for the general architecture and for the development of business models.

2. INTRODUCTION

This document “State of the Art Analysis” summarizes the work done in Task 1.2 for the analysis of different technologies and approaches to user-created location-based services. The main objective of this task is to establish the basis, the necessary background which will be used to define the overall system architecture and to determine the possible business models that arise from that background.

The structure of the document is divided in two main parts. The first part consists of an analysis of the Location Based Services in two different ways: from a general point of view and focusing on user-created services. The second main part of the document tackles the different positioning technologies definition and description with special emphasis on integration between different location models and semantic positioning in order to ease future MUGGES architecture definition.

Finally, the main results of the overall analysis done during the Task 1.2 are presented. This chapter will give guidelines for next tasks.

3. LOCATION BASED SERVICES

During the last years, mobile phones and the Internet have revolutionized the ways of communication between people. Thanks to the great number of mobile phones and the mobile infrastructures improvement people are able to access the Internet and consequently a huge amount of contents, wherever they are and whenever they want.

That huge amount of contents should be managed by using different kinds of criteria in such a way that end-user only receives the suitable information which he needs in a concrete instant. For example, somebody is in a business trip and wants to have a dinner in a restaurant. This person decides to use the mobile phone to access to internet and search information about restaurants. A useful approach to prevent that one gets as search result every restaurant website on the city could be to restrict the search by filtering the result adding a search criteria. For example, a good criterion could be to filter the results according to restaurant position with respect to where the mobile user is located or the actual time regarding the opening times of a restaurant or a special kind of restaurant (Indian, Chinese, Spanish…)

Such kind of restaurant search concerning position, time and personal preferences could be done by using a Location Based Service (LBS). That kind of services provides the possibility of a two way communication and interaction due to the user delivering to the service provider his/her actual context, i.e. the kind of information s/he needs, his/her preferences and his/her position in order to help the provider of such services to deliver useful information to the user. Therefore, if location information is combined with content there are different ways to create useful services.

Location Based Services are made up from the following concepts [3]:

- Position → "40°24'49.32"N - 3°41'31.79"O"

Position is represented in the form of spatial coordinates. Position can be portrayed like a single dot in the Cartesian coordinate.

- Location → "Madrid, Paseo del Prado"

Location is associated with a certain place in the real world. The spatial coordinates are mapped onto a descriptive location in order to be interpretable by the user, namely, location information is used in a more human way.

- LoCation Service (LCS) → "Where am I?"

LCS deals with the target localization and also makes the resulting location data available to external actors. LCS is responsible for the generation and delivery of location data.

By taking into account the previous concepts, a Location Based Service can be defined as the service that adds value to target locations provided by LCS. It uses knowledge of a mobile device's location to offer value to the mobile subscriber or to a third party. As a summary, Location Based Services 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 for adding value to the service [2].

3.1. NATURE OF LBS

Location Based Services are business and consumer services that provide users a set of services which are based on geographic location of the client or the service provider depending on the kind of service. Through Location Based Services, users will be capable of knowing their own position, as well as finding other people, places, vehicles and resources. The request for location can be originated from the service consumer himself or from another entity such as the service provider or the network. Anyway and in order to have access to location information, whenever location is requested, the access to location information should be allowed either by the service consumer or by the service provider depending on where the data location which will be used by the service may be found, i.e., the consumer or the provider has to give permission for the location request in order to allow his position to be known.

Most Location Based Services are based on two main actions:

- Obtaining the location of a user.
- Using this information to provide a service.

As stated above, in any case, this information will be used as a filter in order to provide the users the right contents taking into account their position. Location information also can be used as a pointer in order to depict the user position on a map. Finally, location information will be sometimes used like a launcher initiating different kinds of alarms or services when the target is out of a defined area or when the target reaches a specific area. In other cases, Location Based Services can originate from the client himself in order to satisfy location based requests such as information needs, finding point of interest or people. In short, there are two mechanisms for initiating Location Based Services: automatic and manual.

One of the main purposes of MUGGES project is to reach mass markets using that kind of services based on location, thus the interoperability between operators both at national and international level is required.

3.2. TYPES OF LBS

This section presents a description of the existing different types of LBS. Location Based Services can be classified according to three basic types of LBS considering if information is delivered on user interaction or not: pull, push and tracking services [4].

1) Pull Services: This kind of Location Based Services is characterized because the consumer is the one who makes by himself a request for LBS, i.e., pull services deliver information directly requested from the user. By means of that request, the user gives permission for his/her position to be given because without that location information the request for service can not be completed.

   An example of a pull service could be the following: somebody arrives in a city and s/he would like to know the local weather forecast for the next days. Instead of surfing the Web to search for weather forecast, s/he decides to use a service which is installed on her/his mobile phone menu. When the service is executed by just pressing a button on the device, the user sends a request for local weather forecast. In order to offer weather forecast, the service provider has to know where the request was made. Once user’s location information is known somehow, the service provider will send as a reply a forecast for the area where the user is located.

2) Push Services: The main difference between pull services and push services is that in the push services case, the request for LBS is not made by the consumer but by the service provider, i.e., push services deliver information which is either not or indirectly requested by the user. In that case it is necessary that the consumer gives permission for the service provider to send information to his mobile phone.

   Push services can be activated by an event, which could be triggered when the user enters in a specific area, or triggered by a timer. For example, imagine that the same service than in the previous type of LBS is available on a mobile phone but in this case the user decides to set up a task for requesting local weather forecast every day at 10:00 am. That means the service provider needs to know the position of the user every day at the time of service request in order to deliver the right local weather forecast according to the area where user is located. For the right running of the service, it is necessary that the consumer allows the service provider to access the location information every morning at 10:00 am.

3) Tracking Services: these are the third basic type of Location Based Services. Tracking services are related to the idea of knowing the position of a person who previously has given the necessary permissions which allow services to track him.

   As an example, in this case imagine three friends who are interested in football. One day, they decide to support their favourite team by going to see a game and they decide to meet at the gate X one hour before the game begins. All of them are subscribed to a service which allows them to keep in touch and therefore it means that every one of them has given permission to be tracked by the others. One of them arrives early to the gate and decides to run the tracking service. This service will show on a map the position of each friend and it will be useful in order to know where the other friends are.

3.3. PLAYERS IN LBS

This section presents an overall view of the players who are involved in Location Based Services from a general perspective and not focusing on MUGGES players. If a user wants to use a Location Based Services, the involvement of many different parties will be required in order to provide the complete service. In the following figure the players who take part in Location Based Services are depicted.

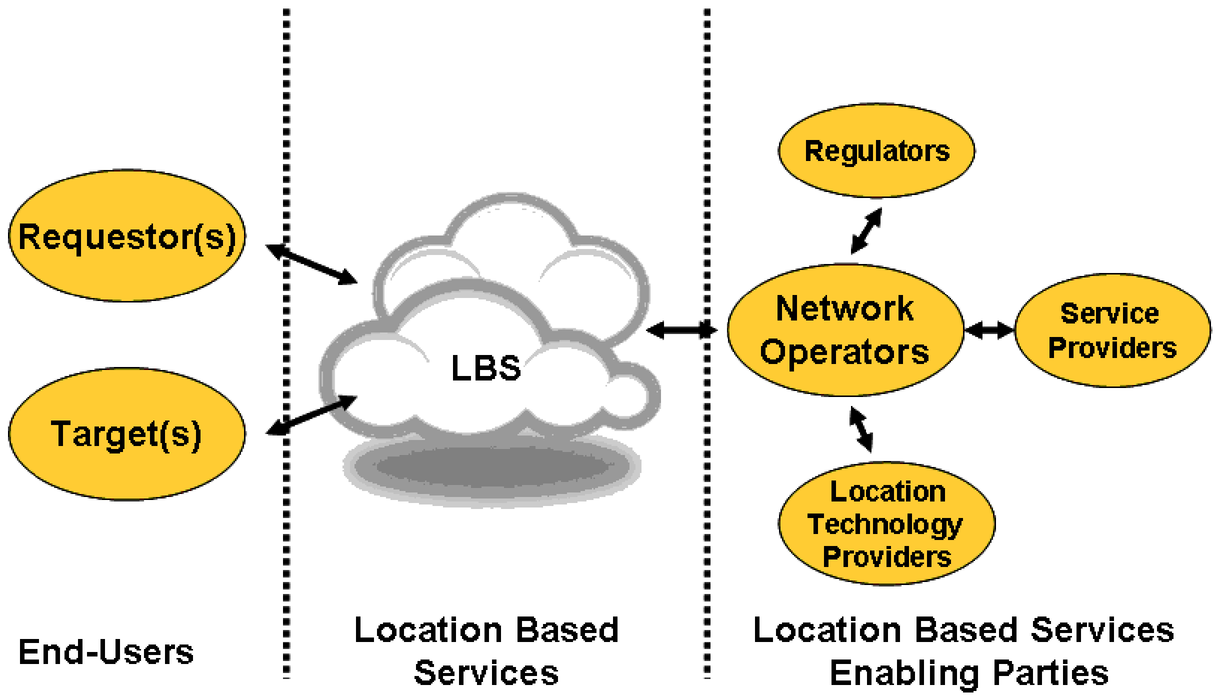

Figure 3.1 - Players in LBS

The figure above is composed of three different parts: End-Users, Location Based Services Enabling Parties and Location Based Services which are in the middle of the two previous parts.

- End-Users are divided in two different categories: The first one, Target(s) are End-Users whose position is requested by someone else or by some service. The second categories, Requestor(s) are those who are requesting the position of some service that they would like to use or some person. The End-User can play the both roles at the same time.
- Location Based Services are end-to-end specific products and applications.
- Location Based Services Enabling Parties are a set of players who make possible to create Location Based Services. From a high level, these players are divided into four categories called: Location Technology Providers (LTP), Network Operators (NO), Regulators (REG) and Service Providers (SP).

- Location Technology Providers are the manufacturers of different hardware and software components which enable to know positioning of a wide range of devices. Some of the positioning systems require specific capabilities both within the mobile terminal and within the network.
- Network Operators are companies that support infrastructure for GSM, GPRS, and UMTS… telecommunications. They are the only agent which is able to effectively position the user by network based methods. That is the reason why their main purpose and responsibility is to protect their subscriber from the wrong use of his/her positioning data.
- Regulators set up laws, regulations …, which give guidelines how Location Based Services can be implemented and used. According to Network Operators main purpose, the most important issue is likely to be privacy, so European Union regulations concerning privacy will need to be followed.
- Service Providers sometimes create and provide Location Based Services which will be used through Network Operators. SPs are the companies that implement service logic and user interfaces between Location Based Services and Network Operators systems. Inside MUGGES, service provider's role will be played by end-users, thus service provision will be carried out by end-users in such a way that an end-user can consume and provide a service at the same time.

3.4. LBS COMPONENTS

Once the different players required in Location Based Services have been described from a high level, this section presents a set of infrastructure elements which are necessary if a user wants to use a Location Based Service [4].

- Mobile Devices will be a user device for requesting the needed information in a straightforward manner. Mobile devices will deliver the information to users through different ways such as using pictures, by speech, text and so on. Nowadays, many devices are available and can be used, e.g. PDAs, Mobile Phones, Laptops … but the device can also be a navigation unit of a car or a toll box for road pricing in a truck.
- Communication Network: The second component is the mobile network which transfers user data and services request from the mobile terminal to the service provider and then requested information back to the user.
- Positioning Component: For service execution, it is necessary to know either the service consumer or service provider position or both. There are several ways to obtain the user position;

i.e., indoor positioning methods like IR, UWB, 2D Barcode…; network based location methods like GSM, GPRS, UMTS, WiFi… and finally GNSS Technologies like GPS, GALILEO or EGNOS. These technologies will be described from a bird sight in the following sections.

- Service and Application Provider: As described in section 3.3, the service provider caters for a number of different services to the user and is responsible for the service request processing. Such applications offer different services to users like finding a route, searching specific information on object of user interest and so on by taking into account user position.

In the next figure the basic components of a Location Based Service and their connections are shown:

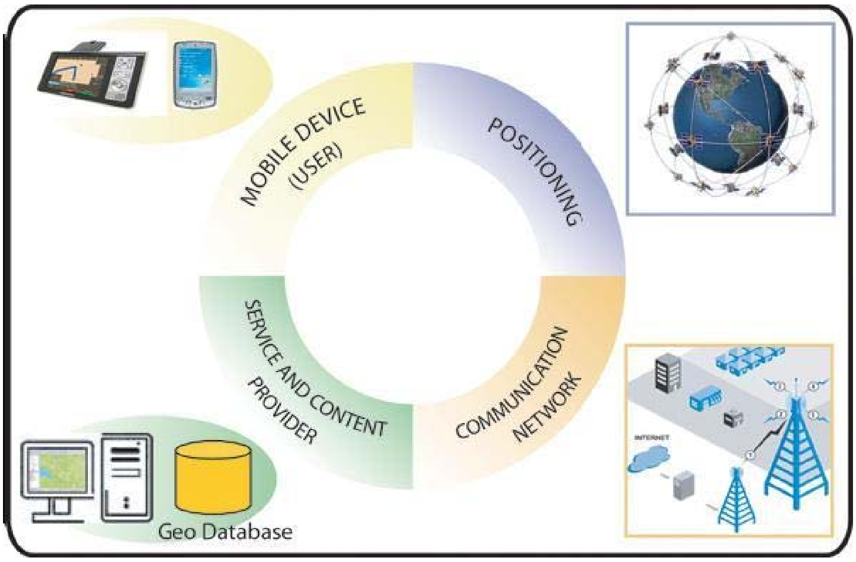

Figure 3.2 - Components of a Location Based Service

In the MUGGES approach, applications or services are targeted to be run on a mobile phone so that a user can both consume and provide a service at the same time. The communication network will transfer service request from the service consumer to the service provider who is located in another mobile device by using positioning components for the processing of the service.

4. USER-CREATED SERVICES

Section 4 provides the issues that influence on user-created services. A special kind of user-created services are user-created location based services. The nature of user-created services in Section 4.1 and types of user created service environments with application examples in Section 4.2. Furthermore, general components for user-created services are presented with STOF (Service, Technological, Organizational, and Financial components) model in Section 4.3. The importance of context in user-created services is outlined in Section 4.4. Finally, the lifecycle of user created services is provided in Section 4.5.

4.1. NATURE

Web 2.0 and Mobile Web 2.0 technologies and services emphases the user as the content creator at the point of inspiration [5]. The user becomes the centre of the service while Internet becomes the platform for developing and delivering services, usually through mixture of functionalities (mashups) and content (syndication) from different Internet Players [6]. The shift in market happens when the actors can contribute both as consumers and providers of telecommunication and Web based services. Therefore, the term “prosumer” refers to actors who assume the roles of service consumer and service provider at the same time. [7]

One of the most interesting developments of user-created services is services that utilize location information and mobility of the user. Travelling can be enhanced with social networking and consumer-generated content. For example, user can create tags to highlight the areas of interest in addition to serve as starting points for future searches and tags. Thereby, a ‘tag cloud’ is created. Folksonomy users can discover tags - created by other users - which may be relevant to them also. [8]

User-generated content (UGC) and user-created content (UCC) are sometimes used equally to describe diverse content produced by end-users. There are at least three ways to perceive users’ contributions to mobile content [9]:

1) Users can create content directly
    - picture, video footage etc.
2) Users can add creativity or explicit value to pre-existing content
    - contributing to a blog, geo-tagging content, meta-data relevant to mobile content usage etc.
3) Content can be the indirect result of mobile social interaction
    - profile in a mobile dating platform, micro-blog message etc.

The user-created content is usually reserved for the first and a part of the second case. However, content can result from the aggregation of users’ interaction. Content that may arise through any of the processes mentioned is denoted as mobile user-generated content (instead of the mobile user-created content). The concept of user-generated content can be examined from the view of the application evolution. The blurred boundaries between content and applications can be noted from that the applications have begun to include content as a core or additional feature to engage users (in order to increase value). Therefore, a number of successful examples of Web 2.0 use a mix of application and content (Flickr, MySpace, YouTube, del.icio.us, etc.), and it is not easy to tell where the application ends and where the content begins. As a result, “user-generated content” also usefully describes content involved in mobile social networks based on applications [10]. In summary, user-generated content is considered here as a broader concept since user-created content does not include the indirect result of, or by-product, of mobile social interaction.

The shift from user-created content to user-created services is a subtle one. Internet's social media sites are blooming with user-created content. Griffiths (2007) [10] describe these sites as prosumer sites. Sites such as YouTube (www.youtube.com) and Flickr (www.flickr.com) offer user-created videos and pictures. One could argue that third-party made applications in Facebook are user-created services, on the other hand the difficulty of creating such applications is a barrier for a common everyday-user and most successful applications are professional-made and thus not really user-made. Blogging-sites like Blogger (www.blogger.com) offer a platform for users to create their own content and services.

The revenue model for these user-created content and services is mostly based on the offered advertisements, for example, by Google's Adwords (adwords.google.com) that is a service that can provide money for developers of great services and popular content. Adwords is a very successful platform and its revenue was 21.8 billion USD in 2008 (http://investor.google.com/fin_data.html)

Third party applications are the new wave for social media sites. Facebook has led the way by offering a platform for creating applications for it. Third party applications make the social media platform richer and it allows it to have more content that the social media site could ever dream to make by itself. The third party applications are now offered by Twitter (www.twitter.com) and several other social media sites.

4.2. TYPES

This section provides examples of different types of service creation environments. The focus is on mobile and web-based user created services. User-centric service creation environments allow end-users to create, manage and share their own, personalized services that fit their needs better. They support fast development and supply of innovative services which benefit actors involved. The end-users can create their own personalized services, whereas the platform provider reduces development expenses by fulfilling the customers' expectations. The provider can obtain a profit from the use of its own services and percentage of the profit from services created by end-users. Combining user-centric environments and social networks can be beneficial in terms of spread of the service: viral marketing and recommended services by other users. [11] Some examples of service creation environments are: m:Ciudad, SPICE, SPRING, OPUCE, PLASTIC and Mscape. More information on state of the art in service description technologies can be found in m:Ciudad deliverable 2.1 [12].

4.2.1. m:Ciudad

m:Ciudad is a service architecture, a set of mobile tools and a platform to allow users to create focused knowledge-based mobile micro-services. Micro services description defined in m:Ciudad project are the following [12]:

1) They are created by users, or more precisely they are simple enough to be created by users
2) They are created on the go, on a mobile device
3) They are provided (and executed) on a mobile terminal

These services are also called as U+ services. The m:Ciudad Service Description Language addresses these requirements. These are some application scenarios defined in the project as microservices [13]:

- *Traffic Jam Killer:* users publish their location, time and speed at given intervals during their car trip. The service can use sensors.
- *CoolClub:* users publish their location, time and a comment on the night club they are at. This is an example of My Likes service.
- *My Big Brother:* a user publishes personal details like location at a given time, status and some personal contents at rather regular intervals.
- *Collections and Personal Advertisement:* users store collections of things on the move of particular interest. MyCollections can be for example: My Services, My Games, and My Personal Data.

Other examples include: MyAgents (e. g. Shopping Assistant) and Authoring (e. g. mBlog).

4.2.2. SPICE

The *SPICE (Service Platform for Innovative Communication Environment)* project researches, prototypes, and evaluates the architecture and framework for rapid creation and deployment of intelligent and personalized mobile communications and information services, life-cycle management, context-awareness and multi-modality [14].

4.2.3. SPRING

The *SPRING (Service platform for Reconfigurable and Intelligent services in Next Generation mobile communication)* is designed with focus on user-centric and the service oriented paradigm. The functions supported are context awareness, service mobility, service adaptation, identity management, profile management, platform federation and security. Examples of these next generation (NG) mobile services are: *U-emergency rescue, U-shopping, U-healthcare, U-tour and U-learning*. [15]

4.2.4. OPUCE

The *OPUCE (Open Platform for User-centric service Creation and Execution)* allows users to create, manage and use their own telecom-based services in an Internet style. The main elements of the OPUCE architecture are: service creation environment, context awareness, user information management, subscription management, service lifecycle manager and service execution environment. [16]

4.2.5. PLASTIC

The *PLASTIC* (*Providing Lightweight and Adaptable Service Technology for Pervasive Information and Communication)* platform helps application designers to optimize and improve the development processes and the quality of services running in heterogeneous networking environments. The platform has a set of applications designed for e-Health, e-Learning, e-Voting and e-Business. The platform has the following functions: behavioural modelling, software development, middleware usage and validation tools. [17]

4.2.6. Mscape

Mediascapes connect the landscape of people's everyday environment with digital content and services. A publishing platform (http://www.mscapers.com) developed by Hewlett Packard Labs allows people to share and distribute mediascapes via a Web portal. A mediascape is a context-aware multimedia experience which allows users to trigger multimedia content based on their context, for example physical locations. Users can employ sensors to provide context and trigger multimedia, including sensors, infrared (IR) beacons, radio frequency identification (RFID) tags, motion sensors, heart rates, and other biomonitors. [18]

4.3. COMPONENTS

The mobile business domain includes the following components: service component, technological component, organizational component, and financial component. Bouwman et al. (2008) [19] refer this model as STOF approach. *Service component* describes the value proposition (added value of a service offering) and the market segment at which the offering is aimed. *Technological component* describes the technical functionality required to realize the service offering. *Organizational component* describes the structure of the multi-actor value network required to create and distribute the service offering and to describe the focal firm's position within the value network *Financial component* describes the way a value network intends to generate revenues from a particular service and how the way risks, investments and revenues are divided among the various actors in a value network. [20]

In the MUGGES project the service component can be seen as the element that gives added value for the users. The technological component is described as the design of the architecture framework for user created services. The organizational component includes all the actors which participate in this MUGGES network. The financial component deals with the outline of a revenue model for user-created services. These components are presented in the following sections.

4.3.1. Service component

Targeting includes defining the customer and his or her needs. The user base should be able to be differentiated, for example to professional communities and disabled users. Value-creating elements of personalization and context awareness for the end-user have to be evaluated. The context-aware services have to compete for the users' time and money; ease-of-use is a must for context-aware services. For example, replicating the service in other geographical areas or focusing on purely technological side may be useless.

4.3.2. Technological component

Personalization technologies like presence awareness and multi-modality technology are technological enablers for the development of innovative context-aware services. The advanced technology platforms need the integration of identity, personalization, intellectual property rights, payment, and trust management systems. The personalization can happen centralized as traditionally or it can take place in end-user terminal because of better usability, response time and privacy. Privacy and trust issues should be considered high because the users allow others to know their context to a certain extent (influenced by different cultures, contexts and situations).

4.3.3. Organizational component

Division of roles predicts the role of different value network actors like telecom operators or IT companies in the emerging context-aware mobile services value network. With the emergence of context-aware mobile services, mobile services value networks can become more complex with a greater number of new value network actors like micro payment providers, aggregators and privacy and trust providers. All actors of the network should find their own niche to be able to deliver and capture value.

4.3.4. Financial component

Pricing for future mobile data service is challenging. Comparing to Internet services, many of the content-based services are free. Division of costs and revenues in the mobile value network can be covered for example by advertising (more focused, personalized and contextualized) or by revenues from content consumption (subscription-based and transaction-based). Dealing with multiple revenue models is a design issue.

4.4. IMPORTANCE OF CONTEXT IN USER-CREATED SERVICES

According to Dey (2001) [21],"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, including the user and applications themselves." Ceri et al. (2007) [22] define context more combined with information technology: Context is any information that can be used to characterize the interaction of a user with a software system (and vice-versa) and the environment where such interaction occurs.

A system is context-aware, if it uses context either for delivering content, or for performing system adaptations, or for doing both [22]. A system is context-aware if it uses context to provide relevant information and/or services to the user, where relevancy depends on the user's task [21]. Context-aware services differ from traditional information services; they are time-critical and context can change quickly. These applications that use context information must be adaptable for changes. [23]

Context-aware services combine mobility, proactiveness and user-centric approach. The applications exploit context to adapt the timing, quality and functionality to the users' situation and resource availability. Examples of context in mobile applications are: user activity, geo-location, GSM cell ID, speed and direction, battery power, idle time, available networks, favourite places, and method of transportation. [24] The goal of context-aware service is to provide the user with the right service at the right time. The service should support the user without too much interaction with a computing device (e. g. mobile phone, PDA). [20]

While local content (location-tagged content) surrounds the mobile user with geographical position (coordinates); the context-aware content blends characteristics from surrounding environment with the mobile personal profile, or from what the person is engaged at the time. The latter can help users to make better choices and to find content that are more suited to them. "Reality mining" and "augmented reality" describe this phenomenon. [9]

A context-aware mobile service adapts to the current situation of the user as well as it should self-adapt (or be adapted) to changes of the context. [25] The self-adaption can be here classified to two possibilities: behavioural and structural. The behavioural self-adaption changes the way an application behaves due changing context, but it does not affect to the actual composition of the application (e. g. increase of volume when playing a certain song). However, the structural self-adaptation has ability of the application to reconfigure the composition of the application (e. g. changing software or protocol components). [26]

With user-created services, the metadata and parameters required for context recognition and reasoning must be provided and mastered by the user. Therefore, context metadata and context information presentation must be easily accessible and simple to use. Simple and well packaged context recognition algorithms are needed to make context awareness accessible and feasible for end users.

4.5. LIFECYCLE OF USER CREATED SERVICES

User-centric service creation enables end-users to create their own services and manage the lifecycle of those services autonomously. This user-centric based service ecosystem requires more flexibility and dynamicity in managing service lifecycle compared to current service management systems. A minimum set of activities a service goes through in a telecom platforms are creation, deployment, maintenance, and withdrawal. [16]

The requirements for the lifecycle management of user generated services are:

1. Users are allowed to decide when and for how long their services must be available (i. e. the lifecycle schedule)
2. Users are able to provision base services and platforms automatically as well as they can register and publish new services in order to be available to other end-users

According to component-based methodology, a service is composed of several connected components. A component is a piece of software that performs a specific function. Components can be optional or mandatory for the service, based on the definition made by the service creator. In addition, the creator cans specify alternative versions of the same component while each version uses different amount of resources. Therefore, using a component oriented methodology enables developing several versions of the same service, each version fitting with the available resources of different devices. [25]

5. PHYSICAL/GEOMETRIC LOCATION

Location is one of the most important concepts in the MUGGES project but, as a general notion, it can be related to several different technologies. This section estabilishes a relationship between the different technologies while describing a short state-of-the-art on location systems. The analysis is broken down into three main points: indoor location methods, network based location methods and GNSS Technologies.

5.1. CRITERIA FOR CLASSIFICATION OF POSITIONING TECHNOLOGIES

An increase in mobile devices' availability and users' mobility has raised the need for location-aware computing. Thus, there is an incremental importance in geospatial data to assist users to accomplish many every day tasks. Nevertheless, methods and characteristics used to measure location can be described through diverse properties. Following sections describe those properties and methods.

5.1.1. Location sensing properties

Location sensing technologies can use metrics to classify a location sensing system. Thus, to determine how well a location sensing system works three metrics can be used, as seen in table 5.1 [50]:

Metric	Definition
Precision	Determined by how well the mobile terminal and/or listener can detect the boundary between two spaces.
Granularity	The smallest possible size for a spatial location such that boundaries can be detected with a high precision degree.
Accuracy	Used to calibrate individual base stations and/or beacons and mobile terminals and/or listeners; it is the degree to which the distance from a beacon, estimated by a listener, matches the true distance.
Latency	Latency is the amount of time since a dimension is measured until the signal is processed. Latency is always envolved in electronical systems and it may cause noticeable delays.

Table 5.1 – Location Sensing Metrics

Precision is the degree to which further measurements or calculations will show the same or similar results. In other words, precision is the ability of a measurement to be consistently reproduced. Figure 5.1 illustrates a high level of precision comparing to a low level of accuracy.

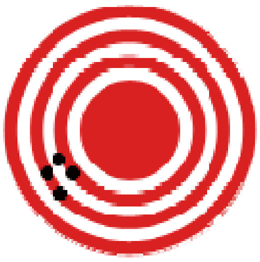

Figure 5.1 - High precision and low accuracy

Granularity is related to the precision of the location sensing system. It quantifies the noise associated with each sensing location system. All trackers are limited in granularity by a quantification unit. Mainly, all technologies are limited by the size of measured technology, namely a quantum of light, or the wavelength of ultrasound wave. However, at the application level the granularity considered is much larger than the limiting quantification considered.

Accuracy is a measure of the absolute error of either position or orientation in the reference system used. Additionally, accuracy provides estimations of position and orientation using noise measurements and averaging them. To calculate accuracy, a large number of measurements should have been gathered to yield unbiased estimates of the mean values of the associated distribution for position and orientation. Opposed to the previous figure, Figure 5.2 illustrates a high level of accuracy opposed.

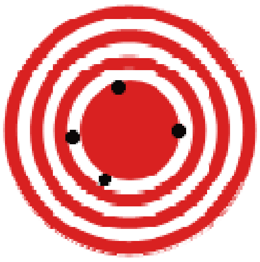

Figure 5.2 - Low precision and high accuracy

Latency, as previously mentioned, is an issue of critical importance. In some systems, virtual information is only generated after proper reception of the signal measurements. This introduces a lag between the moment that an action takes place and the moment that virtual information is shown to the user. This lag involves the establishment of measurements conditions, such as the time to complete the measure before data are available, filtering, signal propagation and transmission times, and synchronization between the location system, the computer and the display.

To solve latency, fusion algorithms, as stated before, are used to estimate where the target object will be based in previous measurements. Moreover, scalability is also an important issue when choosing the sensing technology. Indoor environments require improved accuracy, in comparison with outdoor environments. Indeed, several sensing technologies are suitable for indoor usage but aren't extendable, or can't even be used while outdoors. Scalability is mainly biased by costs in deploying the technology over a larger area.

Therefore, complex algorithms, allowing a seamless transition between technologies used outdoor and indoor, require further research and development, as systems are being scaled and hybrid technologies are being used to surpass the weaknesses of each single technology.

Location sensing can be achieved using three major techniques (see table 5.2) [29]:

Technique	Description
Triangulation	Uses specific measurements from sensors in range to estimate locations. Can be performed using lateration where multiple distances to known points are estimated, or using angulation where angles between known points are used to estimate location;
Proximity	Measures nearness to a point of interest. Can be achieved through physical contact, monitoring, or observation;
Scene analysis	Examines features of interest in the environment.

Table 5.2 – Location Sensing Techniques

Location sensing can be biased by the sensing technology in use, or by the requirements of a specific application. To illustrate the previous sentence, imagine that a location system intends to use radio sensors scenario installed indoor near doorways, then the proximity technique is the technique to use, since neither triangulation nor scene analysis are practical approaches for this problem.

Triangulation uses triangle's geometry to calculate the target object position. Triangulation can be further sub-classified into lateration and angulation. The lateration term is used to mean that distances are being measured. Basically, in 2D three non collinear points and its distances to an unknown point are required to uniquely determine the unknown point. Moreover, in 3D, four non coplanar points and its distances to an unknown point are required to uniquely identify that point. However, previous knowledge of the environment where location sensing is taking place can reduce these requirements.

Distance measurements can be performed using three distinct methods (see table 5.3):

Direct	Involves the usage of physical action to measure distance whether using a rule or, by means of an automatic probe, in a robot context, used by the robot near an obstacle.
TOF	Uses time measurements to determine the travelled distance from the target object to a reference, at known velocity. Several sensing technologies, such as ultrasound, radio or optical systems, take advantage of this method to measure distances. However, optical and radio location sensing systems may require higher time resolution to provide better accuracy, since light and radio travel at higher velocities than sound. Sound waves travel approximately at 344 meters per second in 21ºC air, whether light travels at 299,792,458 meters per second. TOF location sensing also requires methods to synchronize time between the emitter and the receiver. Clocks between all parts involved must be accurately synchronized to allow a greater degree of accuracy. Thus, the receiver and the emitter need some "agreement" methods to synchronize clocks. However, when a round-trip solution is used, only the clock of emitter is used not requiring further improvements in the receiver's clock.
Attenuation	The intensity of emitted signal decreases in the inverse ratio as distance from the emission source increases. This phenomenon is known has attenuation. Given a correct relation between distance and attenuation, for a determined type of emission and emitted signal strength, then it is possible to estimate distance from the emitter and the receiver measuring the received signal strength (RSS). Indoor, attenuation methods may reveal themselves inaccurate, due to multipath factors.

Table 5.3 – Distance Measurements Methods

Angulation measures angles to estimate distances, instead of time as in lateration. Angulation requires knowledge of the distance between two reference points and the measurements of the angles between the vectors defined by known points and an unknown point. Afterwards, the law of sines can be used to find the distance from the unknown point to the vector formed by the two known vectors. Finally, the Pythagorean Theorem can be used to determine the remaining distances.

In three dimensions, one length measurement, one azimuth measurement, and two angle measurements are required to calculate the location of the unknown point. The magnetic north is often used as a reference frame. A practical scenario where angulation can be used requires phased antenna arrays. Multiple antennas with known separations measure the time of arrival of the signal. Afterwards, given the TOA of the signal and the geometry of the receiving array, it is possible to calculate the angle where the emission was originated.

Proximity determines the "nearness" of the target object related to the reference. Three methods are used to sense proximity (see table 5.4):

Detecting physical contact	It's a basic approach to sense proximity. Between the technologies used to sense physical contact are pressure sensors, touch sensors, and capacitive field detectors.
Monitoring wireless cellular access points	This method is also named, cell ID, and determines when a target object is in the range of the reference, namely when a mobile device is in the range of one or more base stations.
Observing automatic ID	This method involves the usage of an automatic identification system such as credit card point-of-sale terminals, computer login histories, land-line phone records, electronic card locks log, and identification

systems	tags.

Table 5.4 – Methods to sense proximity

Furthermore, proximity sensing systems may be combined with identification systems to uniquely identify the target object.

Finally, scene analysis uses features from the scene to determine the location of the observer or the observed objects. Tracked features are chosen so that they can be easily identified. Scene analysis can be further classified in static, or differential.

Static scene analysis matches observed features against a feature database to estimate position. Differential scene analysis tracks differences between different successive scenes to estimate position, or use the tracking of known feature's location to estimate location relative to their position.

Location sensing can be achieved using one or more of these techniques to estimate locations for people, objects, or both. The choice to use each technique is mainly dependent on the sensors being used, and the accuracy needed for a specific application.

Scene analysis or triangulation can supply better accuracy than proximity. However, given the complexity to perform calculations in triangulation or scene analysis, proximity can be a better option making the system simpler and faster.

5.2. ILS POSITIONING METHODS

ILS stands for Indoor Location Services. There are several types of ILS which are analysed by means of the current section.

5.2.1. Infrared-based sensing

Infrared location systems can rely on the infrastructure to locate a user or on the user's mobile device to perform the operation locally. In the first case, the system relies on a periodic, or by demand, emition of an ID from the mobile device which is read by an IR reader in the infrastructure. Afterwards, based on the location of the reader, the identified user is located in space.

The user can also be located within its mobile device; therefore he or she can read the emition of an ID and located the user based on the location of that ID in an internal model. Indoors, the Active Badge was one of the first location systems. The Active Badge system consists of a cellular proximity system that uses diffuse infrared technology. Users have to carry a small infrared badge emitting a globally unique identifier every 10 seconds, or sending the identifier on demand.

Afterwards, a central server collects this data from fixed infrared sensors around the building, aggregates it, and provides an application programming interface for using the data. However, as with any diffuse infrared system, Active Badges have difficulty in locations with fluorescent lighting or direct sunlight because of the spurious infrared emissions these light sources generate.

5.2.2. Ultrasound-based sensing

Acoustic systems use the transmission and sensing of high-frequency sound, emitted around 40 KHz, to sense range. The basis for distance estimation to the target in an acoustic system is the usage of a transmitter/receiver pair, given a known fixed point. To find a 3D point, triangulation can be performed, either from three emitters and one receiver or three receivers and one transmitter.

Indeed, at least three transmitters or three receivers are needed to gather position and orientation. Mainly, two techniques can be used to determine position and orientation:

- Time of Flight (TOF); and
- Phase Coherence.

Both methods use the velocity of sound to convert time into distance measurements. Whether using TOF or Phase Coherence, the inherent delay in waiting for the signal to travel between emitter and receiver is always a drawback, aggravated by the slow speed of sound. At 0º C, the speed of sound in air is 331 m/s. However, sound speed is influenced by temperature and pressure, requiring a new estimation of the relation between time and distance.

The theoretical model for the speed of sound in a gas can be expressed as:

$$speed = \sqrt{\frac{\gamma RT}{M}}$$

γ is the thermodynamic constant of air, R is the ideal gas constant, T is the absolute temperature, and M is the molecular weight. Moreover, acoustic energy diminishes with the square of the distance between the transmitter and the receiver.

In 1968, Sutherland developed a phase coherence ultrasound tracking system. The system used three transmitters, attached to the head of the user, and four receivers, in a grid attached to the ceiling, to track user's head. A continuous wave source was then transmitted, and a computer count major changes in phase to keep track of motions of more than one wavelength [51].

However, phase coherence methods suffer from multipath, similar to radio systems, introducing errors in the system. Walls and objects in a building reflect acoustic signal varying phase and amplitude of the signal, with implications in the user's position calculation. TOF methods overcome the multipath effect, sending signals in intervals and waiting for the first signal to arrive. Since, the speed of sound is slower than radio it is possible to detect the first signal arrived from a direct line of sight (DLOS) and signals resulting from multipath.

Namely, acoustic tracking system can suffer from the following additional problems:

- Omni directional receivers are required in 3D tracking,
- Efficiency of an acoustic receiver is proportional to the active surface;
- Highly resonant receivers affect tracking cycles;
- Ambient noises affect performance;
- The size of the receiver and frequency dependent attenuation of sound in air reduces range;
- Reverberation affects tracking cycles;

Indeed, unconstrained 3D tracking requires omnidirectional receivers, so that the signal can be detected no matter how the emitter is positioned or oriented in the reference space. Thus, to achieve a wide coverage, small speakers and microphones, with active surfaces a few millimeters in diameter, can be deployed in the surrounding space, attached to objects or persons to track. However, the efficiency of an acoustic receiver is proportional to the active surface diameter. A smaller active surface reduces the tracking range.

To overcome the tracking range problem, highly resonant receivers can be used. Nevertheless, usage of such receivers also raises a new problem affecting tracking cycles, due to the shape of the receiving wave. Indeed, the solution to a previously found problem in an acoustic tracking system can raise a new problem requiring a solution.

Namely, acoustic systems can be affected by ambient noises. Thus, higher frequencies can be used; since most ambient noises diminish their impact with increasing frequencies. Moreover, higher frequencies can avoid interference and shorter wavelengths offer higher resolution. However, the size of the receiver and the frequency dependent attenuation of sound in air can also reduce system range [52].

Reverberation is also an important issue. In some environments, tracking cycles have to be delayed due to environment conditions. In conclusion, ultrasound systems performance and accuracy suffer from several restrictions leading to the development of hybrid systems to overcome all mentioned problems. Consequently, Priyantha et al. [53], in the Cricket Location-Support System, combines RF signals and ultrasound hardware.

5.2.3. Inertial sensing

Inertia is the tendency of a body to maintain its state of uniform motion unless acted on by an external unbalanced force. Therefore, the inertial reference frame is a coordinate system where no unbalanced force is applied to a body. This physical phenomenon is explored in inertial sensors to measure acceleration and rotation relative to the inertial reference frame of the earth.

Indeed, the coordinate system of inertial sensors is not inertial, since the earth suffers from changes in acceleration, whether linear or centripetal. However, inertial sensing can be used to estimate absolute position and orientation of an object.

5.2.3.1. Mechanical Gyroscope

Inertial gyroscope is a device for measuring or maintaining orientation, based on the principle of conservation of angular momentum. The device has a spinning wheel on an axle that tends to resist to changes in orientation. The axle of the spinning wheel is defined as the spin axis.

The wheel responds to a force applied about the input axis by a reaction force about the output axis. The 3 axes are perpendicular, and this cross-axis response is the simple essence of the gyroscopic effect, see Figure 5.3 [54].

5.2.3.2. Accelerometers

An accelerometer measures its own linear acceleration. The main specifications for an accelerometer are: single degree of freedom, with some kind of mass; spring-like supporting system; and a frame structure with damping properties. Several technologies are used to implement accelerometers, namely:

- Capacitive
- Piezoelectric
- Piezoresitive
- Hall Effect

- Magnetoresitive
- Heat transfer

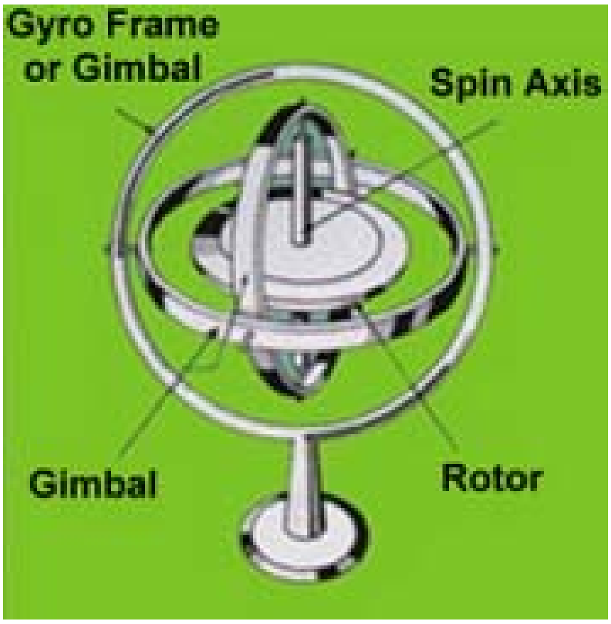

Figure 5.3 - Gyroscope schema.

Capacitive and piezoelectric accelerometers are the most used type of accelerometers. Capacitive accelerometers sense a change in electrical capacitance when acceleration is provided to the system, changing the output of an energized circuit. The sensing elements are two parallel capacitor plates acting in a differential mode. These capacitors operate in a bridge circuit, along with two fixed capacitors, and alter the peak voltage generated by an oscillator when the structure undergoes acceleration. Detection circuits capture the peak voltage, which is then fed to a summing amplifier that processes the final output signal.

Piezoelectric accelerometers take advantage of the piezoelectric effect. The piezoelectric effect is the ability of certain crystals to generate a voltage in response to applied mechanical stress. A piezoelectric crystal has two dipoles where positive and negative charges are symmetrically distributed. When stress is applied to the crystal this symmetry is disturbed and a voltage is generated across the material.

Piezoelectric accelerometers contain a mass between two piezoelectric crystals. When acceleration is provoked in the system the symmetry in the crystals are disturbed, proportionally to the induced acceleration. Thus, it is possible to measure the acceleration knowing the amount of voltage generated in the crystal.

5.2.4. Mechanical sensing

Mechanical sensing involves a direct link between the reference and the target object being tracked. These systems involve a set of articulated linkages interconnected with electromechanical transducers, such as potentiometers or shaft encoders. When some movement is performed the transducers' output reflects the amount of movement performed.

A priori knowledge of the mechanical pieces and associated movement of the mechanical pieces allow the estimation of target object's orientation and position. YDreams developed a Virtual Sightseeing system that employs AR techniques to add virtual information to what the user is seeing. Orientation tracking is performed by mechanical sensing, providing good accuracy results for the AR system [55].

Another project developed by YDreams employing mechanical sensing tracks motion of a fire-fighter, iGarment. In this project, variable resistors are used to measure the angle of body joints of the fire-fighter. Thus, wearable conductive yarns and variable resistors are embedded into the garments. When the shape of a wearable variable resistor changes its resistance also changes. Consequently, by using a direct relation between resistance and the angle of the resistor it is possible to measure the angle of body joints unobtrusively. [56]

5.2.5. Direct-field sensing

Direct-field sensing involves tracking a target through the use of a magnetic-field, magnetic field sensing, or recurring to the inertial reference frame of the earth to track the same object. Direct-field sensing is mainly used for orientation.

5.2.5.1. Magnetic field sensing

Magnetism is one of the phenomena by which materials exert an attractive or repulsive force on other materials. When an electric current is induced in a coil then a magnetic field is generated. If a magnetic field sensor is placed in the vicinity, the magnetic field induces a magnetic flux in the magnetic field sensor, so called magnetic coupling. Afterwards, the magnetic flux can be measured, resulting in a direct relation with the distance of the magnetic field sensor, and its orientation relative to the coil.

Three coils with orthogonal magnetic fields can be used to estimate the position and orientation of a target object. These coils define a spatial reference to be used to track the target object. Afterwards, other three magnetic field sensors are used to measure the components of the magnetic field in the target object position.

Magnetic trackers are inexpensive, lightweight, and compact making them suitable to be used in a wide range of tracking scenarios. However, magnetic trackers have the disadvantage of introducing lag into the system, and can be limited by the attenuation of the signal with distance.

Three types of magnetic trackers can be used for tracking, namely sinusoidal alternating current (AC), pulsed direct current (DC), and Magnetometer/Compass. Sinusoidal alternating current trackers are based on alternating the current feeding the emitting coils. Sinusoidal AC trackers create Eddy currents in the vicinity of metallic objects, distorting the emitted magnetic field, consequently distorting measurements.

Pulsed direct current (DC) use a pulsed constant flux to excite the sensors, in contrast to the alternating current feed of sinusoidal alternating current. However, pulsed DC suffers from the same problem as sinusoidal AC. Nevertheless, it is possible to wait until Eddy currents vanish, introducing a lag. This may be inadequate for some applications.

Finally, the magnetometer/compass measures the magnetic field of the earth to gather the orientation of the target object. Magnetometers include fluxgate, Hall effect, magneto-resistive, and magneto-inductive sensors [57]. With three sensors, the orientation of an object with respect to the magnetic field can be determined. The compass can supply pitch, and the other angular degrees of freedom are measured by other means, for instance by inclinometers. As with other magnetic field sensors there are associated problems with the usage of this technology. Namely, due to the inhomogeneous characteristic of the

Earth's electromagnetic field, feeding angular errors in the orientation measurements. Furthermore, such technology is sensitive to disturbances in the ambient magnetic field.

5.2.6. Radio-based sensing

Radio-frequency identification (RFID) is the use of an object (typically referred to as an RFID tag) applied to or incorporated into a product, animal, or person for the purpose of identification and tracking using radio waves. Some tags can be read from several meters away and beyond the line of sight of the reader.

Most RFID tags contain at least two parts. One is an integrated circuit for storing and processing information, modulating and demodulating a radio-frequency (RF) signal, and other specialized functions. The second is an antenna for receiving and transmitting the signal.

There are generally two types of RFID tags: active RFID tags, which contain a battery and can transmit signals autonomously, and passive RFID tags, which have no battery and require an external source to provoke signal transmission.

RFID technology can be used for location purposes, by using the unique ID of a tag and related it with a location within the world. Additionally, other technologies can also be used to further improve the accuracy provided by the RFID technology. Examples of location systems based in RFID technology can be seen in [31, 32].

ZigBee (IEEE 802.15.4) and Bluetooth (IEEE 802.15.1) are also low power radio technologies that can be used for location purposes. Mainly, for such systems the Received Signal Strength Indicator is used to determine the quality of the communication from one node to another. By tagging vehicles/humans with a ZigBee node or Bluetooth antenna and deploy a number of nodes/antennas at fixed positions in space, the received signal strength indicator can be used to determine the position of tagged object.

Such systems operate by recording and processing signal strength information at multiple base stations positioned to provide information in the area of interest. They can combine Euclidean distance technique with signal strength matrix obtained during offline measurement to determine the location of user. Table 5.5 discusses some characteristics of both technologies.

Technology	Description	Bandwidth	Range	Advantages	Disadvantages
ZigBee (IEEE 802.15.4)	Designed for highly efficient connectivity between small low-power devices.	Up to 250 kbit/s	Up to 76 meters	Up to 76 meter radio range. Low power consumption. Ideal for small household appliances Operates in a free ISM band with a global technology specification. Simple operations	Low data transfer rates
Bluetooth (IEEE 802.15.1)	Revolutionize personal connectivity giving freedom from wired connections –	Up to 2.1 Mbit/s	Up to 100 meters	Low price wireless solution, both voice and data, for short distance. Operates in a free	Only allows for a master and seven slaves in a piconet. Slow discover of

	enabling links between mobile computers, mobile phones, handheld devices, and connectivity to the Internet			ISM band with a global technology specification. Works in stationary and mobile environments. Low power consumption. Uses frequency hopping spread spectrum to minimize interference problems. Up to 100 meters range	neighbor devices. Does not allow for slave-to-slave communications in standard.

Table 5.5 - ZigBee and Bluetooth Overview

5.2.7. 2D Barcode sensing

In the being mobile 2D bar code is a technology that can easily be used within mobile phones or mobile scanners to access location based information. 2D barcodes are often appropriate for indoor and highly urban environments, where they can overcome problems from radio-based technologies, such as the line of sight to the location measurement unit being obscured resulting in inaccurate and unreliable positional information.

2D barcodes can be used to translate an image into a symbol and use that information to access location-based information. Available 2D bar code technologies can be seen in [58]. An implementation of a 2D barcode location system can be found in [59]

5.3. NBL POSITIONING METHODS

NBL stands for Network Based Location. Regarding location-based sensing, location estimation can be performed in the mobile terminal or in the network. Some methods perform location estimation in several steps involving the mobile terminal and the network. Finally, there are location estimation methods that can be performed either in the mobile terminal or in the network, depending on the resources available.

Terminal-based location estimation collects information from one or more sensors and performs all calculations to estimate its location. Sensors can be part of a network, or built-in the terminal. In terminal-based locations systems, privacy is better preserved since the user has full control of the location information. Thus, it is up to his or her decision to forward that information to third party services, namely LBS.

Opposed to terminal-based location methods, there are network-based location methods were no computation is performed in the terminal. All calculations are performed in the network and afterwards delivered to the service requesting for the location. In such cases, privacy issues can be raised since the user has to rely in the network to correctly handle sensitive information, such as his or her location.

Network-based location estimation relies on the infrastructure to perform all operations, thus no transformation is required in the terminal. Mainly, mobile phone operators prefer this approach, since it requires no client-side configuration, modules, or software to allow the network to track mobile terminals. A main disadvantage is the need to deploy and maintain an additional infrastructure for mobile location estimation. When there is a request for accuracy also requiring specialized equipment may be required.

There are also location methods requiring the cooperation between the network and the terminal to estimate location. In such cases, the terminal collects information from sensors. Afterwards, some previous calculations can be performed in the device and the result is sent to the network to estimate the location of the terminal. Finally, to overcome problems in location methods, they can be combined to improve accuracy.

During the research performed in DiWay, a custom radio-based standalone solution was tested. The purposed solution consists of a set of transmitters and one receiver per intervenient. The general purpose of the system is that the intervenient receiver associates media snippets, audio and/or video, to the distance of a given RF transmitter and possibly taking into account the intervenient orientation (here given as it's relative orientation to the Magnetic real North) [61].

Based in Djuknic and Richton [60] classification, Table 5.6 gives an overview of how each location method works and where location estimation is performed.

Network based positioning	Cell ID Based Positioning	Terminal position can be estimated based on current or recent terminal's camping radio cell information. Thus, every cell has a cell ID or cell coverage co-ordinates. Given cell ID or cell coverage, co-ordinates of the fixed known position of base station, terminal position is estimated.
	Round Trip Time (RTT) Based Positioning	RTT can increase cell ID based positioning accuracy. So, RTT is the propagation delay time of the signal traveling from the terminal to the base station and back. Furthermore, calculation of terminal position can be made using RTT measurements of the signal branches from several base stations. Finally, accuracy improves with additional base stations.
	Time of Arrival (TOA) Positioning	TOA calculates position based on the propagation delay of the radio signal from the transmitter to the receiver. So, when there are at least three TOA measurements available, terminal position accuracy can be improved by applying a triangulation technique, minimizing the least square distances between the terminal and corresponding TOA circles. However, TOA has problems with Non-Line-of-Sight, signal fading, reflection and shadowing. So, in measurements, an error margin must be taken into account. In addition, TOA method also requires very accurate base station synchronization.
	Time Difference of Arrival (TDOA) Positioning	Terminal observes TDOA of the radio signals from the neighbouring base stations. Then, unknown terminal position is estimated by processing TDOA measurements between terminal and at least three base stations of known co-ordinates. TDOA terminal measurements are based in two components: TDOA = RTD + GTD Where GTD stands for Geometric Time Difference and is the actual quantity containing information related to the terminal position, since it defines a hyperbola between the two BSs. RTD is the transmission difference between the signals of the neighbouring BSs.

	Angle of Arrival Positioning (AOA)	Terminal position is determined by calculating the intersection of two lines of pilot signal branches, each formed by an angle from the BSs to the mobile terminal. Thus, a single measurement angle forms pairs of lines and provides terminal position. Moreover, when LOS between terminal and two BSs, and measurements of AOA are available, the terminal will be located in the intersection of the lines defined by the angles of arrival. Moreover, in AOA, accuracy can be improved by more than two measurements where Non-Line-of-Sight, reflection, diffraction and cost are obstacles to the development of this approach.
	Multipath Fingerprint	Terminal location is discovered by matching the multipath-produced "fingerprint" of the signal received by one or more base stations with location/fingerprint database. This technique requires continuous database management and updating.
	Timing Advance (TA)	During link establishment terminal aligns its frame/slot times with the serving base station, and uses this as a measure of its distance to base station. So, using network-enforced handoff, at least three measurements with different base stations are made and location is determined via triangulation. Moreover, sequential measurements make the method unreliable when terminal is moving. However, no modifications to handsets and minor changes in base station software are needed.
Network / Mobile station based positioning	Enhanced Forward Link Triangulation (E-FLT)	Solution unique to CDMA, primarily based on TDOA using forward-link signals received by terminal. Performance can be enhanced by complementary methods, including pattern matching of RF characteristics, statistical modelling, round trip delay measurements, and AOA.
Mobile Station based positioning	GPS	A GPS receiver is built-in terminal and works as a standalone device.
	Assisted GPS (A-GPS)	A partial receiver, built in the terminal, is assisted in its function by core network.
	Enhanced Observed Time Difference (E-OTD)	Uses a mathematical algorithm to identify the location of the user based on the time the signal from different base station takes to reach the mobile set. Gathered time signals are then used in a triangulation scheme to determine the approximate area where the caller might be. Requires firmware upgrade in MS.
Composite positioning	TDOA & Received Signal Strength (RSS)	Highly accurate and highly robust methods are combined, and several inputs are used to increase robustness and coverage. A-FLT (Advanced Forward Link Trilateration) and E-FLT are basically the same algorithm. In fact, the main variation is that the former uses the IS-801 standardized message to carry the measurements at the software-upgraded mobile station, and the latter uses the Pilot Strength Measurement Message from TIA/EIA-95 (which was not designed for location but for hand-off purpose) and therefore covers the legacy handsets.
	TDOA & AOA	
	A-FLT & A-GPS	
	E-OTD & A-GPS	
	Reference Node Based (RNBP) Positioning	In RNBP a reference node (movable or fixed) is chosen to provide auxiliary positioning measurements of terminal. Reference node can be a positioning service device, a GPS receiver or any device with known position, which can be used as a reference point when determining terminals position. RNBP can be used with any positioning method. Enhancements by using RBNP came from utilizing additional reference devices in the network.

Table 5.6 - Positioning methods

Network-based location systems are not specially designed for indoor or outdoor usage; they base their functionalities in network domains with radio cells. In fact, mobile positioning importance was foreseen for future cellular systems. Thus, usage of position assistance data allows for advanced location based services and radio system performance optimization.

To illustrate, commercial location based applications are being used in several areas like fleet management, buddy finder, traffic information management, transportation, nearest services, emergency services and follow me services. Additionally, location information can be used for network performance optimization, improving network performance through an optimized planning process.

Consequently, mobile cellular terminals (Mte) can use several positioning methods. Some of the most use positioning methods are [60, 62]:

- Cell ID based positioning
- Round-Trip Time (RTT) based positioning
- Time-of-Arrival (TOA) positioning
- Time Difference of Arrival (TDOA) positioning
- Angle of Arrival (AOA) positioning
- Multipath Fingerprinting
- Timing Advance (TA)
- Enhanced Forward Link Triangulation (E-FLT)
- Reference Node Based Positioning (RNBP)
- GPS
- Assisted GPS (A-GPS)

5.3.1. UMTS specific positioning methods

UMTS networks may supply:

- Cell ID based positioning
- Observed Time Difference of Arrival (OTDOA) positioning
- Assisted GPS positioning

These methods may be network based, network based and mobile assisted or mobile-based and network assisted. The main difference is where calculations take place. Cell ID based method maps a cell ID into a corresponding Service Area Identifier, where Cell ID is seen as an internal reference, not be seen outside the core network. In Observed Time of Arrival-Idle Period Down Link (OTDOA-IPDL), the terminal uses idle periods of the serving BS to measure the signals of neighboring BSs, therefore estimating distance to each one and calculating its location.

In the last mentioned method, assisted GPS can overcome problems found in conventional GPS solutions, achieving higher location accuracy and reasonable costs. In such cases, mobile phones are assisted by the network over the air-interface, whilst determining their own location. This distributed approach leads to a better performance than conventional GPS.

In fact, wireless network will use its own GPS receivers, as well as an estimate of the mobile's location down to cell/sector, to predict GPS signal that the mobile phone will receive and send that information to mobile phone. This assistance allows for a great reduction of search space and time-to-first-fix (TTFF) is reduced from a minute to a second or less. Additionally, assisted GPS receivers in the handset can detect and demodulate signals that are weaker than those required by conventional GPS receivers.

In more detail, assisted GPS is divided in two subcategories: terminal based and terminal assisted. In terminal based position calculation, the network sends assisted GPS data to terminal including:

- Measurements assistance data, like GPS reference time, visible satellite list, satellite signal Doppler and code phase search window. Valid for 2-4 hours, or 30s when differential GPS is used.
- Assistance data for position calculation, like reference time, reference position, satellite ephemeris and clock corrections. Valid for 4 hours, or 30s when differential GPS is used.

In a terminal assisted position calculation, the terminal has a reduced GPS receiver and just performs pseudo-range measurements. After that, realized measurements are sent to a calculation unit in the network, which carries out the rest of the GPS operation. Djuknic et al. [60] refers that assisted GPS is accurate within 50 meters while users are indoor and 15 meters while users are outdoor.

5.4. GNSS TECHNOLOGIES

Global Navigation Satellite System (GNSS) is the standard generic term for satellite navigation systems that provide autonomous geo-spatial positioning with global coverage. GNSS allows small electronic receivers to determine their location (longitude, latitude, and altitude) to within a few metres using time signals transmitted along a line-of-sight by radio from satellites. Receivers on the ground with a fixed position can also be used to calculate the precise time as a reference for scientific experiments.

As of 2009, the United States NAVSTAR Global Positioning System (GPS) is the only fully operational GNSS. The Russian GLONASS is a GNSS in the process of being restored to full operation. China has indicated it will expand its regional Beidou navigation system into the global COMPASS navigation system by 2015. The European Union's Galileo positioning system is a GNSS in initial deployment phase, scheduled to be operational in 2013.

GNSS have also been enhanced to supply further accuracy and integrity monitoring usable for civil monitoring. The first phase of GNSS enhancement is GNSS-1, combined GPS and GLONASS, through Satellite Based Augmentation Systems (SBAS) or Ground Based Augmentation Systems (GBAS). In the United States, the satellite based component is the Wide Area Augmentation System (WAAS), in Europe it is the European Geostationary Navigation Overlay Service (EGNOS), and in Japan it is the Multi-Functional Satellite Augmentation System (MSAS). Ground based augmentation is provided by systems like the Local Area Augmentation System (LAAS).

5.4.1. Differences between WAAS, EGNOS and MSAS

All three systems are essentially equal and compatible to each other. Nevertheless, WAAS is maintained by North America, EGNOS (European Geostationary Navigation Overlay Service) is maintained by the European community and MSAS (Multi-Functional Satellite Augmentation System) is developed by Japan and other Asiatic countries.

While WAAS is operational (IOC = Initial Operational Capability) since January 2003, the EGNOS system made some huge steps forward during 2002 but is still in pre operation. The development of the MSAS system had a major drawback in 1999 after the first of two satellites planned for the system was lost during launch because of a malfunction of the rocket. The start for the replacement satellite was initially planned for August 2004 but was delayed until further notice to investigate the reasons for the malfunction of the rocket in 1999.

While all systems can be called SBAS (Satellite Based Augmentation Systems), this name is seldom used.

5.4.2. How the SBAS work

5.4.2.1. Infrastructure and Principle of the System

The SBAS shall provide additional accuracy and reliability for the GPS system. To achieve this, a number of GPS receiving stations are necessary. In the US, 25 stations are used; Europe uses 10 stations during the test operation and will have 34 when EGNOS is fully operational. The position of these RIMS (Ranging and Integrity Monitor Stations) must be known very precise. This means that the position of the receiving antenna needs to be known exactly to a few centimetres. The RIMS station receives the standard GPS signal (and also the signal from the Russian GLONASS system and the GALILEO system in future). That way it is possible to calculate the difference between the known position of the station and the position as calculated by the GPS receiver. And since the RIMS use receivers that use both GPS frequencies (L1 and L2), the signal delay through the ionosphere can be calculated for every single satellite.

Additionally, if the signals from more than four satellites are received, more information than needed for a position determination is available and this information may be used to check for possible problems with the satellites or deviations in their orbits or time.

The data from all RIMS are sent to a Central Processing Centre. For the EGNOS test bed (ESTB) this centre is in Toulouse (France) and a backup system is located in Hønefoss (Norway). Once EGNOS is fully operational there will be control centers, called MCC (Mission Control Centre) in Germany (Langen near Frankfurt), Spain (Torrejon near Madrid), Italy (Ciampino near Rome) and Great Britain (Swanwick near London). At these stations, the data will be collected and the following data will be calculated:

- Long term errors of the satellite orbits
- Short term and Long term errors of the satellite clocks
- IONO correction grids
- Integrity information

By use of the integrity information, it is possible to inform the users within 6 seconds on problems that occur with the GPS system. The most important feature of the SBAS for common GPS users is the IONO correction grid. Since SA (selective availability) is deactivated, the largest single source of error in GPS position determination is the signal delay in the ionosphere. Being able to correct these errors significantly increases the accuracy of every GPS receiver that is able to process WAAS/EGNOS data.

From the measured data of the RIMS, a ‘map’ of the Total Electron Content (TEC) in the ionosphere for the area covered by the RIMS station is calculated. With decreased accuracy the area where the TEC map is calculated can even be expanded further.

This TEC map is now transmitted to a geostationary satellite that itself acts like a GPS satellite, that means can be used for position determination but also provides the receiver with the information it needs for the correction of the ionospheric effects.

For the EGNOS test system (ESTB) from Aussaguel (near Toulouse in France) data is transmitted to INMARSAT AOR-E and from Fucino (Italy) to INMARSAT IOR. Later when EGNOS is fully operational, data will be sent from Aussaguel and Goonhilly (Great Britain) to AOR-E and from Fucine and Goonhilly to IOR-F5. From the stations Torrejon (Spain) and Scanzano (Italy) data will be transmitted to the satellite Artemis.

The satellite Artemis had an interesting history when in January 2003 it finally arrived at its designated position. After problems with the fourth stage of the Ariane-5 rocket after the launch in July 2001, Artemis had almost to be abandoned but the engineers managed to "walk" the satellite to its planned position by making extensive use of its newly developed ion propulsion system.

The geostationary satellites do provide signals very similar to that of the GPS-satellites and on the same frequency. Therefore these satellites may be used for position calculation and additionally, the correction data sent out can be used to improve accuracy for position calculation with all GPS satellites.

Using the TEC map transmitted by the geostationary satellites, the GPS receiver can now calculate the 'pierce point' and signal delay of the signal of each satellite used for position calculation and then correct the data for higher accuracy in position determination.

The ionosphere is not static but depends on the sun's activity. For example it is known that single frequency receivers are more accurate shortly after midnight than they are during the day.

The other functions that the SBAS provide like integrity check of the GPS system and transmission of warnings in case of problems with the system will probably be never evaluated by standard handheld GPS receivers since the calculations are complex and the information is of not much interest to the common GPS user.

5.5. HYBRID SYSTEMS

Individually, each sensing technology has problems, whether its costs to deploy in larger areas, computational power to allow its usage, accuracy, delay in sensor's measurements, and so many other problems previously mentioned. Thus, to improve measurements and system performance, different technologies and different methods can be combined to improve the overall system performance. Hybrid sensing combines several sensing technologies to empower the overall tracking system and reduce weaknesses suffered by each technology.

Moreover, as stated by Rolland et al. [63], the definition needs to be extended to also include systems that use different principles of operation, possibly using the same technology, such as TOF versus Phase Coherence in acoustic systems. It is a fact that hybrid sensing increase the complexity of the sensing system (and possibly its costs); however both technologies can complement themselves, providing access to a wider number of variables that only one technology cannot offer, or provide more exhaustive measurements.

Thus, sensor fusion procedures, involving filtering and predictive techniques, can be use to take advantage of incomplete data sets from sensors. As mentioned previously, tracking systems such as [64, 65, 66, 67, 68, 69], employ sensor fusion techniques to track the target object surpassing the problems of each single technology.

5.5.1. Fusion of tracking sensors information

For location-based services, knowledge of user position is crucial, in order to supply her or him suitable information related to the contextual information [70]. Therefore, factors like user physical position or specific tracking technology variables influence location and orientation estimation, since accuracy of location information can vary dynamically. So, each tracking system reveals problems related to the technology they use: vision-based trackers are computationally intensive, magnetic trackers have low-accuracy and mechanical trackers are cumbersome.

Hence, a combination of several tracking systems, simultaneously or alternatively, will be ideal to exploit strengths and reduce weaknesses of each system. Combining all of them must account for delay, inner and outer interference, and precision of each device. Thus, to combine tracking measurements, polynomial-based predictors, Kalman filters, Particle Filters, and Single-Constraint-At-A-Time (SCAAT) are some of the techniques used to predict and smooth measurements. To summarize, each technique is described in the Table 5-7.

For example, Azuma et al., [34] developed a motion-stabilized AR display for outdoors based in a compass and tilt sensor, a differential GPS receiver and three rate gyroscopes that works both in hand-held and head-worn modes. In this project, sensor fusion is influenced by a SCAAT algorithm [71].

Hightower and Borriello [72] surveyed and categorized tracking systems for ubiquitous computing. They believed that future research should be directed towards goals like: lowering costs, reducing the amount of infrastructure, improving scalability, and creating systems that are more flexible within the taxonomy.

In addition, independent location sensors must be used to effectively combine increasing accuracy and precision of individual techniques. Hightower and Borriello also alleged that ad hoc location sensing could be used to estimate locations, allowing neighboring objects to cooperate with each other by sharing sensor data to factor out overall measurement error. Moreover, in a cluster, ad hoc objects can be located in twofold: located relatively to one another; or absolutely, if at least an object has a known position.

Technique	Description
Polynomial-based predictors	Provide estimates of future values of polynomial-like signals [73]. Thus, if tracking measurements are according to some polynomial expression than future values can be predicted by evaluation of that expression.
Kalman filter	An algorithm that estimates the non-measured states from the other measurements and smoothes measured inputs [74]. Therefore, when a measured state has values very different from previous ones, these values are smoothed, and, in non-measured states, values are predicted from previous states.
Particle Filters	A technique where weights are dynamically attributed to each measured state. The set of states and weights is named a Belief, where weights are attributed based on a location model and measured locations. Thus, the location prediction is biased by the location model and the number of measurements [75]
SCAAT	A technique based in the premise that single observations provide useful information about the user's state, and thus can be used to incrementally improve a previous estimate [71].

Table 5.7 - Fusion algorithms

Finally, latency is another crucial issue in location-based services with high update rates. Several systems use different devices for input and output, although all systems want to diminish relative latency between streams. So, an ideal end-to-end system does not have latency, although it is very difficult to achieve. Consequently, several techniques can be used to reduce latency. Jacobs et al. [76], describes latency in augmented reality systems.

5.6. COMPARISION OF TECHNOLOGIES

5.6.1. Hardware comparison

Comparing technologies must regard to different parameters, namely:

- Consumption
- Hardware Size
- Cost
- Development Cost (time consumption/human resources)
- Success of detection
- False detection ratio
- Precision
- Accuracy
- Acceptance

Different comparisons have been created targeting combinations of listed variables. Hazas et al. [37] have performed a survey over current location technologies, relating accuracy with user's acceptance. Figure 5.4 shows the current and predicted deployment of location-sensing technologies. GPS is the selected solution while outdoor. Vehicle location applications uses GPS for location purposes, namely route planning and fleet tracking, as well as applications integrated into handheld GPS units. Nevertheless, radio-based technologies are becoming of interest for location purposes since more and more of such technologies are becoming integrated into current mobile devices.

Apart from that, accurate systems are mainly deployed in research labs lacking user general acceptance, also reducing their integration into more general location applications. Another interesting aspect is the adoption of RFID for tracking and location purposes, mainly for assets rather than locating users.

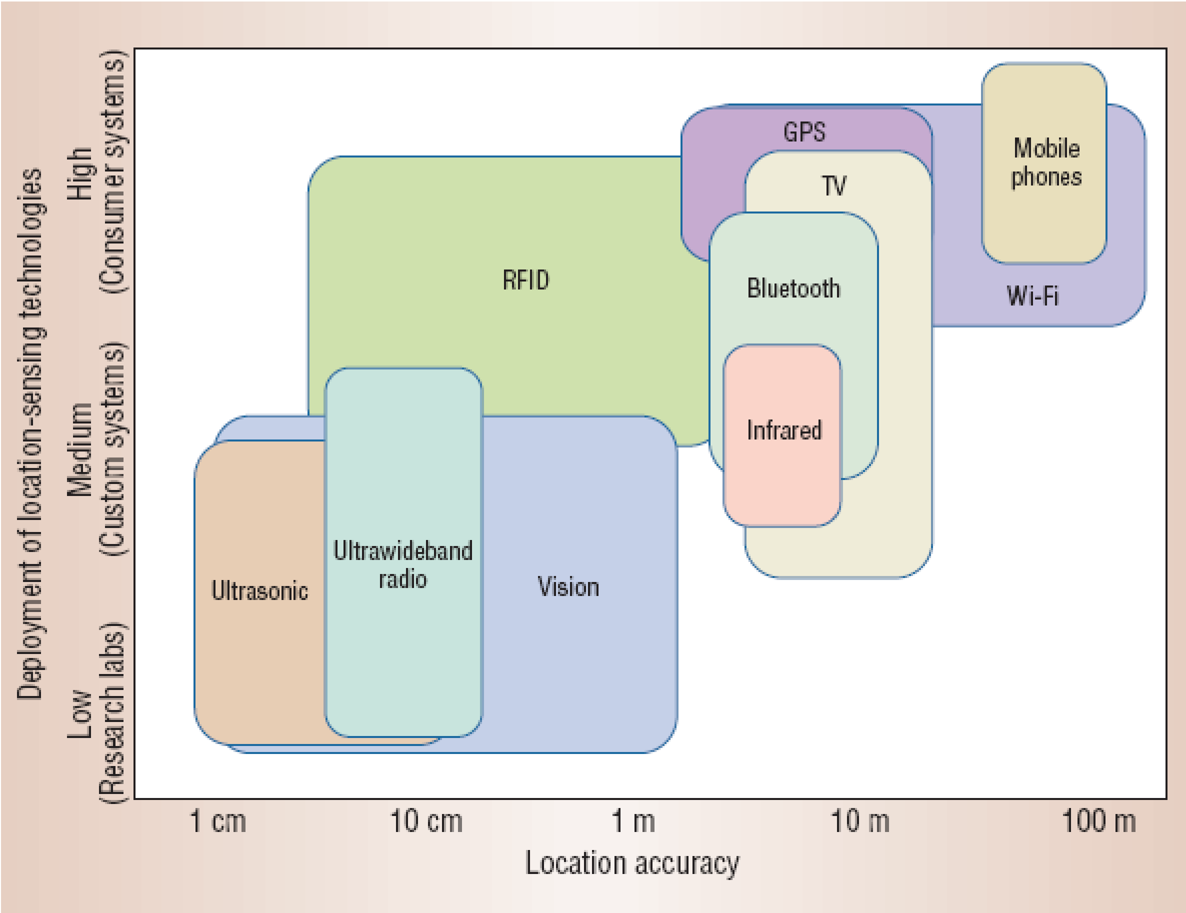

Figure 5.4 - Location-sensing technologies

Broonstra et al. [38] have also compared several location technologies. Accuracy is also addressed within the survey, also focusing in the required modifications to support the technology (software and hardware). Technologies were classified according to the location were calculations take place. In the network based mode the handset requires a location; the network calculates the user position and sends it to a service provider. In the handset based mode the positioning is carried out by software on the handset and then sent back to the service provider. Then there is a hybrid class in which the handset and the network work together to position the user. Finally, there is the class where the user manually inputs his/her location. Table 5.8 and Figure 5.5 present and compare different positioning technologies.

Position Technology		Accuracy	Indoor	Software Installation needed on handset	Enabling Costs	User Costs
Network based	1. Operator Cell-ID	250m-5 Km	Yes	No	Moderate	Low
Handset based	2. Cell-ID	250m-x Km (database dependent)	Yes	Yes	Low	Low
	3. GPS	10m-50m	No	Yes	Low	Moderate
	4. Wifi	20m-40m	Yes	Yes	Low	Low

Hybrid	5. A-GPS	10m-50m	Yes/No	Yes	Moderate	Moderate
Manual	6. Manual Input	Street-level	Yes	No	Very Low	Very Low

Table 5.8 - Location sensing overview

It should also be considered that, for continuous tracking, tracing and navigation services, it should be noted that battery life becomes an issue for GPS/Wifi location sensing.

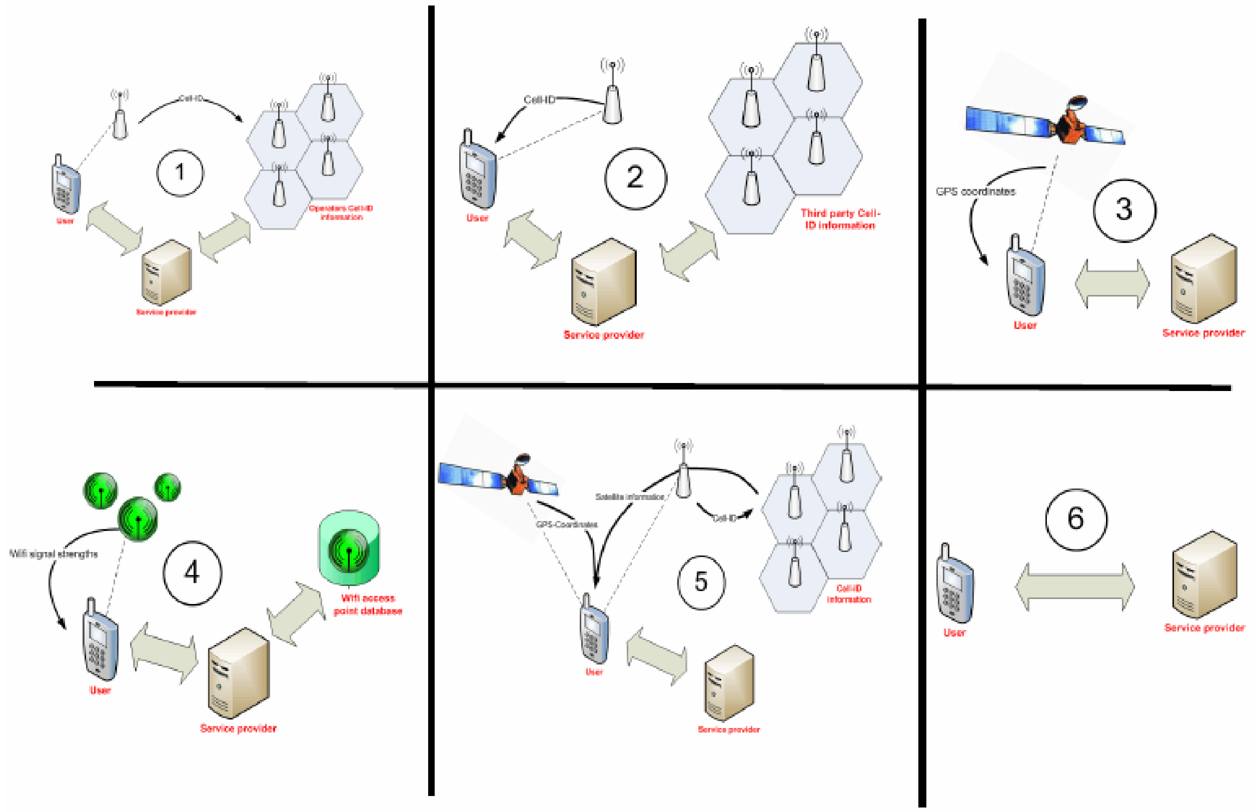

Figure 5.5 - Location sensing description

6. SEMANTIC/SYMBOLIC LOCATION

Location information is usually considered one of the most important pieces of information, regarding context. Nevertheless, location is complex information to model and due to restrictions in location systems, it is usually reduced to a set of coordinates in a determined reference system. How to represent complex spatial relations is a current challenge. As more location sensing devices and systems are available, location models need to evolve to be able to represent more complex situations and location descriptions.

Location information can typically be geometric, symbolic or hybrid. A geometric representation is the simplest one. It uses geometric shapes and a set of coordinate points following a determined reference system. A symbolic representation is usually associated with human-friendly descriptions of the location. Finally, a hybrid representation combines both strategies, where geometric coordinates are related to descriptive labels.

Traditionally, location has been represented either symbolically or geometrically, restricted to one single coordinate reference system. New location models need to be able to use different coordinate systems, even user-defined ones, including relative location representation. Relative representations are particularly useful when the location cannot be exactly defined or when the location information is highly dynamic. Location maps as well can also be represented using hierarchies or graphs, with different levels of granularity, depending on the models used.

There are many approaches in the literature that model location information [37]. Some use geometric location in a multiple coordinate reference systems, based on origin points and axes [40], for example, defining many locations (room, corridor, kitchen) and adding a coordinate reference (x,y,z) inside them. Having the relations between these locations, to change from one reference system to another a mathematical conversion is carried out. Other systems try to represent 3D spaces in what has been called 2.5D, that is, a 2D representation and the height value 41]. In this approach, a 2D polygon is defined and the height value is added to define a 3D model. Several polygons can be combined to define more complex structures. Relative location has also been introduced in some models [42]. Relative location, for example, determines the location as a comparison with a fixed one, for example “a place 100m north from the Town Hall”. Another important aspect when modelling symbolic location is the properties of the representation. If the location is self-contained, it describes precisely an explicit space, which can as well be defined by geometric or symbolic coordinates (“kitchen”, “bank”, [2º 20’ 10’’, 43º 20’ 15’’]). If the location is relative, it is given by the relation of the location of the current entity and another we take as a reference point (“North of …”, “Near ...”). Common relationships between locations are containment (location x “is inside” location y), proximity (location x “is near” location y), connectedness (location x “is connected to” location y), overlapping (location x and location y “overlap”) or even distance (location x “is x km from” location y).

For context-aware and location based applications symbolic representation is more appropriate. The types of symbolic representations can be summarized in [43]: set-based, hierarchical and graph-based. Set-based models are suitable to represent containment and overlapping relations, but the number of sets grows rapidly and the distance between entities is qualitative. Hierarchical models can be seen as a special case of set-based models. These models are more explicit and more intuitive. Besides, hierarchical models are more efficient and more flexible, computationally speaking, because they are based on trees or lattices. While graph-models are suited for representing connections and quantitative distances, containment relationships are harder to define. It also has a limited description level of locations.

A current trend in representing location information is the use of semantic technologies, like OWL [44] or RDF [45]. Any location model can be enriched by the use of semantic information, extending the knowledge about non-spatial features of the locations. Semantic representations are very common in context aware systems, because of the many benefits a semantic representation has. In these kinds of projects, location information is modelled as part of a larger ontology, where it can be easily complemented with additional information.

There is a recent study [46] (available at http://projects.semwebcentral.org/docman/?group_id=84) which analyses several aspects of different ontologies that represent spatial relationships. In this study, three benefits of the use of semantic representations are presented [46]:

- *Annotation*: using classes and properties to represent relevant characteristics of objects.
- *Qualitative Reasoning*: reasoning about spatiotemporal relationships between objects (e.g. containedWithin, connectedTo, During).
- *Information Integration*: facilitate interoperability by mapping other data models to/from common encompassing reference ontology.

Many ontologies are compared in this study (up to 18). Next we reproduce some of the most important aspects found in this study for selected location ontologies:

Cyc

The Cyc ontology is defined by a research community of contributors and intended to represent the “sum of human knowledge.” Cyc’s knowledge base has been created over the past 20 years by hundreds of people. The overall assessment of the Cyc ontologies is that they indeed contain some useful concepts and relations to address the core subjects of geospatial and temporal ontologies. The primary difficulty of using Cyc Ontology is finding the appropriate ontology subsets. This is due in part to the open base of knowledge represented in Cyc, which tends to clutter the ontologies with trivial information and concepts unrelated to a field of interest. The aspects included in this ontology are: Geodesy, Linear Object, Map Projection, Surface Geometry, Terrain, and Topology.

ISO TC 211 Geographic Information Ontologies

The standards approved by ISO Technical Committee 211 define a model of geographic information that is comprehensive and well organized. In 2004, Drexel University represented the ISO standards as written at the time in separate ontologies. The standard schemas from the ISO Geographic Information series of specifications (191xx) considered for incorporation into ontologies, most of which are in OWL, are as follows.

- Conceptual Schema Language (ISO/CD TS 19103:2005): used to build other schemas, not inherently geospatial.
- Spatial Schema (ISO 19107:2003) – spatial geometry for points, lines, curves, surfaces, topology (nodes, edges, faces, solids) and variations on these entities.
- Temporal Schema (ISO 19108:2002) – representation of time (periods, instants, date & time).
- Rules for Application Schema (ISO/ FDIS 19109) – schema definition (associations, constraints, feature types, properties) used to develop application schemas using the general feature model (not inherently geospatial).
- Methodology for Feature Cataloguing (ISO/ FDIS 19110:2005) – feature catalogue (version, registration of features, feature types, attributes, associations).
- Spatial Referencing by Coordinates (ISO 19111:2003) - geodesy, coordinate reference systems, datums.

- Spatial Referencing by Geographic Identifier (ISO 19112:2003) –location identification such as used in a gazetteer (toponyms).
- Metadata (ISO 19115:2003) - metadata elements of a geographic dataset.
- Coverage (ISO 19123:2004) – a specialization of features with a range of attribute values that vary in space or time to provide a grid of data for geometric types (point, surface).

SUMO

The Suggested Upper Merged Ontology (SUMO), developed as one of several candidates for an IEEE Standard Upper Ontology, contains 1,000 classes judged to be of general interest and utility across a wide range of applications. It is accompanied by the MILO Mid-Level Ontology, which adds 1835 classes with additional detail, and a number of domain ontologies (including Geography and Countries and Regions) focused on specific application areas. Some of the pertinent characteristics of SUMO, regarding geospatial classes include Region and TimePosition.

SOUPA

SOUPA (Standard Ontology for Ubiquitous and Pervasive Applications) is an ontology designed to support pervasive computing. It is partitioned into 9 core and 9 extension modules, with owl:imports relations among them. SOUPA is self-contained, with no references to other ontologies.
Geospatial representations in SOUPA are limited. Geo-measurement defines a LocationCoordinates class with latitude, longitude, and altitude datatype properties with range xsd:string. Space defines SpatialThing with such coordinates. Rcc defines RCCSpatialRegion as a subclass of SpatialThing. No other representations involving points, regions, lines, or polygons are provided. SOUPA supports qualitative reasoning. Rcc contains a nice representation of the Region Connection Calculus, using more accessible relation names. Time includes a nice representation of Allen relations.

NSG Data Models

"The National System for Geospatial-Intelligence (NSG) is the combination of technology, policies, capabilities, doctrine, activities, people, data, and communities necessary to produce geospatial intelligence in an integrated, multi-intelligence, multi-domain environment." (NGA Strategic Intent, 2007)
This system is still in various stages of development and integration, but has already produced data models that effectively capture significant geospatial knowledge. One of the most interesting developments of the NSG is the feature catalogue (FC), now called the GEOINT Structure Implementation Profile (GSIP) NSG Application Schema (NAS), which is used to describe and store information about all natural and man-made geographic features.

NASA SWEET

The Semantic Web for Earth and Environmental Terminology (SWEET) ontologies were developed by JPL (Jet Propulsion Laboratory). SWEET 1.0 defines 16 ontologies: Earth Realm, Physical Phenomena, Physical Process, Physical Property, Physical Substance, Sun Realm, Biosphere, Data, Data Center, Human Activity, Material Thing, Numerics, Sensor, Space, Time, and Units. SWEET Space seems to conflate coordinate reference systems and projections.

```
<owl:Class rdf:ID="OceanRegion">
<rdfs:subClassOf>
            <owl:Restriction>
             <owl:onProperty rdf:resource="http://sweet.jpl.nasa.gov/ontology/space.owl#isPartOf" />
             <owl:allValuesFrom rdf:resource="#Ocean" />
            </owl:Restriction>
  </rdfs:subClassOf>
```

```
<rdfs:subClassOf rdf:resource="#TopographicalRegion" />
</owl:Class>
```

Figure 6.1 - Example of SWEET definition of an Ocean Region being a Topographical Region and part of an Ocean

In the context aware world, many other projects reuse some of the ontologies presented before or define its own, like Codamos [47], Conon [48] or Comanto [49], which usually include the location information as a set of classes and properties which apply to the different entities in the system. There are also some attempts to formalize the location and space information in a global ontology which could theoretically be reused in many different applications and scenarios. However, this is not always possible because of the size of these general purpose ontologies or because of special needs an application might have.

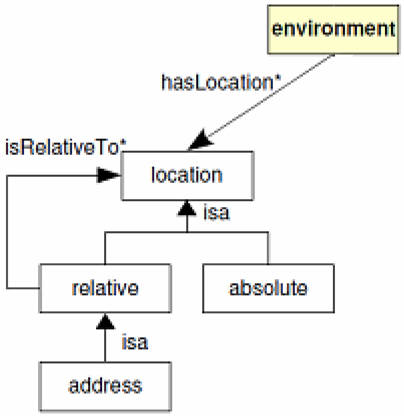

Figure 6.2 - Simplified view of the location ontology in CODAMOS.

In summary, real spaces are complex by nature. It is a good starting point using a predefined ontology or adapting an existing model, but even in this situation, defining a comprehensive location model is always a huge time-consuming effort. Another aspect that must not be forgotten is that location, as part of a more comprehensive model is closely connected with time, which should be analysed as well.

As it has been stated in this section, there exists much previous work regarding the semantic definition of location information. So, taking some of these approaches as a starting point for the MUGGES project is recommend. Here, not only symbolic information is going to play an important role but also relative location. Therefore, considering an ontology like SOUPA or SWEET, both of which include these concepts, can be advantageous in the development of the MUGGES location model.

7. STANDARDS AND PROTOCOLS REGARDING POSITIONING AND LOCATION

Global Positioning Systems are not suitable to establish indoor locations, since their microwaves can be scattered by roofs, walls and other objects. An IPS uses other radio technology, infrared, or ultrasound, to overcome this limitation. Infrared and ultrasound are useful in environments where wireless radio frequencies may interfere with critical equipment.

Through the development of different IPS, different protocols were created to exchange location information. Nevertheless, there is a lack for a common infrastructure and no major enforcement is performed towards integration of existing protocols.

7.1. PROTOCOLS TO EXCHANGE LOCATION INFORMATION

Designing a location system for a single environment presents difficulties when the system is applied to other environments. Depending on the aim of the positioning system, different environments may need to handle different sensor data, whether absolute or relative. This fact raises the need to have a positioning system that successfully bridges the differences between absolute and relative. For instance, without a tracking sensor technology, it is difficult for a person to go to a museum, given its destination position 38º 39' N, 8º 13' W. Accordingly, it will be difficult for a "driver" to know what is the distance to the gas station if the location model is only operating with symbolic names.

Thus, a Bluetooth Special Interest Group (SIG), the Local Positioning Work Group, has worked on the definition of a Local Positioning Profile (LPP) [28] for Bluetooth. In LPP, a set of XML messages, the Local Positioning Messaging Protocol (LPMP), can be used to exchange location information between devices. The location can be latitude and longitude, or additionally a hierarchical message can be exchanged with information about the environment.

In the NEXUS Project, a query language and a modelling language, named Augmented World Query Language (AWQL) and Augmented World Modelling Language (AWML) respectively, were developed to describe the objects in the environment and query the augmented world model [29]. Both languages are defined using XML. In AWML, Objects geometry is described using Geographic Mark-up Language (GML).

AWML models geographic location, geometry of objects and symbolic descriptors of the objects, such as room numbers and relationships between objects. In addition, AWQL allows the querying of the world model for objects holding to certain restrictions. Given these restrictions it is possible to know spatial relationships to other objects, such as: includes, inside, closest, excludes, overlaps and inside. Moreover, these restrictions can be combined with Boolean operators. The querying language also supports generalization and aggregation rules allowing small details to be removed and small objects to be combined into larger objects.

GPX, or (GPS eXchange Format) is a simple and widely used XML Schema designed to standardize the communication of Geo-Referenced data between applications. The main format types are waypoints, tracks and routes and these can have other data attached, such as descriptions and timestamps

The OMA Mobile Location Protocol (MLP) is an application-level protocol for obtaining the position of mobile stations (mobile phones, wireless personal digital assistants and so on) independent of underlying network technology. The MLP serves as the interface between a Location Server and a Location Services (LCS) Client. This specification defines the core set of operations that a Location Server should be able to perform. Basic MLP Services are based on location services defined by 3GPP. The Mobile Location Protocol (MLP) is described in LIF TS 101 Specification [30].

NMEA0183 is a set of standards that encompasses several communication layers and was defined by the North American National Marine Electronics Association. This standard is used for communications between sensing devices. NMEA is defined as a very simple, ASCII-based, serial communication protocol.

7.2. MUGGES AND OTHER PROTOCOLS

The Mobile Location Protocol unveils the work performed in the OMA to achieve a common platform to standardize location information exchange. Nevertheless, consensus hasn't been achieved towards MLP, as well as with LPP from the Bluetooth SIG. New efforts need to be performed to achieve a common platform and perceive common requirements between different platforms.

The performance achieved with a XML-based protocol can be compromised. However, the system can evolve to use a binary approach and achieve a better performance. In future, MLP can be integrated within DiWay given that the architecture of the system and communication protocol can be changed to comply with MLP specification.

8. INFLUENCE OF ONGOING PROJECTS

8.1. M:CIUDAD FP7 PROJECT

m:Ciudad is a project funded under 7^{th} Framework Programme inside “Service and Software Architectures, Infrastructures and Engineering” research area whose final goal is to design and develop a complete new service infrastructure for the mobile super-prosumer. m:Ciudad tackles the definition of the required tools to let each user to become a service provider with a mobile device by providing user-friendly creation tools for the mobile, an optimised execution environment, a model for knowledge warehouse, a proposed specific searching engine and a set of business models for users, for service providers and for third parties, mainly SMEs [27].

M:Ciudad project intends to design the main components for a wide business environment. These components consist of the open micro-service description concept and a general architecture with its associated tools, server and terminal side but they will be just prototype tools / concepts. Thus, m:Ciudad final goal is not to develop a trial but only system tests.

MUGGES project aims to be the continuation of m:Ciudad project because one of the main goals of MUGGES is to test the m:Ciudad idea in the field. In order to achieve this goal, MUGGES project does not intend to develop many new tools but to use and adapt the m:Ciudad tools for the specific MUGGES scenario which is focused on Location-aware micro-services. MUGGES architecture will be defined during task 1.3 but currently a brief description of its elements can be exposed mentioning if these elements will be developed from scratch or will be adapted from m:Ciudad tools. From a bird sight, MUGGES architecture is composed of the following tools:

- MUGGES Kits consist of:
- Mugglets sample applications and templates: these will be completely new in MUGGES.
- Mugglet editor / player: it will be used to edit or modify mugglets templates and to render the mugglet execution to the user. These tools will be an adaptation of the general-purpose creator editor of m:Ciudad.
- MUGGES Execution Environment: it will execute MUGGES applications invoking the necessary service enablers at the terminal side. This tool will be adapted to the mugglets philosophy.
- GNSS & Service Enablers: They will be a set of APIs to access the required service at the required format, from location to communication, in the terminal side. These enablers will be a specific development for MUGGES.
- Terminal Capabilities: These capabilities will be new for location capabilities and the remaining set of capabilities will be reused from m:Ciudad.
- MUGGES Network components:
- MUGGES Warehouse: This module stores templates and manage information about published MUGGES applications. It will be reused from m:Ciudad service warehouse.
- Search Simple Engine: This engine will be used to perform templates and MUGGES applications searching. It will be adapted.

- MUGGES Accounting: This is the module that will be used to the tracking and accounting of the usage of MUGGES applications. It will be developed from scratch due to m:Ciudad will not have this kind of module.

As can be seen in the following figure, MUGGES project is based on m:Ciudad project, hence m:Ciudad and MUGGES work plans are synchronised.

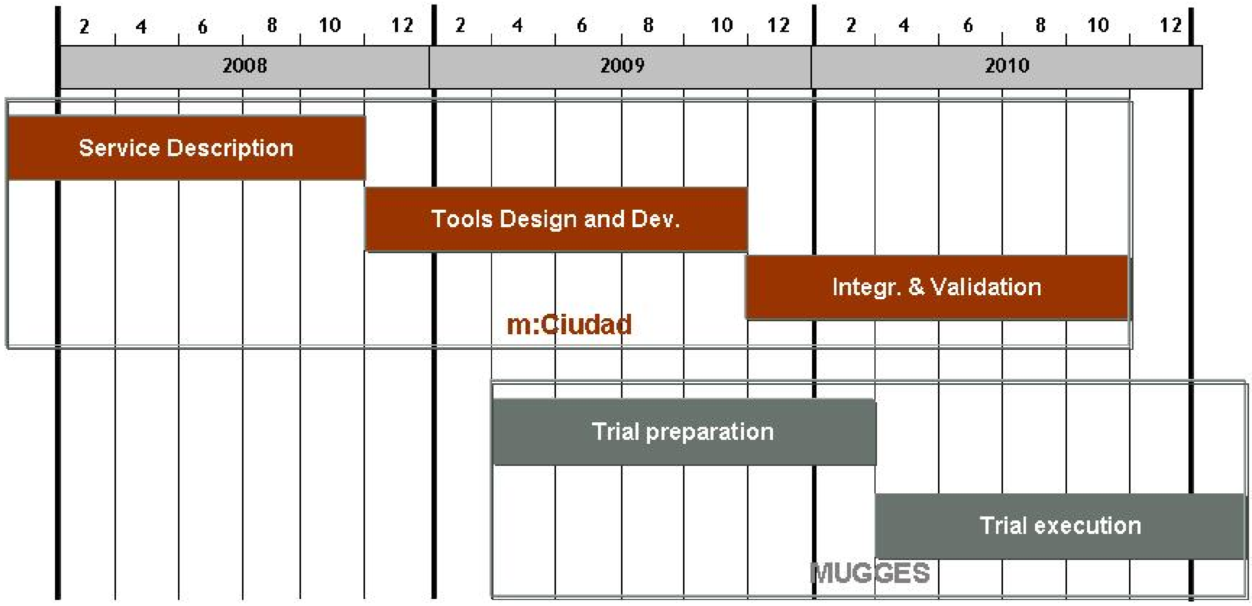

Figure 8.1. MUGGES and m:Ciudad work plans

8.2. AGILE FP6 PROJECT

Application of Galileo *in the Location-Based Services Environment* (AGILE) was a project supported by the Galileo Joint Undertaking with funds from the EU's Sixth Framework Programme. The goal of the project was to address the LBS mass market by focusing on all aspects that may facilitate the acceptance and success of EGNOS and Galileo based solutions from the perspective of delivering profitable business returns. It addressed challenges such as:

- Seamless integration of diverse positioning techniques, namely GPS, network-based and Wifi-based positioning;
- Simulation of application-specific Galileo enhancements
- Assisted GPS technology, etc.

There is little relation between the AGILE project and MUGGES beyond their common focus on Location-Based Services. Specifically, no work will be reused or adapted. The objectives of the MUGGES project are strongly oriented towards the prosumer concept, and its business model possibilities, which clearly differentiate it from the AGILE project.

8.3. DIWAY PROJECT

The main goal of DiWay is to detect places and urban objects in indoor spaces, and providing contextualized services to users. Each service explores the web 2.0 concept. For example, a service Content is deployed exploring the concept of social-networks mixed current location, allowing users to contribute and access content shared between all. Mashups can also be developed combining core services to provide new services.

Another interesting aspect in DiWay is the possibility to navigate in space without a previous mapping of each object in it.

8.4. OTHER RELATED APPLICATIONS

Apart from the previously explained projects, other initiatives are exploring the idea of prosumers and location aware systems, from different points of view. Next we summarize the different aspects of some of the most interesting projects, extracted from the correspondent web sites or publication papers.

CloudMade (http://cloudmade.com/) lets developers create interactive, customised map based applications across web, mobile and desktop platforms. Using CloudMade's rich tools and APIs, developers can build applications that let their users browse maps, plan routes, store their favorite locations, search for places, streets, points of interest and much, much more. All of the map data that CloudMade offer is crowd-sourced - meaning that it is richer and more up-to-date than traditional maps. CloudMade's first sets of developer tools and APIs were launched in February 2009 and are rapidly attracting a community of developers who are building applications on the web and mobile.

Figure 8.2 - m-LOMA concept

The project m-LOMA (http://www.init.hut.fi/research&projects/m-loma/) is a technical demonstrator to study if a realistic 3D map can be implemented on mobile devices with challenging features. The combination of impressive looking and recognizable 3D models and an intuitive user interface makes it a very good alternative to traditional paper maps. This is achieved either by GPS tracking or by simply recognizing the buildings or other landmarks near the user on the 3D map. In addition to this the application offers the possibility to leave messages for other users to read, the chance to read information about restaurants, public transportation etc. The application runs on many different devices including mobile phones, portable computers and personal computers.

Socialight (http://socialight.com) is a mobile phone and web based platform that allows users to create and share location-based messages called StickyShadows. Socialight's mobile and web tools give you access to location-based media on your mobile and on the web. StickyShadows are virtual multimedia sticky notes that you create using your mobile phone or this web site. A StickyShadow is made up of media, such as text and a picture, and information about who can see it and when and where it's available.

Figure 8.3 - Social Light Concept

The idea of overlaying information on top of the real world by tagging and noting real places, while still connected to a social tissue is also the theme of the project Sentient Graffiti (http://www.ctmd.deusto.es/dsg/), which was developed by the University of Deusto. Sentient Graffiti is a proposition for providing a simple, Web 2.0-inspired, globally accessible AmI infrastructure enabling natural interaction (touching, pointing or being close to nearby augmented objects) that simplifies context-aware application creation and deployment. It is a platform which merges the Ubiquitous Web (UW) or Internet of Things (IoT) concepts, where all physical objects are web resources accessible by URIs, providing information and services that enrich users' experiences in their physical context, with Web 2.0, where users accompanied by mobile devices or web browsers can browse, discover, search, annotate and filter surrounding smart objects in the form of web resources.

CITIZEN MEDIA (http://www.ist-citizenmedia.org) is a collaborative research project which unites leading creative and technology experts from across Europe on research, development and validation of A/V systems to enable multiple non-professional users to co-create networked applications and experiences based on their own user-generated content. In this project new ways are investigated on how to exploit the huge amount of user-generated content in innovative ways to support people in their daily lives and how technology will enable social change to strongly involve users for co-creating networked applications. This work will introduce new concepts that may modify the role of stakeholders in the classical value chain for content delivery. To this end, applications, services, systems, infrastructure, technology and architectures are developed based on a user-centric approach. The goal is to enable any user at any location with any device to consume, author and publish his own content towards a networked A/V system.

There are also some interesting concept-ideas, not yet available, such as the Sekai Camera (http://sekaicamera.com/) project. Just point a camera anywhere around to have instant feedback about whatever is on the screen. Directions, reviews, messages, offers, and any tag the user can imagine will appear floating in front of him/her, adding a graphic overlay to the world. Tonchidot, the enterprise behind the idea, defines their Sekai Camera concept as a "social tagging device" for the iPhone. It combines most technologies in the iPhone 3G, from the camera and the GPS to the internet connectivity and its microphone. At that point the user can do two things. One, see information about places and objects around, overlaid on the real-time video. Two, add his/her own information, whether the user is an individual, a business, or any other kind of organization. He/she just point and add a tag, which can include text, images, or sound.

Figure 8.4 - Sekai Camera concept

Other projects were funded in the FP6 program that were somehow related to the user generated content creation and management, being the location an important parameter of the system: DIVAS (http://www.ist-divas.eu/portal), CHORUS (http://www.ist-chorus.org), VISNETII (http://www.visnet-noe.org), VICTORY (http://www.victory-eu.org:8080/victory), CONTENT (http://www.ist-content.org), SAMBA (http://www.ist-samba.eu) and GAMES@LARGE (http://www.gamesatlarge.eu/).

9. CONCLUSIONS

As stated in Annex I [1], the main objective of MUGGES project is to design and develop the necessary basic components in order to deploy a set of new innovative social location-aware mobile user-generated services using the GNSS Technology. Accordingly, one of the key concepts in MUGGES project is the "location".

Deliverables 1.1 and 1.2 are the beginning of MUGGES project for the achievement of the objective stated above. The main intention of the present document was; on the one hand to describe and analyze the different approaches to user-created Location Based Services and on the other hand to survey existing positioning technologies stressing on the integration of heterogeneous location models and semantic positioning.

Nowadays, Mobile phones have become powerful enough devices and mobile infrastructures have enhanced as well, in such a way that people are able to access to a huge amount of contents. In addition, location information itself does not provide a good service. However, by combining that location information with the huge amount of contents useful location based services could be created.

Regarding the user role, one trend in actual market is related to the fact that the user becomes the center of the service whereas internet becomes the platform for developing and delivering services. This trend is taking into account in MUGGES project since the end-user does not only act as a service consumer but also as a content creator as well by providing contents and services to other users. By means of this document different service creation environments were surveyed in order to ease the selection process of the most suitable way among the existing creation technologies for the service creation.

As stated above, location is a key concept therefore different positioning technologies were listed and analyzed by means of section 5. Depending on the kind of Mugglet provided by the user indoor, outdoor or hybrid location methods will be employed to access to location information. Location information provided by positioning technologies on mobile devices is useful but it could be more appropriate if geometric and semantic locations are combined. Semantic representation technologies and approaches were compared and studied in order to serve as starting point for the semantic representation of the location.

Finally, the ongoing projects whose outcomes have an influence in MUGGES were mentioned. As can be seen, MUGGES is mainly based on m:Ciudad architecture due to MUGGES intends to be the continuation of m:Ciudad.

As a summary, Deliverable 1.2 aim to be the reference document for further deliverables since it gives a state of the art about all the geo-referenced technologies and examines the different approaches to user-created services.

10. COMMENTS FROM EXTERNAL REVIEWERS

10.1. REVIEWER 1 – TELEFONICA I+D

Date: 8th June, 2009

The general impression of the document is good with a high detailed analysis of the gathered information and accurate data sources.

The following points summarize some problems detected and improvements suggested:

- The big amount of information provided should be accompanied with a clear and defined structure to follow up the sections. Sometimes is difficult to mentally organize all the information presented to the reader. Small introductions in each section describing what is going to be presented and the target of the section could help.

  → Taking into account the previous suggestion, small introductions in sections 4 and 5 will be included in the next release.

- Some sections of pure text explanation can be too complex for the reader. More images and figures could be added to the document in order to explain the main ideas.

  → More images and figures will be added in the next release.

- The weight of location technologies and concepts is very significant in the document and sections like the user generated services, in the middle of the document, change around the main argument line of the report. Perhaps you could swap section 3 and 4 to keep a logical order.

  → According to Annex I "Description of Work" [1], "Task 1.2 and accordingly D1.2 will examine the different approaches to user-created location-based services from several viewpoints, namely user-created services initiatives and location-based mobile services". Thus taking into account the previous sentence stated in Annex I, we decided in consensus to begin the document with a general description of Location Based Services. After knowledge about Location based Service has been achieved, from our point of view it is easier to focus on a special kind of Location Based Services like User-created location based Services.

- There is an ambiguous use of the terms application and service that sometimes makes the reader to misunderstand the concept that is being explained. The use of the terms could be clarified.

  → Application and Service terms refer to the same concept. Service concept means an application which will be installed and executed on different devices.

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10.2. REVIEWER 2 – UNIVERSITY OF DEUSTO

Date: 8th June, 2009

The document has been revised and no error has been found. Document structure is clear enough and the text is well written and includes enough significant references and details about the current state of the art. The index, references, figure captions and abbreviations have been checked and they seem correct.

Additional comments and improvements suggested to the document are the following:

- It is not very clear the difference between mobile user-generated content and mobile user-created content, page 12 of document, if there is any.

  → A clarification about the difference between both concepts will be included inside section 4 in the next release.

References that could be added to different sections in the document:

- Section 5.2.2: Ultrasound-based sensing , reference to Active Bat system, the best ultrasound indoor location system in terms of accuracy, should be added
- Section 5.2.7: Reference to the following vision-based tagged indoor location system: TRIP: a Low-Cost Vision-Based Location System for Ubiquitous Computing. Diego López de Ipiña, Paulo Mendonça and Andy Hopper, Personal and Ubiquitous Computing journal, Springer, vol. 6, no. 3, pp. 206-219, May 2002.
- For section 5.6, a good reference, although a bit old already is "Jeffrey Hightower and Gaetano Borriello, "Location Systems for Ubiquitous Computing," Computer, vol. 34, no. 8, pp. 57-66, IEEE Computer Society Press, Aug. 2001". It provides an excellent comparison of existing indoor location technologies at the time the review was made.
- Section 8.4: The following issue of IEEE Pervasive Computing is full of "user-generated-content" applications. I consider of special interest the Open Street Map project reviews in such issue: http://ieeexplore.ieee.org/xpl/tocresult.jsp?isYear=2008&isnumber=4653458&Submit32=Go+To+Issue.

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11. ABBREVIATIONS

2D	2-dimensional
3D	3-dimensional
3G	Third Generation
3GPP	Third Generation Partnership Project
AC	Alternating Current
A-FLT	Advanced Forward Link Trilateration
A-GPS	Assisted GPS
AOA	Angle of Arrival
API	Application Programming Interface
AWML	Augmented World Modelling Language
AWQL	Augmented World Query Language
CDMA	Code division multiple access
DC	Direct current
DLOS	Direct line of sight
D-GPS	Difference GPS
E-FLT	Enhanced Forward Link Trilateration
EGNOS	European Geostationary Navigation Overlay Service
E-OTD	Enhanced Observed Time Difference
ESTB	EGNOS test bed
FC	Feature catalogue
GBAS	Ground Based Augmentation Systems
GNSS	Global Navigation Satellite Systems
GPRS	General Packet Radio Service
GPS	Global Positioning System
GSIP	GEOINT Structure Implementation Profile
GSM	Global System for Mobile Communication
GTD	Geometric Time Difference
ID	Identification
IEEE	Institute of Electrical and Electronics Engineers
ILS	Indoor Location Services
IOC	Initial Operational Capability

IoT	Internet of Things
IPS	Indoor Positioning System
IR	Infrared
ISO	International Organization for Standardization
JPL	Jet Propulsion Laboratory
KHz	Kilohertz
LAAS	Local Area Augmentation System
LBS	Location Based Services
LCS	LoCation Service
LOS	Line of Sight
LPMP	Local Positioning Messaging Protocol
LPP	Local Positioning Profile
LTP	Location Technology Providers
MCC	Mission Control Centre
MILO	Mid-Level Ontology
MLP	Mobile Location Protocol
MSAS	Multi-Functional Satellite Augmentation System
MUGGES	Mobile User Generated GEO Services
NAS	NSG Application Schema
NBL	Network Based location
NO	Network Operator
NSG	National System for Geospatial-Intelligence
OPUCE	Open Platform for User-centric service Creation and Execution
OTDOA	Observed Time Difference of Arrival
OTDOA-IPDL	Observed Time of Arrival-Idle Period Down Link
OWL	Web Ontology Language
PDA	Personal Digital Assistant
PLASTIC	Providing Lightweight and Adaptable Service Technology for Pervasive Information and Communication
Rcc	Region Connection Calculus
RDF	Resource Description Framework
REG	Regulators
RF	Radio frequency
RFID	Radio-frequency identification

RIMS	Ranging and Integrity Monitor Stations
RNBP	Reference Node Based
RSS	Received Signal Strength
RTT	Round Trip Time
SA	Selective availability
SBAS	Satellite Based Augmentation Systems
SCAAT	Single-Constraint-At-A-Time
SIG	Special Interest Group
SME	Small and medium enterprises
SOUPA	Standard Ontology for Ubiquitous and Pervasive Applications
SP	Service Provider
SPICE	Service Platform for Innovative Communication Environment
SPRING	Service platform for Reconfigurable and Intelligent services in Next Generation mobile communication
SUMO	Suggested Upper Merged Ontology
SWEET	Semantic Web for Earth and Environmental Terminology
TA	Timing Advance
TEC	Total Electron Content
TDOA	Time Difference of Arrival
TOA	Time of Arrival
TOF	Time of Flight
TTFF	Time-to-first-fix
UCC	User-created content
UGC	User-generated content
UMTS	Universal Mobile Telecommunications System
URI	Uniform Resource Identifier
UW	Ubiquitous Web
UWB	Ultra Wide Band
WAAS	Wide Area Augmentation System
WiFi	Wireless Local Area Network (commercially used Wi-Fi)
XML	Extensible Markup Language

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